problem should really be attacked by the methods used by Mr. Soper in studying the frequency distribution of partitioning a population into a stated number of categories of variable content. Dr. Isserlis thought no conclusion could be drawn from the small correlations of 0·12 ± 0·13 found between mean ages and numbers notified, apart from the fact of all the variations being in one direction. To a layman it seemed natural that a big epidemic should involve higher mean age in the same way that a larger army meant a higher mean age of soldiers during the war.

Dr. GREENWOOD suggested that the small arithmetical value of the correlation between mean age and prevalence might be a consequence of non-linearity of regression, that the correlation ratio might be larger and significant. Were this the case, the statistical result would come into line with what, as Dr. Isserlis had said, seemed *a priori* reasonable.

Dr. CARNWATH said that he would refer to one point only in Dr. Turner's paper, viz,, the alteration in the age-incidence of the disease during times of epidemic. In periods of "normal" prevalence the disease affected mainly the early years of school llfe. He thought it was a natural presumption that when the wave rose the overflow should be forwards in the direction of the adjacent school years rather than backwards towards the years spent in the home. In the schools the children were aggregated in a way that made extension of an epidemic easy as compared with the opportunities for infection in isolated homes. He was disposed to think that some such explanation might also account for the gradual rise in the average age of incidence during the last twenty years. Home conditions were admittedly still far from satisfactory; nevertheless a gradual and substantial improvement had taken place; there was less overcrowding, and there was a higher standard of cleanliness, and families were of smaller size than formerly. The opportunities for infection, therefore, during the early years of life in the home had been considerably reduced, and as a consequence the natural tendency was towards a higher proportionate incidence on the later school years.

Dr. TURNER (in reply) alluded to one point not mentioned in his paper. If a child caught scarlet fever, he was necessarily nursed at first by his mother, and sometimes by the elder daughter. This might account for some of the excess of females over males at ages from 15 to 30.

The Relationship between Rainfall and Scarlet Fever.

By JOHN BROWNLEE, M.D., D.Sc.

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IN April 1880, the late Dr. Longstaff[1] read a paper before this Society on the relationship between scarlatina, erysipelas, puerperal fever, &c., and showed that between certain of these diseases there was similarity in the amount in which they were present from year to year. The part of his paper, however, which concerns us to-night is that in which he showed that from 1855 to 1875 a close relationship appeared to exist between the amount of rainfall and the prevalence of scarlet fever, wet years being associated with less scarlet fever and dry years with more. From 1875 to 1880 the association was less marked. There is no doubt of this agreement, the only question is, as to whether it is accidental or permanent. The data used by Dr. Longstaff related solely to deaths. If the death-rate is high, this is no drawback, but from about 1874

[1] *Trans. Epid. Soc. Lond.* (1880-81), 1881, iv, p. 421.

onwards scarlet fever became a much less fatal disease and from the middle eighties the number of deaths have been relatively so small that it is hardly possible to trace accurately the epidemic variations of the disease from deaths alone. From this cause, therefore, the later figures in Dr. Longstaff's table do not weigh much negatively. The general correspondence between the variations of the weather and of scarlet fever was so marked however, that it seemed impossible to deny the association.

This conclusion I had accepted until I began to investigate the periodicity of epidemic disease. After examining the statistics of scarlet fever in a large number of towns it became evident that, as with measles and whooping-cough, the intervals between epidemics varied greatly in different places. If, therefore, there was an association between rainfall and scarlet fever, there must be local variations in the rainfall, of temporary if not permanent periodicity,

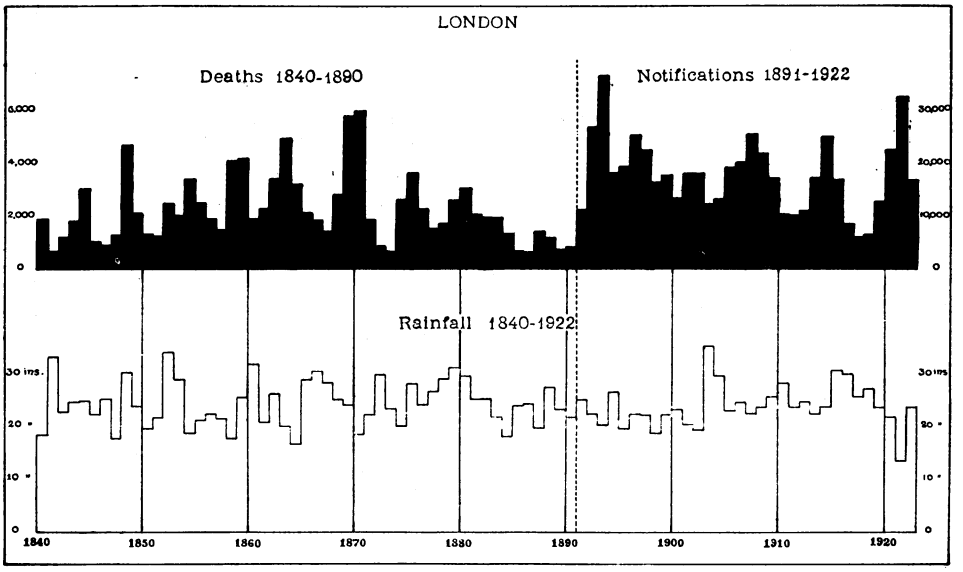

DIAGRAM I.—In this diagram the annual number of deaths from scarlet fever is shown from 1840-1890 and the number of notifications from 1891-1922 on a different scale. The course of the rainfall is graphed below.

in different districts of England and Scotland. This promised to open up not only a fresh chapter in epidemiology but also another chapter in meteorology. It seemed exceedingly unlikely that such variations could take place. It was determined, therefore, to investigate systematically a number of the large towns for which rainfall statistics were obtainable and for which the number of deaths or notifications were large enough to render the course of the epidemics of sufficient certainty to act as a basis for quantitative work. In England the towns selected were London, Birmingham, Manchester, Liverpool, Newcastle-on-Tyne; and in Scotland, Glasgow and Edinburgh.

In the first place it may be noted that the statistics of Manchester and Edinburgh show very little evidence of definite periodicity of scarlet fever. With regard to Manchester this is the third disease for which this has been found, measles and whooping-cough being the other two.

The first town to be examined is London. The facts are shown in Diagram I (p. 31). The amount of rainfall and the number of deaths from scarlet fever are graphed from 1840-90. From 1890 the number of deaths is replaced by the number of notifications. In the first part of this period from 1840-57, diphtheria is not separated from scarlet fever, but the amount of diphtheria at that time was very small, and checking the figures against such diseases as laryngitis and croup nothing but a small error can have been introduced. It will be observed that during the first period 1840-57, the correspondence between the amount of scarlet fever and the rainfall described by Dr. Longstaff is not present. From 1855-76, the association is very close. The correlation is high, being in the region of 0·7. From 1876-90, the correspondence again ceases. In the early period, intervals between epidemic waves of scarlet fever are very nearly five years but in 1890 a new epoch begins. The very large epidemic of 1893 is the starting point of a seven-years period, the succeeding epidemics culminating in the years 1907, 1914 and 1921, the epidemic due in 1900 not appearing. This fact will be referred to later. In this period it may be said that there is a fair correspondence between drought and scarlet fever, the very dry year of 1921 associated with the largest epidemic since 1893 serving to bring the subject again into public notice. It is, however, to be noted that the epidemic due in 1900 did not appear, although the years around this were associated with comparative drought, and that therefore it cannot be said that drought in itself will bring about an epidemic, if other conditions tending to prevent an epidemic exist.

Considering Glasgow next, we find that from 1855 to 1880 the period between the epidemics is very closely five and a half years. Here, again, some relation between dry years and scarlet fever can be made out. There are, however, some curious exceptions. The year 1857, a middle year in an epidemic wave, was a dry year in Glasgow and yet the autumnal outbreak of scarlet fever was absent, though marked in 1858, a year considerably wetter though not a wet year. In Diagram II the average relationship is shown. This is obtained by taking the average number of deaths in each six months and the rainfall in each six months, choosing five and a half years' interval as the most constant phenomenon and adding together the corresponding numbers in each five and a half years' period. The inverse relationship is quite marked, but in view of the preceding remarks too much should not be made of it.

Notification was introduced into Glasgow in 1891. As in London, there was a great epidemic in 1893, but this was not the starting point of a seven-yearly period. The epidemic occurring in 1894 seems to have been the starting point of a strict five-yearly period; the acme of the next epidemic occurs in 1899; the epidemic due in 1904 does not appear. It was previously noted that in London, a like phenomenon occurred at the same time; the epidemic in 1907 turns up true to time as likewise do those in 1914 and 1919. It is to be noted that the year 1921, a year of large amount of scarlet fever in London, and a dry year both in London and Glasgow, was not marked by any epidemic of scarlet fever in Glasgow; the crest of the wave being passed, dry weather had not sufficient power of itself to sustain the prevalence.

Liverpool exhibited a very remarkable series of epidemics. In view of the importance of the subject, the Registrar-General gave me facilities for having the weekly deaths from scarlet fever in Liverpool extracted from the registers in Somerset House from 1853 onwards. One of the most regular periods with which I am acquainted is found to exist at this time, the period being exactly four years. In the accompanying diagram (Diagram III) the quarterly

deaths from scarlet fever have been graphed from 1857 to 1876. The rainfall in each year is indicated by circles below the graph; a dry year is shown by a circular black dot and a wet year by a circle enclosing a cross. A dry year is defined as one in which the rainfall is 3 in. below the mean, and a wet year one in which the rainfall is 3 in. above it. Years with rainfall between these limits are not marked; years for which the statistics of rainfall are not recorded are marked with a horizontal

DIAGRAM III.

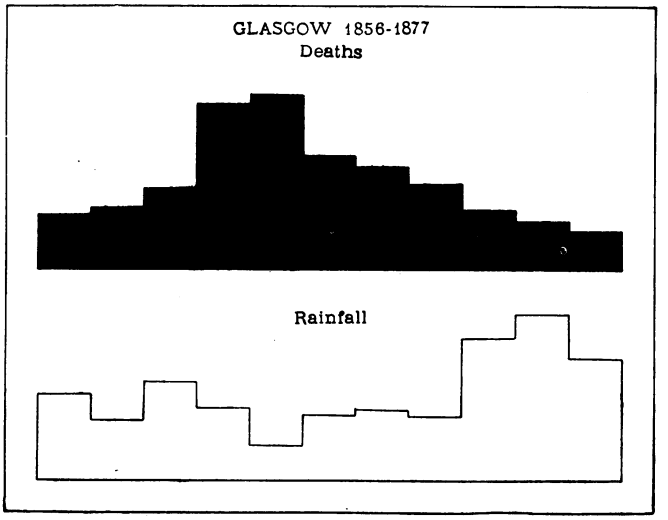

DIAGRAM II.—This diagram shows for twenty-two years, 1856-1877, the average number of deaths from scarlet fever in five-and-a-half-yearly periods and the corresponding average rainfall.

DIAGRAM III.—In this diagram the quarterly deaths from scarlet fever are shown in four-yearly periods from 1853-1876. A dry year, that is one in which the rainfall is less than the average by 3 in., is indicated by a black circle, and a wet year, one in which the rainfall is more than 3 in. above the average, by a circle enclosing a cross. For the years with a horizontal line beneath them, the rainfall records are not available.

line. Here it is to be noted that on two occasions, 1858 and 1866, the largest unit of the epidemic wave occurred with a mean rainfall. In 1866 the amount of scarlet fever was comparatively small and the rainfall just fails to qualify that year as a wet year. Nothing definite can be said about 1862, for the rainfall is not recorded in Liverpool for that year, but in Manchester the rainfall is nearly exactly the mean. The year 1874 was remarkable for its dryness and the size of the epidemic was greater than on any other occasion. Subsidiary waves occur three times. Two of these, the years 1855 and 1857, were associated with dryness. The larger, however, occurred in 1869, which was a wet year.

With regard to the other towns it is not necessary to particularize especially. The same features are apparent as have just been described. One remark, however, may be made about Edinburgh. In this city there has been no regular periodicity of the disease, so that it might be possible to find a closer association between the rainfall and scarlet fever. The association found is not remarkable.

As to the relationship, then, between rainfall and scarlet fever, I think it must be said that it is not causal. There is, a strong presumption that if the conditions are suitable for an epidemic, a dry year will tend to increase its size and a wet year to diminish it. As, however, at the present moment there is apparently no satisfactory statistical method of dealing with an association such as this; in cannot be measured quantitatively.

DISCUSSION.

Sir GEORGE BUCHANAN thought that this investigation was very useful. It gave them facts by which to check the different statements which were often made about the relation between scarlet fever and wet seasons. It would be interesting to know whether the comparison of scarlet fever epidemic years and years with high rainfall had also been extended to months. With such a variable climate as that of the British Isles the total annual rainfall might be quite misleading, for example, as an index of the rainfall in the autumn. In this connexion he thought another question deserved study, namely the facts about seasonal incidence of scarlet fever in different countries and their explanation. Speaking from memory be believed that the characteristic autumn maximum of Great Britain was not found in some Continental countries and was sometimes replaced by a spring maximum. In North America and Japan the maximum incidence of scarlet fever undoubtedly fell in the early months of the year.

Dr. BROWNLEE (in reply) said that when the correspondence between the amount of scarlet fever and the rainfall was examined in smaller periods than the year the relationship became less definite.