A STUDY OF RESPIRATORY TUBERCULOSIS IN RELATION TO HOUSING CONDITIONS IN EDINBURGH

I.—THE PRE-WAR PERIOD

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INTRODUCTION

In the course of the last hundred years, during which the mortality caused by tuberculosis declined considerably in many countries, it has come to be publicly recognized that this disease in modern society is not one of medical import alone, but is set in a social and economic background, the influence of which is far-reaching. In particular, it has long been accepted as axiomatic that unsatisfactory housing conditions affect the prevalence of respiratory tuberculosis, that illness is more common and death more frequent where people live in the most crowded circumstances. This is not to say that bad housing is the direct cause of tuberculosis, or that any of the other social and environmental factors which may increase the prevalence of this disease can be singled out as being directly responsible for incidence or mortality, for the primary cause of tuberculosis is the tubercle bacillus. But where an association can be found between the aetiology of the disease and any environmental factor such as poor housing, and where regional and local differences in the incidence of the disease correspond with differences in that environmental factor, it is reasonable to affirm that improvement in such a factor would result in a proportional reduction in the morbidity and mortality caused by tuberculosis.

In Scotland, this belief in the connexion between housing conditions and respiratory tuberculosis has been supported by the results of a number of studies carried out at various times, particularly in Glasgow. Chalmers (1913) investigated the mortality rates in Glasgow in relation to size of house, and showed that in every age-group the rate of mortality was lower in houses of three and four apartments than in smaller houses. Peters (1933) considered incidence as well as mortality in relation to size of house and to number of persons per room, and found that mortality in the one-apartment house was 340 per cent. greater than in the four-apartment dwelling, although he considered that the specific effect of overcrowding, as measured by the average number of persons per room, was less evident than might have been expected. Laidlaw (1933) analysed all deaths of young adults which occurred in the Eastern Division of Glasgow (covering about one-fifth of the whole population of the city) in the quinquennium 1928-1932, and showed not only that a distinct difference existed between the three-apartment

house and smaller dwellings, but also that the greatest effect of this difference was felt by those aged 15 to 19, particularly males. Similar findings have been obtained in other studies of the incidence of tuberculosis (e.g. Laidlaw, 1946; Medical Officer of Health for Glasgow, 1932; Tuberculosis Officer for Edinburgh, 1938).

Recently, however, the acceptance of such a connexion between housing conditions and respiratory tuberculosis has been challenged in Scotland. McKinlay (1947) studied the changes in mortality in the triennia 1911-1913, 1921-23, and 1931-33, as they occurred in the regions of Scotland, in relation to housing changes in these regions, and found no correlation whatever. Lockhart (1949) compared the housing of tuberculous families in Stirling Burgh with that of the population as a whole, and showed that, while there was a greater concentration of tuberculous families in the smaller houses, and the proportion of families with a case of tuberculosis increased at first with overcrowding, there was no uniform increase, nor was there regularity about the rates in the smaller houses.

These results, obtained by using indices of housing or overcrowding for regions and burghs of Scotland, are in accordance with results obtained on occasion by other investigators in this field who have noted irregularities or very small correlations in their findings. Greenwood (1926) investigated the boroughs of London for the triennia 1911-1913, and 1921-23, and commented on the difficulties of arriving at housing indices which were representative even of individual boroughs, saying,

“Such an index applied without discrimination to the whole country would be of little value.”

In his conclusion he discussed some of the discrepancies in his findings, and warned against the drawing of too hasty inferences:

“The one conclusion I do decidedly draw from the statistics is that only by an exact study, upon a small scale, can truth be reached. The massed data of official statistics are too complex to yield any decisive answer.”

Such criticisms as Greenwood's of the validity of one index to represent the character of the housing of an area are based on the unsuitability of large areas for this kind of analysis. Population density per unit area will remain the same whether the majority of the population is crowded into one part of the area or whether it is well dispersed: yet the aetiology and spread of a disease may be very different. In small and relatively homogeneous cities this kind of anomaly is less likely to arise than in large regions, where it is the rule rather than the exception. And though within a city there may be uneven distribution, the smaller the sub-areas into which the city is divided, the more this anomaly of uneven distribution will disappear. Further criticism may be made of the validity of time comparisons not only of large areas but also of small units homogeneous in respect of housing. Over a period of years, many changes take place in environmental conditions and in medical practice, and many social upheavals disturb the life of a community,

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and the combined effect of these on the aetiology of a disease may be more marked than any gradual change in the housing of an area.

This study is an attempt to elucidate the problem of assessing the contribution which housing makes to the incidence and mortality due to respiratory tuberculosis, and to determine which other measurable environmental influences also make their contribution, by following the advice of Greenwood and comparing like with like. In following this advice, by considering small and well-defined units of one city in a series of individual years, so that, as far as possible, conditions in the units are comparable, a clear connexion between tuberculosis and housing is established; and Greenwood's refusal to draw hasty inferences from his own results and his doubts of the validity of some of his own indices are justified.

TRENDS OF RESPIRATORY TUBERCULOSIS IN SCOTLAND AND IN EDINBURGH

During the 19th century the mortality rate from respiratory tuberculosis recorded annually in Great Britain declined progressively. This decline occurred in Scotland as in England and Wales, and the fall in the Scottish rate, less affected by the first world war than the rate in England and Wales, was so consistent that after the war the rate was lower than that of England and Wales and continued to be lower until 1935. The steady downward trend of the Scottish rate was remarkably constant from 1908 until 1931, but from 1931 until 1939 a change in direction was already noticeable, though the rate still continued to fall slightly. At the outbreak of the second world war the mortality rate rose sharply, and remained high throughout the war and in the subsequent years for which figures have been published: the notification rate rose much more steeply than the mortality rate, and has continued at this high level, if it has not risen still further, in succeeding years. Thus the trend in Scotland has differed greatly from that in England and Wales, where the consistent decline of the inter-war years was only reversed in the first two years of the second world war, after which the rate fell again. It has now become apparent that it was not merely the second world war which interrupted the progressive decline of Scottish rates, but that other factors have operated to give rise to the position which obtains today and which so disturbs the people of Scotland.

The influence of the Glasgow rates of mortality and notification was, and still is, preponderant in Scotland, since Glasgow contains more than 20 per cent. of the total population. In the 1930s the Glasgow rates were almost the highest in Scotland, and in recent years have been the highest in Great Britain. From 1918 until the middle 1920s the Glasgow rates fluctuated considerably, but did not decline to any marked extent.

The trends in Edinburgh during the inter-war years in respect of respiratory tuberculosis were to some extent comparable with those of Glasgow. The rates were not so high: indeed, at the beginning of the period the Edinburgh rates compared quite favourably with those of many of the Scottish burghs. But in Edinburgh, as in Glasgow, there was little change in the mortality rate until the late

1920s, although there had been in pre-war years a steady downward trend for over forty years. In notification rates, too, there was little real improvement until the middle 1920s, in spite of vigorous campaigns by the Edinburgh Public Health Department. Towards the end of the decade, however, a decline both in incidence and in death rates became established, and though this decline was not great, the Tuberculosis Officer for Edinburgh said in his report of 1928:

"It is a well-known fact that, since 1870, Tuberculosis has been gradually disappearing from Scotland. . . . I do not think that anyone with these figures in front of him can be blamed for taking an optimistic view regarding the future of Tuberculosis, and while a good deal still remains to be done, I am of opinion that Tubercle as a cause of death and as a cause of expense to the community will shortly be of very much less importance than it is at present."

FIG. 1(a).—Movement of crude rates of notification of respiratory tuberculosis in Edinburgh and of mortality from the disease in Edinburgh and in Scotland as a whole (1900-48).

While similar opinions were expressed during the next few years, the improvements which had taken place in the crude rates for Edinburgh were not evenly distributed among the population, either in different age-groups or in different localities of the city. This can be clearly seen in Fig. 1 (a) and (b), showing the difference between the crude rates for Edinburgh and the cases (notifications and deaths) among young adults of both sexes. The rates for those aged 15 to 24 remained persistently high, and each year a large proportion of the new cases were of young men and women in these age-groups. By 1934 it became clear that little progress was being made, and that

"the results of the campaign against Tuberculosis were not in any degree commensurate with the knowledge which had been accumulated about the disease, the organism causing it,

and the various factors governing its habits of growth and dissemination".*

During the period 1939-45 the Edinburgh tuberculosis death rate rose, to fall again towards the end of the war. The notification rate rose much more seriously during the war, and fell only slightly at the end; and in the post-war years both increased again, and notifications are rising annually while deaths have recently

* Report of the Tuberculosis Officer for Edinburgh (1934).

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FIG. 1(b).—Deaths from and notifications of respiratory tuberculosis among young adults in Edinburgh between 1926 and 1948, differentiated by sex and age group.

fallen a little. Thus, while Edinburgh rates are now lower than those of Scotland as a whole, the lack of real progress in respect of mortality and the continued increase in incidence are causing serious disquiet.

“This was a disappointment at a time when the trend of nearly all other afflictions was to diminish . . . it is doubtful if the peak has been reached.”*

In the opinion of the Edinburgh Public Health Department there were strong indications that the disturbing increases in tuberculosis were connected with the conditions under which the people of Edinburgh live—conditions which are at the same time considerably better than those obtaining in many parts of Scotland. Investigations of such connexions between disease and social conditions are difficult in all countries, since the measurable social factors are few, and those for which statistics of measurements exist fewer still. In Scotland the problem is considerably greater, both because of the absence of social data other than certain housing figures and because of the differences between housing in Scotland and elsewhere.

HOUSING IN SCOTLAND AND IN EDINBURGH

The housing problem in Scotland is a peculiar legacy of the building which went on in the 19th century and the early 20th century, when the great majority of dwellings built were of only one or two rooms. This resulted in the position obtaining in 1931, when 46·5 per cent. of all dwellings in Scotland had only one or two rooms, and a further 25 per cent. had only three rooms. And in many of the Scottish burghs the percentage of such small “houses”† was far greater than the average: but in Edinburgh the position was better than that in Scotland as a whole. The distribution of houses of various sizes, and the proportion of the population which inhabited them in 1931, can be seen from Table I.

TABLE I
SIZES OF HOUSES IN EDINBURGH (1931)

See also Fig. 2 (a)

No. of rooms	1	2	3	4	5 or more
Number of houses	7,123	33,591	26,934	15,687	22,367
Percentage of all houses	6·7	31·8	25·5	14·8	21·2
Population in such houses	20,144	134,787	108,546	60,541	93,735
Percentage of city population	4·8	32·3	26·0	14·5	22·4

In many wards of the city the position in respect of small houses was far worse than this average, eight of the 23 wards having less than 20 per cent. of their houses of four rooms or more, and four of these wards having 88 per cent. or more of their

* Report of the Medical Officer of Health for Edinburgh (1948).

† A “house” in Scotland is the dwelling occupied by a household, and is not a separate building: it may be located in a large or small building, and may be a single room.

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FIG. 2 (a).—Housing conditions in Edinburgh, 1931. Distribution of persons in all houses, with degree of overcrowding in each size of house, and percentage of population in Wards 18 and 12 living in each size of house.

FIG. 2 (b).—Housing conditions in Edinburgh, 1935. Distribution of persons in houses under £45 rental, with degree of overcrowding in each size of house, and percentage of the population of Wards 20 and 13 living in each size of house.

total houses of only one, two, or three rooms. However, by the existing standard of overcrowding,* less than half of these *small dwellings* were officially recognized as overcrowded, although Fig. 2 (a) and (b) shows that a large percentage of the *persons* living in these houses were in fact overcrowded.

In 1935, when the Survey of Overcrowding in houses of rental of £45 or under was carried out, Edinburgh was stated to have 19·8 per cent. of all such houses overcrowded; and in its worst ward 34·5 per cent. of these houses were considered to be overcrowded, although several wards had a greater proportion as well as a greater number of houses of only one, two, or three rooms than they had had in 1931. Moreover, the percentage of houses overcrowded did not give a complete picture of the percentage of the population living in overcrowded conditions, as can be seen in the upper diagrams of Fig. 2 (a) and (b) showing the difference for Edinburgh as a whole. Unfortunately, the data for individual wards was only collected

* The standard by which overcrowding is defined is that of the 1935 Housing (Scotland) Act, details of which are given on p. 155.

with reference to houses, and it is impossible to do more than estimate the percentages of ward populations that were statutorily overcrowded.

The most recent survey, carried out in Edinburgh in 1946, covered houses of all rentals, and made it clear that there had been little change in the character of the housing of the city as a whole and of most of the wards. The shortage of houses was so acute that 7 per cent. of the families of Edinburgh were living as sub-tenants in one room of a two- or three-roomed house, officially occupied already by one, and in some cases two, other families. The standard by which overcrowding is assessed is still that of the 1935 Housing (Scotland) Act, in which all rooms of 50 sq. ft. or more are included in the count of rooms, and the permitted number of "persons" in one-, two-, three-, and four-roomed houses is respectively two, three, five, and seven and a half: infants under one year of age are not counted, and children up to ten years count as half-persons.

It seems possible that the type and size of house occupied by the citizens of Edinburgh may not necessarily be determined by their income, and that people occupying small houses or living in overcrowded conditions may do so for reasons other than poverty or poor social circumstances. In many countries housing and overcrowding indices are used as indications of economic status in general, and are held to be a measure of the complex of social factors such as poverty, poor nutrition, casual employment, and the like, from which it is believed that housing cannot be separated. In Scotland, however, as in Edinburgh, there may be less justification than in some other countries for relating social indices to housing indices, for today, as for many years past, the factor which largely determines where people live is the availability of any sort of house.

These housing conditions, peculiar to Scotland, not only indicate the possibility of a lesser association with economic circumstances than is commonly assumed, but also present another difficulty in the consideration of the type of index which can represent such housing in a locality, and the overcrowding index which can distinguish between "normal" living conditions and statutory overcrowding. The choice of indices to represent local conditions is discussed more fully in the section describing the indices used: it is only necessary to say here that such indices, measuring closeness of contact between persons in a locality, need to be especially accurate in studies of Scotland precisely because of the possibility that they are not also necessarily measures of other social factors. The housing indices used in some countries might, even if not fully representative of closeness and frequency of contact, still give considerable evidence of correlation with respiratory tuberculosis, such correlation being compounded of the indirect influence of other social factors as well as the direct influence of housing. But under Scottish conditions, and in view of the widely spread infection in the community, the indirect influence of other social factors—which vary so greatly within regions having the same housing index—might not add to the correlation: and measures of local housing conditions must represent as truly as possible the realities in each locality which may affect this disease.

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SCOPE OF THIS STUDY

In this paper an attempt is made to assess the influence which housing conditions in general, and overcrowding in particular, have had on the incidence of and mortality from respiratory tuberculosis in Edinburgh. In this part of the study the decennium from 1930 to 1939 is considered, and measures of housing conditions and rates of tuberculosis prevalence are analysed from several aspects. The analysis is concerned with the smallest units for which published data are available, namely, the electoral wards of the city, and tuberculosis rates are related to housing conditions in each year of the decennium. Mortality due to all causes and to certain selected causes is also considered, in order to establish whether or not the incidence of tuberculosis is simply a reflection of general mortality and morbidity. In addition, the mortality caused by respiratory tuberculosis is analysed in relation to the incidence of this disease: and the various measures of housing are considered in their connexion with each other.

The scope of the paper is limited to the decennium preceding the second world war, since the published data for post-war years are limited to those for 1946-1948, and in the first of these years the civilian population was still far from normal in its age-distribution. A second part of this study will consider the post-war period, when sufficient information has been made available, in a way similar to that used in this study of the pre-war years, and will also make some comparisons between the pre-war and post-war periods.

SOURCES OF INFORMATION.—All data used were officially published in local and in national reports, and these partly determined the choice of indices.

The Annual Reports of the Edinburgh Public Health Department have made public each year the number of deaths and of newly-notified cases of respiratory tuberculosis in Edinburgh and in each ward. In the same reports, annual estimates of population for the whole city and for each ward were made, and the number of inhabited houses was given annually by the Burgh Assessor.

Deaths and notifications of other diseases were also given in the annual reports for some years, but only a limited number were published annually and were available for the whole decennium.

The data in respect of types and sizes of houses in the city and in each ward in 1931 were published in the Report on the 14th Decennial Census of Scotland (1931), and the figures for overcrowded houses of rental of £45 or under were published in the Report on Overcrowding issued after the Survey was made under the Housing (Scotland) Act, 1935.

Other rates of respiratory tuberculosis were obtained from the numbers of deaths and notifications in the annual reports of the Registrar-General for Scotland and in the local reports of Public Health Departments, and from the population figures published in the sectional reports on the 14th Decennial Census for Scotland.

INDICES USED.

(a) *Mortality and Notification Rates.*—For all rates, whether in reference to

respiratory tuberculosis or to any other cause, two-year moving averages are used. Since the number of cases in each ward in any single year was small, the fluctuations, which in Edinburgh occurred usually in the form of alternations in consecutive years, are reduced by the use of biennial averages. By the use of triennial averages, little is gained and more is lost, since in several of the years considered the changes in housing conditions within some of the wards were sufficient to introduce more inaccuracy in the use of triennial than of biennial averages.

All rates used in relation to housing indices are total rates for all ages (except in the case of infant mortality). Age-sex specific rates were also considered, but in almost all wards the numbers of cases and of deaths in each age-group were so small that any conclusion drawn from such results would have been unwarranted.

All rates are considered both in the crude and in the logarithmic form in order to assess whether a linear or a proportional relationship would give a more accurate description of the association which is found to exist. Correlations are calculated both for the crude and for the logarithmic forms of the rates, but regression equations are finally given for all crude notification rates and for logarithms of all mortality rates.

Rates of mortality and of notification of respiratory tuberculosis, of mortality from all causes, of pneumonia mortality, and of notifications of non-respiratory tuberculosis are given per 10,000 ward population. Infant mortality rates used are per 1,000 live births. The rate of mortality due to epidemic diseases is taken per 100,000 ward population in order to avoid negative logarithms. All logarithms are to the base 10.

Since all rates are derived from published material, Tables II and III do not give the detailed rates for each of the 23 wards for each year; but means and standard deviations of means are tabled, as well as the range covered each year by the ward rates.

(b) *Housing and Overcrowding Indices*.—The choice of indices as a measure of conditions existing in any region or locality is always partly determined by the limits of the published data available. In the case of housing indices in any part of Scotland in the 1930s, the published information is sufficient to derive a number of different indices, both those used traditionally in investigations of the influence of environmental factors on disease and others not so commonly used. It becomes necessary, therefore, to consider more carefully what these different indices measure, and to what extent these measures represent conditions of reality in the localities, particularly conditions which may play a large part in the aetiology of tuberculosis.

The data available make it possible to derive three different indices of population density, namely, density of room-occupation, density of house-occupation, and density of population per acre. All these give indications of the closeness of contact of the local population but attach different weight to the influence of the house itself: and all three ignore the standard and quality of the accommodation, the sizes of rooms and similar factors which in some diseases are of importance.

Since density per acre is quite unsuitable in the comparison of housing

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TABLE II
RESPIRATORY TUBERCULOSIS IN 23 WARDS OF EDINBURGH, 1930-1939
Rates of mortality (M) and notification (N) per 10,000 ward population (2-year moving averages)

Year	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38	1938-39
<i>Mortality Rate: M</i>									
Range	3.99-17.23	3.45-18.22	2.12-16.20	2.92-12.45	2.45-10.85	2.30-12.44	2.08-13.45	2.80-16.64	2.60-13.95
Mean rate	7.526	6.955	7.006	7.013	6.286	6.110	6.585	6.551	6.287
S.D. of mean	3.160	3.141	2.932	2.401	2.709	2.755	2.949	2.976	2.660
Mean log. rate	0.845	0.808	0.810	0.820	0.757	0.742	0.776	0.780	0.767
S.D. of mean	0.163	0.170	0.186	0.157	0.199	0.203	0.203	0.179	0.180
<i>Notification Rate: N</i>									
Range	6.39-24.18	5.50-22.59	3.20-22.25	6.37-20.82	4.71-19.64	3.21-16.14	4.49-16.35	5.35-17.22	—
Mean rate	12.261	11.507	11.547	11.945	10.694	10.041	10.621	10.605	—
S.D. of mean	4.991	4.582	4.752	3.899	4.091	3.624	3.265	3.689	—

TABLE III
OTHER RATES OF MORTALITY AND NOTIFICATION IN EDINBURGH, 1930-1936

1930-32, 1934-36	Mortality rate from all causes, per 10,000 ward population. Infant mortality rate per 1,000 live births.			
1930-32	Mortality rate from epidemic diseases, per 100,000 ward population.			
1934-36	Notification rate of non-respiratory tuberculosis, per 10,000 ward population. Mortality rate from pneumonia (all forms), per 10,000 ward population.			
Year	1930-31	1931-32	1934-35	1935-36
<i>General Death Rate</i>				
Range	104.5-172.0	107.0-156.0	98.0-153.0	93.0-169.5
Mean	133.3	130.0	131.2	134.6
S.D. of mean	18.335	14.839	12.839	18.602
<i>Infant Mortality Rate</i>				
Range	26.7-103.0	32.4-90.6	45.9-102.6	42.9-91.2
Mean	71.2	68.5	65.6	68.0
S.D. of mean	16.513	13.445	13.154	12.912
<i>Epidemic Diseases Mortality Rate</i>				
Range	4.6-89.8			4.8-51.8
Mean	40.8			27.2
S.D. of mean	22.193			14.3
<i>Non-Respiratory Tuberculosis Notification Rate</i>				
Range		2.78-10.19		
Mean		5.97		
S.D. of mean		2.154		
<i>Pneumonia Mortality Rate</i>				
Range			4.71-13.07	4.32-15.58
Mean			8.35	9.67
S.D. of mean			2.334	3.040

conditions obtaining in different areas, the choice of an annual density index lies between persons per room and persons per house, depending on the importance attached to the room or to the house. Where the majority of the population lives in large houses (in England and Wales during the 1930s the houses of one or two rooms were together approximately 5 per cent., and the houses of three rooms another 10 per cent., of all houses, so that 85 per cent. of the population lived in

houses of four or more rooms), a large number of persons per room in any locality is indicative of considerable aggregates of people living in close contact, and may be a better index than persons per house, since the variations in types and sizes of houses are usually far wider than similar variations in rooms. The vastly different housing conditions in Scotland, however, make it appear more reasonable to consider the number of persons per house, for the reasons that the overwhelming majority of houses is small, that the types of houses are very similar (a large proportion being located in tenements built in the 19th century, as was shown as recently as 1946 in Edinburgh, where 65 per cent. of all houses were in tenements and another 14 per cent. in flatted villas), and all rooms, whether kitchens, bedrooms or living-rooms, are counted, although in small houses the family spends most of the day in one room.

The index used for each year of the decennium studied here is that of density of house-occupation, that is, the average number of persons per inhabited house in each ward in each year. A "house" is defined in the Scottish sense of a dwelling occupied by a household, and is not a separate building. The average number of persons is based on the total estimated ward population, and children are counted equally with adults.

For the triennium centred in the Census year of 1931, two additional indices are used, as ascertained from census data. These are: density of room-occupation, that is, the average number of persons per room in each ward; and percentage of the ward population living more than two per room. The latter is the usual measure of overcrowding, and the former is also often used as an overcrowding index, although for this purpose it is in many respects unsatisfactory in that it ignores not only local variations in rooms and houses but also the size of the

TABLE IV
HOUSING AND OVERCROWDING IN 23 WARDS OF EDINBURGH, 1930-1938

1930-38	{	Density of dwelling-occupation: A (average number of persons per house).								
1931		Density of room-occupation: P (average number of persons per room).								
		Percentage of population living more than two per room: T.								
1935		Percentage of overcrowded houses in the wards: U.								
Year	..	1930	1931	1932	1933	1934	1935	1936	1937	1938
<i>Average per Dwelling: A</i>										
Range	..	3.16-4.66	3.30-4.59	3.15-4.61	3.05-4.55	3.15-4.50	3.15-4.45	3.11-4.40	3.06-4.35	3.02-4.31
Mean	..	3.86	3.93	3.91	3.85	3.82	3.78	3.74	3.69	3.65
S.D. of mean	..	0.315	0.320	0.363	0.381	0.349	0.321	0.320	0.321	0.320
<i>Persons per Room: P</i>										
Range	..	0.650-1.793								
Mean	..	1.194								
S.D. of mean	..	0.358								
<i>Percentage living more than Two per Room: T</i>										
Range	..	2.2-51.3								
Mean	..	27.5								
S.D. of mean	..	13.962								
<i>Percentage of Overcrowded Houses: U</i>										
Range	..						1.29-34.41			
Mean	..						17.35			
S.D. of mean	..						9.605			

household aggregated together. Neither of these measures is arrived at by the statutory standards of overcrowding, but both indicate the relative adequacy or otherwise of housing in the different wards.

For the triennium centred in the year of the Overcrowding Survey, 1935, one additional index is used, as ascertained from the results of this survey. This is the percentage of houses of rental £45 or under which were found to be overcrowded by the standard of the Housing (Scotland) Act of 1935: this percentage is taken in relation to all houses in the wards regardless of rental. Although this would seem to introduce a discrepancy, the number of houses of over £45 rental was, even in 1946, only 12 per cent. of all houses in Edinburgh, and the overcrowded houses of over £45 rental were only 1 per cent. of all overcrowded houses, so that this discrepancy does not materially affect the index used.

In Table IV are given the ranges, means, and standard deviations of the means for the annual ward density figures and for the various overcrowding measures.

STATISTICAL METHODS.—Those used throughout this analysis of association between housing and disease rates are the methods of correlation and of regression analysis, the latter being omitted only when the coefficient of correlation is insignificant or negative, in the case of mortality due to all causes. Each of these methods gives similar measures of the basic relationship between the various data, but the analysis of regression gives some additional information concerning aspects of this relationship.

In the consideration of mortality due to respiratory tuberculosis in relation to notification, the same two methods are used, and a time-lag of one year is allowed between the period of notification and the period of death.

The relationship between the various housing measures is assessed only by the method of correlation, since the aspects which regression analysis clarifies are of greatest interest in reference to respiratory tuberculosis and other diseases.

Tables of ungrouped data are used in every case, and coefficients of correlation are calculated between the pairs of variables under consideration. Standard errors are given, but the more suitable test of significance of correlation coefficients of such magnitude, namely, the probability of obtaining them by chance, is used.

Regression equations are calculated by the usual method of minimizing the squares of the deviations, standard errors of regression coefficients derived, and significance assessed by the ratios of coefficients to their standard errors. Standard deviations from regression are compared with standard deviations from the means: and the variance accounted for by regression is calculated and compared with the variance due to error of estimate.

Scatter diagrams with regression lines or curves fitted are shown in the text: these diagrams illustrate the dispersion of the actual ward rates about the estimates of regression. The diagrams selected were chosen in order to show the relation of incidence and mortality caused by respiratory tuberculosis with housing conditions, however measured, and to illustrate the consistency of this association as compared with mortality from other causes.

FIG. 3.—Wards of Edinburgh (1930 and 1931). Relation of notification and mortality rates of respiratory tuberculosis to average number of persons per room (P) and to average density of dwelling-occupation (A).

RESULTS.—A brief summary is given here, and a detailed statement of the results of each analysis and comparison follows.

The coefficients of correlation between rates of respiratory tuberculosis and measures of housing are all highly significant. Those for mortality rates in relation to housing conditions are more consistent and in most cases higher than those for notification rates. Further, the correlation with overcrowding is in most instances greater than that with the average number of persons per house. The coefficients of regression confirm these results.

The comparison made of mortality due to other causes gives evidence of highest correlation in the case of epidemic diseases, variable correlation in the case of infant mortality and of pneumonia, and none in mortality due to all causes.

The correlation between mortality due to respiratory tuberculosis and notification in the previous year is marked, and the curvilinear regression gives a much more accurate description of the relationship than does linear regression.

(a) *Respiratory Tuberculosis Rates and Housing Measures.*—Table V (p. 159) shows the coefficients of correlation between rates of mortality, logarithms of these rates, and rates of notification, with annual density of house-occupation, density of room-occupation in

FIG. 4.—Wards of Edinburgh (1931 and 1932). Relation of notification and mortality rates of respiratory tuberculosis to percentage of persons living more than two per room (T) and to average density of dwelling-occupation (A).

1931, percentage of persons living more than two per room in 1931, and percentage of overcrowded houses in 1935 respectively.

It can be seen that all the correlation coefficients are highly significant. Those for mortality rates in relation to housing conditions are, with one exception, well above 99.9 per cent. significance for each of the years of the decennium, although the actual coefficients vary in different years. Those for notification rates in relation to housing conditions are in most instances well above the 99.9 per cent. level of significance, but the range of variation is wider than in the case of mortality.

When the various housing indices are considered separately, it is seen that the correlation between mortality and density of house-occupation decreased until 1933 and then increased steadily until 1939, but the correlation between incidence and density of house-occupation increased in the first part of the decennium, fell in 1935 and then increased until the end of the period. Further, it can be seen from Figs 3 and 4 as well as from Table V that the correlation between mortality or incidence and persons per room in 1931 is higher in 1931-32 than for persons per house, but is lower in 1930-31, whereas the correlation with percentage living more than two per room is consistently higher. Fig. 5 (p. 158) also shows that in 1935 the correlation with overcrowding is consistently higher than that with density of house-occupation.

In general the coefficients of correlation give evidence of strong association between housing conditions and both mortality and incidence of this disease,

FIG. 5.—Wards of Edinburgh (1935 and 1936). Relation of notification and mortality rates of respiratory tuberculosis to percentage of houses overcrowded (U) and to average density of dwelling-occupation (A).

stronger and less variable for mortality than for incidence, and more consistently associated with overcrowding even than with density per house. Further, the correlation obtained when the logarithms of mortality rates are used are almost without exception higher than for crude rates, and are more consistent and more closely associated with overcrowding.

Tables VIa and VIb (pp. 160 and 161) show the regression coefficients and the analysis of variance for rates of mortality, logarithms of these, and rates of notification in relation to housing and overcrowding. These confirm the results obtained by correlation coefficients, both in respect of significance of association and in respect of greater variability of association for incidence, and stronger connexion with overcrowding than with density per house. For mortality, regression coefficients, and variance ratios are all of the highest level of significance. Standard deviations from regression are in all instances considerably lower than standard deviations of means both of mortality and of incidence rates. The variance accounted for by regression is in most years from 50 to 65 per cent. of mortality variance, and from 40 to 60 per cent. of variance of incidence.

The coefficients of regression indicate, further, that whilst in the mid-years of the decennium a unit increase in density of house-occupation resulted in a smaller increase in the estimate of mortality or notification rate than at the beginning of the period, towards the end of the decennium the increase of estimate with an increase in persons per house

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TABLE V

CORRELATION COEFFICIENTS BETWEEN RESPIRATORY TUBERCULOSIS INCIDENCE AND MORTALITY, AND HOUSING AND OVERCROWDING. EDINBURGH, 1930-38

Notification rate per 10,000 ward population (2-year moving average): N

Mortality rate per 10,000 ward population (2-year moving average): M

Log. of mortality rate per 10,000: L

Density of dwelling-occupation: A

Persons per room in each ward in 1931: P

Percentage living more than two per room in 1931: T

Percentage of overcrowded houses in each ward in 1935: U.

Average Persons per House: A			1932	1933	1934	1935	1936	1937	1938	
Year	..	..	1931	1932	1933	1934	1935	1936	1937	1938
Respiratory Tuberculosis			1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38	
Year	..	..	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38
Mortality M with Average Density A										
Correlation coefficient										
r	..	..	0·711	0·647	0·613	0·631	0·672	0·675	0·692	0·713
S.E. of r	..	..	0·103	0·121	0·130	0·126	0·114	0·114	0·109	0·103
Log. of Mortality L with Average Density A										
r	..	..	0·765	0·730	0·735	0·652	0·648	0·719	0·702	0·751
S.E. of r	..	..	0·087	0·097	0·096	0·120	0·121	0·101	0·106	0·091
Notifications N with Average Density A										
r	..	..	0·633	0·667	0·754	0·776	0·597	0·681	0·691	0·714
S.E. of r	..	..	0·125	0·116	0·090	0·083	0·134	0·112	0·109	0·102
			Persons per Room: P	Percentage Living more than Two per Room: T			Percentage Overcrowded Houses: U			
Respiratory Tuberculosis			1931-32	1930-31	1931-32	1934-35	1935-36			
Year	..	..	1930-31	1931-32	1930-31	1931-32	1934-35	1935-36		
Mortality: M										
r	..	..	0·704	0·701	0·705	0·663	0·678	0·724		
S.E. of r	..	..	0·105	0·106	0·105	0·117	0·113	0·099		
Log. of Mortality: L										
r	..	..	0·755	0·797	0·769	0·762	0·667	0·797		
S.E. of r	..	..	0·090	0·076	0·085	0·087	0·113	0·076		
Notifications: N										
r	..	..	0·766	0·718	0·732	0·738	0·630	0·754		
S.E. of r	..	..	0·086	0·101	0·097	0·095	0·126	0·090		

For 23 observations: The probability of a correlation coefficient of such magnitude arising by chance is:

Probability = 0.001 0.01
 r = approx. 0.639 0.526

Hence almost all these results are above 99.9 per cent. significant.

was comparable with that at the beginning, and was rising. At the same time, the standard deviation from regression—an indication of the dispersion of the actual observations about the estimate—was tending to fall.

In general the analysis of regression gives evidence of the continued association between housing conditions and tuberculosis mortality and incidence throughout the decennium, and of the considerable percentage of variance between the wards

TABLE VIA

REGRESSION COEFFICIENTS AND ANALYSIS OF VARIANCE

(A) BETWEEN INCIDENCE AND LOG. MORTALITY FROM RESPIRATORY TUBERCULOSIS AND HOUSING

<i>With Average per House A</i> Year	1931	1932	1933	1934	1935	1936	1937	1938
Mortality: M	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38
Regression coeff. <i>b</i> ..	7.035	5.595	4.717	4.337	5.668	5.808	6.359	6.627
S.E. of <i>b</i>	1.517	1.440	1.327	1.164	1.362	1.387	1.450	1.424
Variance ratio F ..	21.518	15.104	12.635	13.871	17.320	17.529	19.243	21.653
Log. of Mortality: L	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38
Regression coeff. <i>b</i> ..	0.391	0.342	0.359	0.294	0.401	0.455	0.445	0.421
S.E. of <i>b</i>	0.072	0.070	0.072	0.075	0.103	0.096	0.099	0.081
S.D. of mean L ..	0.163	0.170	0.186	0.157	0.199	0.203	0.203	0.179
S.D. from regression	0.108	0.119	0.129	0.122	0.155	0.144	0.148	0.121
Squares of deviations from mean L ..	0.5862	0.6376	0.7611	0.5442	0.8671	0.9035	0.9091	0.7075
"Explained" by regression ..	0.3429	0.3397	0.4115	0.2316	0.3646	0.4667	0.4480	0.3992
	58.5%	53.3%	54.1%	42.5%	42.0%	51.7%	49.3%	56.4%
Variance ratio F ..	29.587	23.944	24.718	15.553	15.233	22.436	20.404	27.182
<i>With Average per House A</i> Year	1931	1932	1933	1934	1935	1936	1937	1938
Notifications: N	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38
Regression coeff. <i>b</i> ..	9.880	8.411	9.410	8.661	7.601	7.708	7.034	8.233
S.E. of <i>b</i>	2.639	2.053	1.787	1.539	2.229	1.811	1.607	1.761
S.D. of mean N ..	4.991	4.582	4.752	3.899	4.091	3.624	3.265	3.689
S.D. from regression	3.956	3.496	3.193	2.519	3.359	2.717	2.417	2.643
Squares of deviations from mean N ..	547.94	461.87	496.72	334.37	368.13	288.93	234.55	299.39
"Explained" by regression ..	219.32	205.18	282.65	201.10	131.18	133.86	111.90	152.70
	40.0%	44.4%	56.9%	60.1%	35.6%	46.3%	47.7%	51.0%
Variance ratio F ..	14.018	16.785	27.720	31.684	11.623	18.132	19.158	21.864

which is accounted for by regression. It indicates that the influence of density of house-occupation was not declining in the years just prior to the war of 1939, but was possibly greater, even though actual rates of death and of incidence were not then increasing.

(b) *Other Mortality Rates and Housing Measures.*—Table VII (p. 164) shows coefficients of correlation and of regression between mortality due to other causes and indices of housing and of overcrowding, for the years 1930-32 and 1934-36, that is, the years for which measures of overcrowding were available.

The correlation between housing conditions and general death rates is negative in some instances and so small as to be negligible in the others. For mortality due to pneumonia the correlation is much greater, though not comparable with that of tuberculosis, significance being from 95 to 99 per cent. Infant mortality gives coefficients of correlation

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TABLE VIb

REGRESSION COEFFICIENTS AND ANALYSIS OF VARIANCE

(B) BETWEEN INCIDENCE AND LOG. MORTALITY FROM RESPIRATORY TUBERCULOSIS AND OVERCROWDING

	With Persons per Room: P (1931)		With Percentage living more than Two per Room: T (1931)		With Percentage Overcrowded Houses: U (1935)	
Mortality: M ..	1930-31	1931-32	1930-31	1931-32	1934-35	1935-36
Regression coeff. <i>b</i> ..	6.211	6.148	0.1595	0.1491	0.1912	0.2078
S.E. of <i>b</i> ..	1.369	1.366	0.0351	0.0367	0.0452	0.0432
Variance ratio F ..	20.577	20.262	20.702	16.471	17.864	23.154
Log. of Mortality: L	1930-31	1931-32	1930-31	1931-32	1934-35	1935-36
Regression coeff. <i>b</i> ..	0.344	0.379	0.00899	0.00930	0.0140	0.0168
S.E. of <i>b</i> ..	0.065	0.063	0.00163	0.00172	0.00332	0.00278
S.D. of mean L ..	0.163	0.170	0.163	0.170	0.199	0.203
S.D. from regression	0.110	0.105	0.107	0.113	0.150	0.125
Squares of deviations from mean L ..	0.5862	0.6376	0.5862	0.6376	0.8671	0.9035
"Explained" by regression ..	{ 0.3340	0.4647	0.3463	0.3706	0.3968	0.5737
	{ 57.0%	63.5%	59.1%	58.1%	45.8%	63.5%
Variance ratio F ..	27.804	36.497	30.345	29.146	17.717	36.533
	With Persons per Room: P (1931)		With Percentage living more than Two per Room: T (1931)		With Percentage Overcrowded Houses: U (1935)	
Notifications: N ..	1930-31	1931-32	1930-31	1931-32	1934-35	1935-36
Regression coeff. <i>b</i> ..	10.681	9.189	0.262	0.242	0.268	0.284
S.E. of <i>b</i> ..	1.955	1.944	0.053	0.048	0.072	0.054
S.D. of mean N ..	4.991	4.582	4.991	4.582	4.091	3.624
S.D. from regression	3.282	3.265	3.482	3.164	3.253	2.437
Squares of deviations from mean N ..	547.94	461.87	547.94	461.87	368.13	288.93
"Explained" by regression ..	{ 321.64	238.02	293.36	251.62	145.87	164.22
	{ 58.7%	51.5%	53.5%	54.5%	39.6%	56.8%
Variance ratio F ..	29.849	22.330	24.200	25.132	13.782	27.654

For 23 observations: Probability of chance occurrence = 0.001 when $F = 14.585$
= 0.01 when $F = 8.015$

Hence almost all these results are above and the remainder well above 99 per cent. significance.

slightly higher than those for pneumonia mortality, though not as high as those for tuberculosis; moreover, there is considerable variation in the correlation.

The highest correlation is obtained in the relationship between mortality due to epidemic diseases and conditions of housing or overcrowding, being of the same order and of similar levels of significance as the correlation found for tuberculosis. Figs 6 (a) and 7 (a) and (b) illustrate the regression estimates and the scatter of the actual observations about regression for mortality due to these various causes.

Notifications of non-respiratory tuberculosis have only been considered for the beginning of the decennium, since the annual number of new cases in each ward

was not published after 1931. The correlation for incidence of non-respiratory tuberculosis in relation to conditions of overcrowding is significant at the 99.9 per cent. level, though of a lower order than the corresponding correlation for respiratory tuberculosis, as is seen in Fig. 7 (a) and (b) as well as in the Tables.

(c) *Relationship between the Various Measures of Housing Conditions.*—Table VIII (p. 165) shows the coefficients of correlation between the annual housing index of persons per house and the relevant additional indices of overcrowding in 1931 and in 1935. They are consistently high, merely confirming the obvious fact that all these indices reflect the relative conditions in the wards, and that this relative position changed little during the decennium.

The correlation coefficients between the three measures of overcrowding are still higher and all three are almost unity. It is of interest to note that the lowest of the three coefficients is that between the two indices for 1931, and the highest that between the 1935 index based on statutory overcrowding and the 1931 index of the percentage of persons living more than two per room.

(d) *Relationship between Mortality and Incidence of Tuberculosis.*—Table IX (p. 165) shows the coefficients of correlation between mortality in each two-year period and notification in the preceding period; these are all considerably above 99.9 per cent. significance,

FIG. 6 (a).—Wards of Edinburgh (1934 and 1935). Relation of infant and pneumonia mortality rates to overcrowding.

FIG. 6 (b).—Wards of Edinburgh. Relation of mortality rates from respiratory tuberculosis for 1935-36 and 1936-37 to the notification rates for the two previous years (1934-35 and 1935-36 respectively).

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and are of a similar order to the correlation coefficients between density per house and overcrowding. Further, the correlation tends to increase towards the end of the decennium, as does the degree of significance: and though the coefficients of regression do not increase regularly, they are considerably higher towards the end of the ten years considered than at the beginning, indicating that a unit increase in incidence rates in the late 1930s resulted in a much greater increase in the estimate of mortality than did an equal increase in incidence in the early 1930s.

The small amount of scatter of the actual observations about the estimate is illustrated in Fig. 6 (b). The regression curves fitted show high levels of significance and the standard deviations from regression are small. The variance accounted for by regression is almost uniformly above 60 per cent. and towards the end of the decennium rises to over 70 per cent., and the variance ratio in most years is 40 or more.

All regression equations using the logarithms of mortality rates give a much better fit than those using crude rates, and much smaller standard errors of estimate.

DISCUSSION AND INTERPRETATION OF RESULTS

There are several indications that, even within the comparatively small units represented by the electoral wards of Edinburgh, the indices used to represent housing conditions and to distinguish these from overcrowding are not sufficiently refined. Further, there are indications that for the inter-census years the estimates

FIG. 7 (a).—Wards of Edinburgh (1931-32). Infant mortality and incidence of non-respiratory tuberculosis related to percentage of persons living more than two per room (T).

FIG. 7 (b).—Wards of Edinburgh (1935-36). Epidemic and general mortality rates related to percentage of houses overcrowded (U).

TABLE VII
COEFFICIENTS OF CORRELATION AND REGRESSION BETWEEN MORTALITY DUE TO SELECTED CAUSES
AND HOUSING AND OVERCROWDING

Indices	Housing		Overcrowding		Housing		Overcrowding	
	A, 1931	A, 1932	Persons per Room: P (1931)	Percentage more than Two per Room: T (1931)	A, 1935	A, 1936	Percentage Overcrowded Houses: U (1935)	
Year	1930-31	1931-32	1930-31	1931-32	1930-31	1931-32	1934-35	1935-36
<i>General Mortality Rate</i>								
Correl. coeff. <i>r</i>	0.172	0.032	0.217	-ve	0.211	-ve	-ve	-ve
Regr. coeff. <i>b</i>								0.0022
<i>Log. of General Mortality</i>								
<i>r</i>	0.156	0.027	0.205	-ve	0.202	-ve	-ve	-ve
<i>b</i>								0.0057
<i>Infant Mortality</i>								
<i>r</i>	0.429	0.536	0.502	0.554	0.585	0.565	0.592	0.591
<i>b</i>	22.186	19.843	23.146	20.827	0.691	0.544	24.251	23.826
<i>Log. of Infant Mortality</i>								
<i>r</i>	0.483	0.554	0.521	0.559	0.608	0.573	0.620	0.623
<i>b</i>	0.183	0.147	0.177	0.151	0.0053	0.0040	0.155	0.174
<i>Epidemic Diseases Mortality</i>								
<i>r</i>	0.607		0.749		0.747		0.713	
<i>b</i>	42.132		46.432		1.187		31.873	
<i>Log. of Epidemic Diseases Mortality</i>								
<i>r</i>	0.705		0.702		0.751		0.770	
<i>b</i>	0.729		0.648		0.0178		0.669	
<i>Pneumonia Mortality</i>								
<i>r</i>							0.455	0.490
<i>b</i>							3.304	4.658
<i>Log. of Pneumonia Mortality</i>								
<i>r</i>							0.454	0.509
<i>b</i>							0.181	0.231
<i>Non-Respiratory Tuberculosis Notifications</i>								
<i>r</i>	0.594		0.674		0.695			
<i>b</i>	4.003		4.053		0.107			

For 23 observations: Probability of chance occurrence = 0.001 0.01 0.02 0.05 0.1
when *r* = approx. 0.639 0.526 0.483 0.415 0.353

of ward populations were not completely accurate, and this is borne out by the 1935 Overcrowding Survey figures.

In spite of such possible inaccuracies, however, all the results obtained show that there is an association between differences in housing conditions in the wards

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TABLE VIII

CORRELATION COEFFICIENTS BETWEEN HOUSING AND OVERCROWDING INDICES, 1931-1938

Density of dwelling-occupation: A annually.

Persons per room: P, 1931.

Percentage living more than two per room: T, 1931.

Percentage of overcrowded houses: U, 1935.

	Correlation coefficients between	P	T	U
P	$r =$	—	0.950	0.967
T	$r =$	0.950	—	0.985
A, 1931	$r =$	0.819	0.868	—
A, 1932	$r =$	0.812	0.812	—
A, 1933	$r =$	0.811	0.810	0.848
A, 1934	$r =$	0.840	0.859	0.880
A, 1935	$r =$	—	—	0.862
A, 1936	$r =$	—	—	0.863
A, 1937	$r =$	—	—	0.864
A, 1938	$r =$	—	—	0.863

TABLE IX

CORRELATION AND REGRESSION COEFFICIENTS BETWEEN NOTIFICATION RATES IN ONE PERIOD AND MORTALITY RATES IN THE NEXT PERIOD DUE TO RESPIRATORY TUBERCULOSIS. EDINBURGH, 1930-1938

Notification rate per 10,000 ward population (2-year moving average): N.

Log. of mortality rate per 10,000 population (2-year moving average): L.

Notifications: N	Log of Mortality: L	Correlation coefficient r	Regression coefficient b	Standard Error of b	$t = \frac{b}{\text{S.E. of } b}$
1930-31	1931-32	0.824	0.0281	0.0042	6.653
1931-32	1932-33	0.713	0.0289	0.0062	4.659
1932-33	1933-34	0.763	0.0253	0.0047	5.414
1933-34	1934-35	0.830	0.0423	0.0062	6.825
1934-35	1935-36	0.791	0.0392	0.0066	5.391
1935-36	1936-37	0.821	0.0461	0.0070	6.590
1936-37	1937-38	0.830	0.0456	0.0067	6.819
1937-38	1938-39	0.851	0.0416	0.0056	7.428

For 23 observations: The probability of a correlation coefficient of such magnitude arising by chance is:
Probability 0.001 when $r = 0.639$ approx.

The probability of chance occurrence of a regression coefficient of such magnitude is:
Probability 0.001 when $t = 3.819$ ($F^2 = t$).

Hence all these results are well above 99.9 per cent. significance.

and variations in the prevalence of respiratory tuberculosis. The trends of the coefficients of correlation and of regression during the decennium are sufficiently clear to show that the association was consistently high each year, and that this association was not decreasing, but if anything increasing, with the passage of the years. Discrepancies in individual years may be due to chance or to inaccuracies in population or other figures: it would be unreasonable to expect complete regularity in the sequence for the decennium, in view of the comparatively small number of cases and of deaths annually in most wards, and in view of the possible time-lag in notification or in death-registration or of the many other sources of

inaccuracy. The increasing levels of significance in the years just prior to the war of 1939, and the greater consistency and degree of association in respect of mortality—for which diagnosis is likely to have been more accurate than for incidence—support this argument.

That the connexion with housing conditions is closer for mortality than for incidence of tuberculosis is evidenced whether coefficients of correlation are considered or whether any of the other statistics which measure slightly different aspects of this connexion is considered. From the percentage of “explained” variance it is clear that, in spite of improvements in the incidence and death rates of this disease, and in spite of housing changes which did take place in the wards, a consistent portion of the deviations of ward rates of tuberculosis from the city averages was associated with the differences in housing conditions in those wards from the city average. Moreover, the higher correlation shown to exist for overcrowding indicates that in wards where a large percentage of the houses was statutorily overcrowded there was an added effect on the tuberculosis rates.

It may be argued that this association which has been found is not really one of housing, but is due to other factors in the environment, or is caused by the existence of contacts in the crowded wards, or is connected with some unknown cause related simultaneously both to tuberculosis and to housing. The facts remain that in the population of Edinburgh there were contacts in *every* ward, and that in the crowded wards there was less space available for avoiding closeness and frequency of contact. Moreover, this association which has been shown to exist has been arrived at by a variety of measures of housing, and it is reasonable to interpret it as related to housing as such, until such time as it can be clearly proved that it is really something quite different. It is easy to speculate what other environmental influences may perhaps be represented by indices of housing, but until these factors can be singled out it must be assumed that this consistent and definite connexion with housing is responsible for part at least of tuberculosis deaths and cases.

The higher correlations obtained by the use of the logarithms of tuberculosis mortality rates, both in relation to housing measures and in relation to incidence rates, bear out this conclusion, for they indicate that in the densely populated wards mortality increased more than proportionally with increases in the number of persons per house, and that the degree of connexion of mortality with crowded housing was considerably greater in the densely populated wards than in the less crowded wards. When the logarithms of notification rates were considered with the housing indices, the correlations were higher in some years and lower in others than those given by use of the crude rates: and the wider variations in notification correlation than in that for mortality may be due to a number of causes, not the least of which are difficulty of diagnosis and variation in diagnostic methods.

The lower correlations between the various measures of housing or overcrowding and all other mortality except that due to epidemic diseases give further support to the evidence that housing itself is causally connected with the prevalence

of tuberculosis. These lower correlations imply that in the case of some diseases housing conditions do not have as great an influence as in the case of diseases spread by infection. Moreover, all the rates used for the diseases which are compared with tuberculosis are total rates, without standardization for age. Since in the more densely populated wards the birth rates were in most years higher and the proportion of children always greater than were the city averages, these diseases, especially epidemic diseases, may be more affected than tuberculosis by ward differences in age composition. The correlations actually found may therefore be higher than they would be if age differences were eliminated, in which case the contrast between tuberculosis and other mortality in respect of the influence of housing would be heightened. Further, the absence of correlation with housing for mortality due to all causes is evidence that the high tuberculosis mortality was certainly not a reflection of increasing mortality in general, and that crowded wards had no significantly different general death rate than did other wards.

The relationship between mortality rates of tuberculosis and notification rates is shown by the high correlation coefficients, and this is not unexpected. But the close and regular association and the consistent increase of mortality in relation to previous notification, and the better estimate of this association by the use of logarithms of mortality rates, indicate that where the incidence of this disease is great the increase in mortality is much more than proportional to the increase in incidence. This may be due to a number of reasons. The obvious explanation is, of course, that, if notifications were accurate and at approximately the same stage of the disease throughout the city, then this "build-up" of mortality represented a real shortening of the interval between onset and death, and that the conditions in the wards affected the speed with which notified cases became fatal cases. On the other hand, notification in the wards where incidence is great may be less accurate, since almost all of these were the most crowded wards: so that the abscissal value of notification in the regression equation may be smaller than was the actual prevalence of the disease. This, however, is not a likely explanation, since detailed examinations of contacts and regular supervision of homes are instituted when a case is first notified: and it is possible that in wards where incidence rates are high notification may be more accurate, and not less so, than in other wards. Another possible explanation is that notifications in these more crowded wards were at a later stage of the disease, so that the "build-up" of mortality represents an apparently shorter interval between onset of the disease and death. Many other explanations, probable and improbable, spring to the mind, but if this phenomenon is a real one then it requires detailed studies of other small units, and a follow-up of a large number of case records, to arrive at an answer which is more than speculative.

The high correlations between the housing indices for each year and the measures of overcrowding of the triennia centred about 1931 and 1935 imply that there was not much change in the relative housing conditions of the different wards, and that the most densely populated and overcrowded wards in 1931 were

still so in comparison with the better wards in 1939. This is known to be so for 1935, when figures of housing and overcrowding were obtained by actual survey and not by estimate: and the correlation until 1939 merely confirms that the density of house-occupation and the percentage of overcrowded houses did not change materially in the years subsequent to the 1935 Survey of Overcrowding.

CONCLUSION

This investigation shows quite clearly that in a well-defined area which can be sub-divided into meaningful units the relationship between high density of dwelling-occupation and prevalence of respiratory tuberculosis is overwhelming. Relations of this kind have been found elsewhere. It would not have been considered worth while to go into so much detail about one Scottish city for a period during which the prevalence of this disease was apparently declining, had it not been suggested recently that in some way Scotland differed from other countries and other regions, and that in Scotland tuberculosis was not associated with housing conditions. It may be concluded from this that where there has been failure to find any such association this failure may in part be due to the use of unsuitable indices, or to the study of excessively large and varied units of area, or to time comparisons in which other circumstances than housing varied so greatly as to make the units which were compared incomparable.

It is hoped that in the later part of this study, in which the post-war years will be considered, some of the problems which have been revealed by this preliminary study will be clarified.

SUMMARY

(1) This study has been occasioned both by the disturbing trends of respiratory tuberculosis incidence and mortality in Scotland in the last 20 years, and by the doubt thrown in some recent Scottish studies on the widely-held opinion that poor housing conditions are directly associated with infection and death from this disease. It attempts to ascertain whether such association does exist, or whether the doubts expressed are based on firmer evidence than that which supports this believed association. It attempts also to estimate the degree of connexion which exists, by means of an analysis of small well-defined localities in comparable periods of time.

(2) The movements of respiratory tuberculosis mortality and incidence rates in Scotland as a whole and in Edinburgh in particular are discussed, and it is shown that the increases both in prevalence and in deaths which became apparent upon the outbreak of war in 1939 were in part the continuation of trends already well-established and clearly visible in the rates for young adults before 1939.

(3) Housing in Edinburgh is considered in relation to housing in Scotland as a whole, and is analysed according to size of house and degree of overcrowding; possible differences are shown in the interpretation of indices of housing and

overcrowding in Scotland as compared with the meaning of similar indices in other countries.

(4) The scope of this study, which is limited to the investigation of respiratory tuberculosis and housing conditions in Edinburgh in the decennium preceding the second world war, is outlined. The published sources of data and the derivation of indices and rates used are given; reasons for the selection of certain indices are stated.

(5) The methods used to analyse the possible connexion and the degree of such connexion between tuberculosis and housing are defined, as the methods of correlation and of regression analysis.

(6) The results obtained are stated in detail. They are consistent and highly significant in their evidence of the existence of a strong association between both mortality and incidence of respiratory tuberculosis and aspects of housing. Moreover, the association is found to be greater in respect of mortality than of incidence, and greater in relation to overcrowding than to density of house-occupation. The comparisons made with mortality due to various other causes show that, except in the case of epidemic diseases, other causes are much less strongly associated with conditions of housing. A close and consistent association is found between mortality due to respiratory tuberculosis and incidence in the previous year.

(7) It is further found that a fairly regular increase occurs in coefficients of correlation and regression throughout the latter part of the decennium, indicating that the connexion between the ward variations in housing and in disease rates was not decreasing but was if anything tending to increase in the years before 1939.

(8) It is found that a better "fit" is obtained by the use of logarithms of mortality rates than by the crude rates, indicating that the degree of association was more than proportionally greater in wards where the density of dwelling-occupation or overcrowding was greatest.

(9) The conclusion is drawn that there is very strong evidence of association between the rates of respiratory tuberculosis and conditions of housing.

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