COMPARISON OF THE SPECIFIC MORTALITY RATES IN TOWN AND COUNTRY DISTRICTS OF SCOTLAND SINCE 1871

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(With 4 Figures in the Text)

In a previous paper (Kermack, McKendrick & McKinlay, 1934*a*) a method was developed for the analysis of the death rates of various countries, which exhibited in a concise fashion the main changes which have been occurring during the period for which data are available. The method was shown to be applicable to Scotland and to England and Wales, and it not only demonstrated in a lucid manner the way in which the fall in mortality rates had taken place, but also indicated the further changes which were likely to occur during the next few decades.

The population of any one country is composed of sections which differ widely in their social and economic circumstances. It would be of interest to examine the changes which have occurred in the mortality rates of a few limited and approximately homogeneous groups in order to find out what regularities such simple aggregates present and also to compare one group with another. However, the data available in the published reports of Registrars General are not sufficiently detailed to allow of an investigation of this kind being undertaken. Nevertheless, it so happens there is one major division of the population in respect of which the published Scottish figures permit an analysis to be made. This is the division of the whole area into "town" and "country". The contrasting conditions prevalent in these two sections of the community make such an analysis of special significance at the present time. Even although, as will be explained, available data are in some respects imperfect, it was decided to examine them in the light of the principles already found to hold for the whole community. A brief description of this previous work will facilitate the understanding of the rest of this paper.

In our previous paper it was shown that the specific mortality rate for any age group at any time could be approximately expressed as the product of two factors, one of which, β, depended only on the age of the group, the other, α, only on the date of birth. This really means that the same generation—say those born in 1900—throughout its life experiences at every age a series of mortality rates which are in the same relative proportion to each other as

https://doi.org/10.1017/S0022172400027911 Published online by Cambridge University Press

those experienced at the same ages by another generation, e.g. those born in 1860. For the 1900 generation the specific mortality rates are the same as those for the 1860 generation except that they are all altered by a constant factor—the factor, of course, being the ratio of the appropriate α values. Since, in the ordinary method of drawing up a table of mortality rates, the progress of one particular generation is parallel to the dextro-diagonal, the above principle has been described as the "diagonal law". This generalization does not hold for the infantile mortalities, the improvement in which lags fully a generation behind, nor for the 1–5 age group. The β values and the α values for Scotland as a whole are shown in Figs. 1 and 2. (It is to be noted that in all cases the age groups, 5–15, 15–25, 25–35, etc., extend over 10 years, but for brevity are denoted by their approximately central years, 10, 20, 30, etc.) The great improvement in health conditions is summed up in the α curve which shows a fall from 0·0158 for those born in 1841 to 0·0042 for those born in 1921.

Town and country mortality rates

In the tabulation of specific mortality rates for town and country separately, certain technical difficulties are encountered which are for the most part the result of changes having been introduced at various times by the Registrar General in the classifications employed in his annual reports.

The main troubles arising in this way are the following:

I. Up to and including 1870 Specific Mortality Rates for Scotland are given for (*a*) "Town Districts", (*b*) "Mainland-Rural Districts" and (*c*) "Insular Districts". From 1871 to 1910 five divisions are given in the Registrar General's Reports: (1) "Principal Towns", (2) "Large Towns" (over 10,000 inhabitants), (3) "Small Towns" (over 2000 inhabitants), (4) "Mainland-Rural Districts", and (5) "Insular-Rural Districts". Up to 1900 the "Principal Towns" had over 25,000 inhabitants, but in 1901 the lower limit was raised to 30,000. In 1911 a substantial alteration in classification was introduced. The "Principal Towns" over 30,000 are continued under the heading of "Larger Burghs". Other towns which happened to have the legal status of Burghs were included under the heading "Smaller Burghs", irrespective of size, whilst the rest of Scotland was included under "County Districts", the latter including certain medium-sized towns which happened not to possess burgh status (e.g. Carluke). This naturally involved a substantial increase between 1910 and 1911 in the "Country" population.

In 1931 the lower limit for "Larger Burghs" was reduced from 30,000 to 20,000 (Arbroath, with a population of 18,000, being specially included as a Large Burgh). In addition the "County Districts" were renamed "Landward Areas".

A complete account of the finer points involved would require a somewhat lengthy discussion.

Briefly, it was decided to count as "Town" population, from 1871 to 1900 the "Principal Towns" with over 25,000 inhabitants; from 1901 to 1930 the "Principal Towns" (or "Larger Burghs") over 30,000; and from 1931 onwards the "Large Burghs" over 20,000, plus Arbroath. For the Country population we have taken during the period from 1871 to 1910 the "Mainland-Rural" districts, from 1911 to 1930 the "County Districts", and from 1931 onwards the "Landward Areas". It will be seen that an intermediate group of what may be called small towns has been completely excluded from our present analysis. Previous to 1871 the available information could only be divided into "Town" and "Rural" and the consequent impossibility of separating the smaller towns makes the change from 1870 to 1871 a substantial one of such importance that it can scarcely be neglected.

II. Up to 1910 the age groups given are 5–10, 10–15, 15–20, 20–30, 30–40, etc. From 1911 onwards they were 5–10, 10–15, 15–25, 25–35, 35–45, etc. For our purposes the figures for the age groups 5–15, 15–25, 25–35, etc. for all periods were obtained by a process of averaging.

III. Up to 1910 the rates for males and females were given separately; from 1911 onwards the figures for both sexes combined are alone available. For the earlier periods a process of simple averaging was employed to obtain the "total" rates (i.e. for both sexes combined).

It will be seen from the above that at various periods certain changes occur in the definition of town and country. The largest anomaly is avoided by excluding all years previous to 1871. In our previous paper dealing with the whole of Scotland the mortality rates for the various census years were actually calculated by taking the mean of the three successive years centred round the census year in question, in order to reduce transient irregularities. The same course has been adopted in the present paper, except for the first census period, 1871, the figures for which are based on only two years, 1871 and 1872, in consequence of the 1870 rates having to be omitted. The remaining variations in classification are unfortunate, but it is unlikely that the errors introduced are sufficiently large to influence the final results appreciably.

The rates upon which the present analysis is based are presented in Tables 1 and 2. These are not strictly accurate, as they are obtained in some instances by the process of averaging referred to above, but the errors introduced in this way are relatively small.

Table 1. *Specific mortality rates, town*, 1871–1931

Age	1871	1881	1891	1901	1911	1921	1931
10	10·9	7·9	5·8	4·4	3·7	2·6	2·4
20	10·27	8·1	6·6	5·4	3·9	3·6	3·1
30	13·65	10·4	9·8	8·5	6·0	5·3	4·0
40	18·2	15·0	14·9	13·3	9·8	8·1	6·5
50	26·55	23·3	24·5	23·1	17·5	15·3	11·3
60	43·5	40·1	43·9	42·8	34·3	33·0	24·2
70	80·8	73·2	83·3	79·7	71·4	69·0	61·3

Table 2. *Specific mortality rates, country*, 1871–1931

Age	1871	1881	1891	1901	1911	1921	1931
10	4·8	4·0	3·7	2·9	2·4	2·1	1·9
20	7·0	5·8	5·5	4·9	3·8	3·4	2·8
30	8·6	7·5	7·7	6·9	5·4	4·4	3·7
40	9·1	8·7	9·3	8·9	7·3	6·0	5·4
50	12·8	12·3	13·7	13·9	11·8	9·8	8·8
60	23·3	23·1	26·6	27·4	24·2	22·3	19·0
70	53·5	52·8	60·1	59·1	52·3	46·7	47·5

The next step in the analysis is to calculate all rates as percentages of those existing in what we have called the standard period. This standard period is supposed to give the rates which obtained before the fall which has characterized recent decades had set in. The choice of the years 1871–2 as the standard period is justified by the facts (1) that for the whole of Scotland the specific mortality rates showed little or no change up to and including 1871, and (2) that for both town and country the year 1870 showed no fall as compared with the 3-yearly period 1860–2, but if anything a slight rise. The rates as percentages of the standard are shown in Tables 3 and 4. Inspection shows that for the country (Table 4) the figures along the dextro-diagonals are approximately constant.

Table 3. *Relative specific mortality rates, town*

Age	1871	1881	1891	1901	1911	1921	1931
10	100	72	53	40	34	24	22
20	100	79	64	53	38	35	30
30	100	76	72	62	44	39	29
40	100	82	82	73	54	45	36
50	100	88	92	87	66	58	43
60	100	92	101	98	79	76	56
70	100	91	103	99	88	85	76

30 40 50 60 70 80

Table 4. *Relative specific mortality rates, country*

Age	1871	1881	1891	1901	1911	1921	1931
10	100	83	77	60	50	44	40
20	100	83	79	70	54	49	40
30	100	87	90	80	63	51	43
40	100	96	102	98	80	66	59
50	100	96	107	109	92	77	69
60	100	99	114	118	104	96	82
70	100	99	112	110	98	87	89

50 60 70 80 90

The lines in the figure indicate the positions of the 90, 80, 70 %, etc., contours, and these as will be seen are approximately straight and at an angle of 45° to the vertical. In the case of the towns (Table 3), similar results are obtained. The uniformity, however, is not quite so great, the chief disturbance being caused by a fall between 1871 and 1881 which is not confined to the lower age groups. This deviation from regularity in the case of the towns suggests that some of the 1871 rates may be unduly high. In order to control this point calculations were carried out from the data, omitting the 1871 values. No standard rate being now available, the alternative procedure developed in a previous paper (Kermack, McKendrick & McKinlay, 1934*b*) had to be applied. The results are found to be in substantial agreement with those obtained by the first or "standard rate" method. For sake of completeness the country figures have also been worked out by the second method.

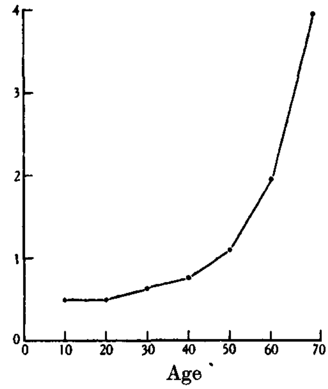

Fig. 1. β values for all Scotland.

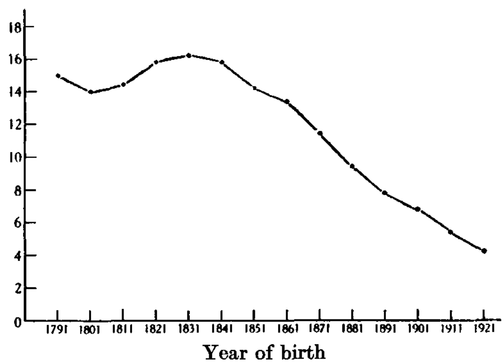

Fig. 2. Values of α ($\times$ 1000) for all Scotland.

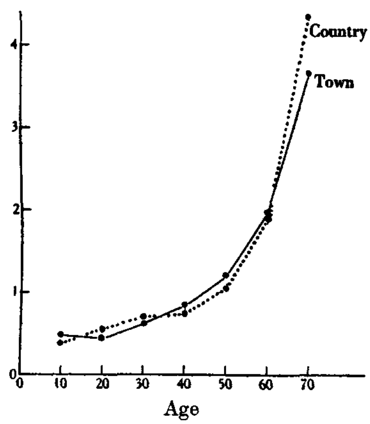

Fig. 3*a*. Normalized β values for town and country, calculated by first or standard-rate method.

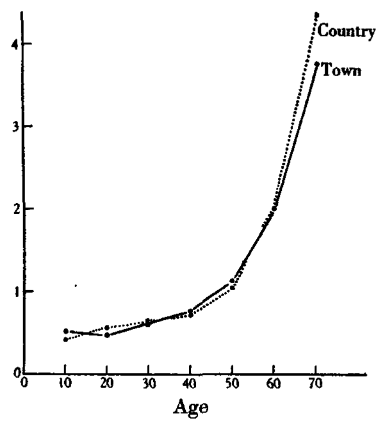

Fig. 3*b*. Normalized β values for town and country, calculated by second method.

For purposes of comparison it is necessary to "normalize" the sets of β values. This results from the circumstance that the observed rate is the product of two factors α and β, and that the same products would be obtained by using the factors $k\alpha$ and β/k (where k is any constant), that is to say, both α and β contain a factor which is at our disposal. In order to normalize the β values, the factor is chosen so that the product of the β's is unity. The α values no longer begin in the neighbourhood of 100 in consequence of this normalization. The α and β curves for town and country as calculated by the first or standard rate method are shown in Figs. 3*a* and 4*a*, whilst those calculated by the second method are shown in Figs. 3*b* and 4*b*.

https://doi.org/10.1017/S0022172400027911 Published online by Cambridge University Press

COMPARISON OF CHANGES IN TOWN AND COUNTRY RATES

So far the data for town and country have been considered independently. It now becomes necessary to compare the town α with the country α in order if possible to obtain information as to the relative healthiness of urban and rural environments. To discover how this can best be done, it is desirable to

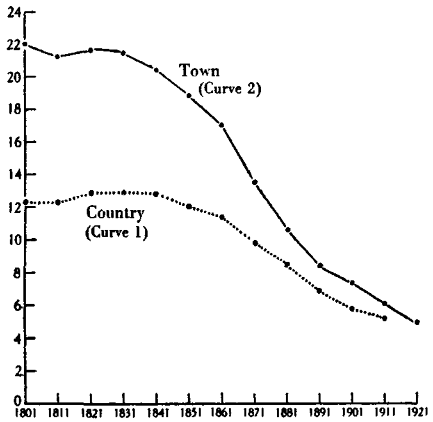

Fig. 4*a*. Values of α ($\times 1000$) derived from normalized β's: standard-rate method.

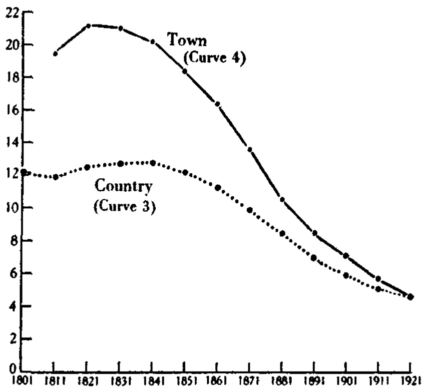

Fig. 4*b*. Values of α ($\times 1000$) derived from normalized β's: second method.

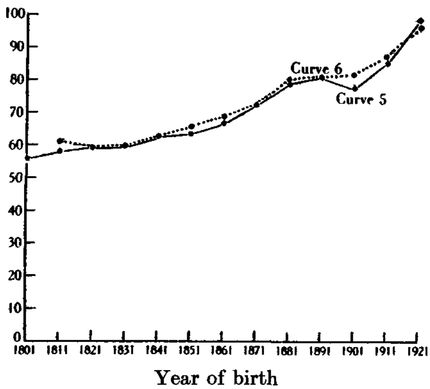

Fig. 4*c*. Percentage ratios of α values: Country/town. Curve 5 (full line) calculated by standard-rate method. Curve 6 (dotted line) calculated by second method.

In interpreting Figs. 4*a*, *b* and *c*, it is to be remembered that the date given is the date of birth of the generation, and not that of the period, about 10 years later, of which the α value reflects the social environment.

discuss somewhat more fully what the α and the β curves really represent. Broadly speaking, we may regard the β curves as reflecting the physiological constitution of the population as a function of age, whilst the α curve is a measure of the influence of the environment. This statement requires a slight qualification, for it seems clear that if the environment is such as to affect peculiarly some one particular age group, this fact will be reflected in the shape of the β curve. We have in fact to regard the β curve as reflecting the relative viabilities of the population at different ages in the economic and social conditions existing during the whole period under examination. The existence of the diagonal law shows that the shape of the β curve from 10 years of age upwards is approximately the same for all generations, from which it is inferred that the major effect of the environment is exerted during childhood, largely before the tenth year of age. Thus the α value is a measure of the general level of the environment during childhood, the period during which the general constitution of the individual is being built up. If the individuals in the towns were entirely unrelated to, and innately different in vigour from the individuals in the country, no comparison between the mortality rates would shed light on the state of the environment, but it seems reasonable to assume that the mean innate vigour of the individuals in the towns is the same as that of the country population. The plausibility of this is increased by the consideration that the town population has within recent generations been largely derived from the surrounding country, so that the genetic constitutions of the two groups cannot differ very greatly. In order then to compare one β curve with another, it is necessary to multiply the values in the one set by a factor chosen so as to make the "mean" value of this set equal to the "mean" value of the other set. In practice the geometric mean is more satisfactory than the arithmetic mean, as the latter gives undue weight to the high values corresponding to the older ages. The use of the normalized β values (where the product, and therefore the geometric mean of the β's, is always unity) automatically ensures the equality of the geometric means, and so the corresponding α values are directly comparable. In other words, when the normalized β's are used, the corresponding α values may be compared without further adjustment. The result of this argument may be summarized by saying that environmental conditions in town and country may be compared by the use either of the α curves in Fig. 4*a* obtained by the first or standard period method; or by the α curves in Fig. 4*b* derived by the second method. Examination shows that the corresponding curves in Fig. 4*a* and 4*b* are very similar, so that any conclusions to be drawn are practically independent of the method of analysis employed.

A comparison of the environmental conditions in town and country may be conveniently represented by the ratio of the corresponding α values, that is to say, of the points on curve 2 as compared with curve 1, Fig. 4*a*, or on curve 4 as compared with curve 3, Fig. 4*b*. These relative indices are given in curves 5 and 6 in Fig. 4*c*. The substantial agreement of these two latter curves again shows that the result is practically independent of the precise method of analysis employed.

Discussion

The above analysis of the mortality statistics for the urban and rural districts of Scotland shows that in both these divisions the same regularities are observed as for the whole population. The level of the mortality rates

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especially in the past has been different in the two areas, but the changes which have occurred have been similar and approximately in accordance with the diagonal law. It is perhaps scarcely to be expected that the agreement would be as good as for Scotland as a whole, because during the period under consideration, large movements of population have undoubtedly taken place. There has been much migration from rural to urban areas, and in addition considerable immigration from Ireland to certain parts of Scotland—chiefly, it would seem, to urban areas. Emigration has also been considerable, but this has affected the whole nation, and has not acted differentially on the two divisions of the community which we are comparing. With the statistics at present available it would be difficult to make adequate allowance for such migratory movements of the population. Furthermore, it should perhaps be pointed out that the separation of the two populations representing town and country respectively is to some extent an arbitrary one, and is dependent on peculiarities of local administration. The fact that the intermediate group of small burghs has been omitted helps, however, to ensure that the two populations analysed are in sufficient contrast and represent broadly town and country conditions.

It is natural to enquire to what extent inferences can be drawn from the above analysis in regard to the relative "healthiness" of town and country. It should be pointed out that the idea of the "healthiness" of a particular environment is a somewhat vague one, as the manner in which an environment affects health may depend on the age or the innate constitution of the population subjected to it. However, it will be generally conceded that an environment which results in a high death rate is an unhealthy one. We may then take the level of the death rates in a community as an indication of the "healthiness", or rather the unhealthiness of the environment, provided that there is no reason to believe that there is any substantial variation in the genetic constitution of the populations in question, and provided also that suitable allowance is made for differences of age and, if necessary, of sex. The analysis we have undertaken, based as it is on specific mortality rates and not, for example, on total death rates, is independent of any age differences there may be in the two populations under investigation. The data do not allow of the two sexes being considered separately, but it seems scarcely likely that the effect of environment on the two sexes would be sufficiently different to make it necessary to analyse separately in respect of this factor.

It is not easy when confronted with the two complete sets of specific mortality rates for various age groups and for various calendar periods—one for the town and the other for the country—to see how best to obtain some measure of their relative levels. The ratios of the corresponding rates for town and country may differ very widely according to the age and calendar period. It is here that our analysis of the rates into the component α and β values proves specially useful. We have already given reasons for believing that the set of β values is, broadly speaking, a reflexion of the physiological changes

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produced by age, whilst the α value of the generation, which may be called the "generation mortality coefficient", is a measure of the social conditions which existed during the childhood of the generation. Thus if we want to compare the relative conditions in town and country in say 1890, we simply compare the α values belonging to the two generations—town and country respectively—who were in their childhood at that time, that is, those who were born some 10 years previously, say in 1880. Naturally one cannot be absolutely precise with regard to the extent of the interval. Although of course one is not justified in correlating in a quantitative sense the numerical value of α with the essentially vague idea of "healthiness", it nevertheless seems justifiable for purposes of comparison to adopt this value as an indication of the environmental conditions. We have therefore presented in Fig. 4*c* the ratio of the α values in order to give some indication of the relative conditions in town and country at the different calendar periods. In interpreting this figure and also Figs. 4*a*, *b*, it is necessary to remember that the dates given are dates of birth and that the social environment reflected by the mortality rates is that of some 10 years later. On this basis it will be seen from Fig. 4*c* that up to about 1851 the relative "healthiness" of town was about 60% of that of the country. About that time the ratio began to increase, but only very slowly, reaching 70% 30 years later (about 1881). After a delay between 1891 and 1911 the increase has continued at a somewhat accelerated pace, with the result that about 1931 the ratio was in the neighbourhood of 100%. In other words, our analysis appears to indicate that the real healthiness of the town environment has by now become approximately equal to that of the countryside. This gives a verdict rather more favourable to the town at the present day than the mere inspection of the crude figures would suggest. However, as the conception of healthiness in town and country is a somewhat vague one, the α values must be taken as a general indication rather than as an exact quantitative measure. We therefore conclude that the relative healthiness of the town is now at roughly the same level as that of the country. The balance of advantage may still be with the latter, but if so, it cannot be very great.

It may be objected that a direct comparison of the town and country death rates does not seem to support this conclusion. For example, in 1911 the ratio of the corrected total death rates for country and town areas was 0·715, in 1921 it was 0·737, whilst in 1931 it was still as low as 0·814. In other words, the mortality in the country in 1931 was on an average 19% lower than in the town. It is to be remembered, however, that much of this mortality is contributed by the relatively aged who do not seem to reflect in their health their immediate environment but rather that of their youth.

In the case of the 15–25 group, the ratios have remained approximately constant during the last 25 years, at about 92%, whilst for the younger age group of 5–15, it has steadily risen from 71% in 1911 to 92% in 1935. In specific considerations of this type temporary or minor perturbations tend to distort the picture and so we have a certain lack of uniformity in these two

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neighbouring groups. Both, however, indicate that the ratio has reached at least 90%.

It is of interest to compare the town rates in 1935 with the country rates in 1931. These are given in Table 5.

Table 5

Age group	1935 Large burghs	1931 Country
5–10	2·2	2·1
10–15	1·6	1·6
15–25	2·8	2·9
25–35	3·6	3·6
35–45	6·0	5·1
45–55	11·3	8·7
55–65	23·5	18·5
65–75	58·9	48·6

As will be seen the corresponding rates are almost equal up to age 35, from which it may be concluded that for these younger age groups the town conditions lagged at most only a few years behind those of the country. However, although these special comparisons are of interest as confirming our general conclusion, we attach more importance to the trend of the figures as a whole which is revealed by the "relative generation mortality" curves shown in Figs. 4*a*, *b* and *c*.

It may be of interest to give predicted mortality rates for 1936, 1941 and 1951 for town and country (Table 6), calculated on the basis of the α and β curves (deduced from data referring to 1931 and earlier periods). The figures actually observed for 1936 are given for comparison and the agreement may be considered satisfactory. For 1941 and 1951 prediction is naturally somewhat more hazardous, especially for the lower age groups where an extrapolation of the α curve is involved. The social disturbances caused by the war, and the evacuation of children, introduce further elements of uncertainty into predictions of this kind, the degree of which cannot at present be estimated.

Table 6. *Predicted mortality rates for* 1936, 1941 *and* 1951, *with the observed rates in* 1936

	Observed		Predicted					
	1936		1936		1941		1951	
Age	Town	Country	Town	Country	Town	Country	Town	Country
10	1·9	1·7	2·2	1·8	2·0	1·8	1·6	1·7
20	2·9	2·5	2·5	2·7	2·3	2·5	1·9	2·3
30	3·6	3·1	3·8	3·6	3·4	3·3	2·8	3·0
40	5·7	5·0	6·1	4·7	5·5	4·3	4·4	3·7
50	11·9	9·1	11·0	8·1	9·9	7·3	8·2	6·2
60	23·9	18·6	24·0	18·5	20·9	17·1	16·9	14·1
70	59·4	47·5	56·4	46·3	51·2	43·3	39·5	37·1

Summary

1. An analysis by the "generation mortality" method of the specific mortality rates of the urban and rural areas of Scotland for various calendar periods from 1871 onwards shows that the "diagonal law" previously demon-

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strated for the population of Scotland as a whole, as well as for certain other European countries, holds for these two subdivisions of the community.

2. Reasons are given for the assumption that the normalized "generation mortality coefficients" (α values) may be taken as a rough measure of the "healthiness" of the environmental conditions which obtained during the childhood of the generation to which they refer. This affords a basis for the comparison of the "healthiness" of the environment of town and country at different periods in the past.

3. Whereas in the earlier half of the nineteenth century the ratio of the α values of country to town was in the neighbourhood of 0·6, indicating that the health conditions in the country might be said to be almost twice as good as in the towns, in 1931 it had risen to almost unity, showing that by that time the town had almost if not quite made up on the country. During this period both town and country conditions showed remarkable improvements, which are reflected in falls of the respective α ($\times 1000$) values in the country from about 12 and in the town from over 20 in 1841, to a common level of about 4·7 in 1931.

4. The essential vagueness of the conception of the "healthiness" of an environment is emphasized. It is consequently necessary not to attach too great importance to the estimate of the date, but the figures given in Table 5 confirm the conclusion that, as regards "healthiness", between 1930 and 1935 conditions in town and country had become nearly equal.

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(*MS. received for publication* 25. IV. 40.—Ed.)

https://doi.org/10.1017/S0022172400027911 Published online by Cambridge University Press