THE EPIDEMIOLOGY OF AN INFLUENZA OUTBREAK IN LEEDS

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(With 5 Figures in the Text)

Although influenza caused many more deaths in England and Wales during the seven years 1926–32 than did scarlet fever, diphtheria, measles and whooping-cough taken together, comparatively few accounts of the clinical and epidemiological features of influenza outbreaks have been published. This is probably explained by the fact that influenza is not a notifiable disease; consequently, reliable figures are difficult to obtain, and investigations are robbed of much of their interest. During the outbreak of influenza which affected Leeds in the winter of 1932–3, I was able, through the courtesy of the heads of many large commercial firms and official departments, to obtain information regarding the extent to which their respective establishments were affected. These particulars served to augment the data which were otherwise available, and made possible the following account.

The outbreak evidently started early in December, 1932, since in the second week of this month there was a significant increase in the notifications of influenzal pneumonia. Thereafter, although it was evident from other information that influenza was very prevalent in the city, there was a slight lag until the first week of January 1933, when the notifications of cases of influenzal pneumonia reached eleven, and in the following week they reached their peak figure of thirty-two. The number of deaths registered as due to influenzal pneumonia continued to rise until the weeks ending January 21st and 28th, during each of which forty-eight deaths from this condition were registered. Since it was probable that in each of these cases some days had elapsed between the actual onset of the disease and the fatal termination, it seemed likely that the peak of the epidemic in Leeds was reached during the week ending January 14th. The notifications of influenzal pneumonia decreased fairly rapidly after the peak period, and by the beginning of March 1933, cases were very few.

Investigation of a selected population

During the decline of the epidemic arrangements were made with the heads of large firms and corporation departments, and these gentlemen kindly supplied figures showing the number of new cases of influenza among their

respective employees, which had been notified to them week by week. Owing to lack of reliable records the figures from certain firms and departments had to be neglected. The remaining figures were subjected to as thorough an examination as was possible in the circumstances, and every effort was made to ensure that the cases had actually been certified as influenza by medical practitioners. In many instances consent was given for an official of the Health Department to examine the sickness returns of different establishments. As a result of this selection it was possible to give weekly figures for the incidence of influenza in a selected population of 17,195 persons during the period from the week ending December 3rd, 1932, to the week ending February 25th, 1933. This selected population was made up of twenty groups. Table I gives the total number of persons in each group, together with the total number of cases and deaths in each during the period under investigation, and certain other particulars.

In this investigation it was unfortunately impossible to obtain the age and sex of each patient, so that the age and sex distribution of the 2772 cases of influenza is unknown. It was not thought necessary, therefore, to give details regarding the sex distribution of each group of the selected population, since this would have entailed a further special enquiry and additional inconvenience to the firms and departments concerned. The information in column 2 of Table I is of no importance so far as the investigation is concerned: the

Table I. *Incidence of influenza in selected population.*

Designation of firm or department	*Approx. sex constitution	Total employees	Total cases	Total deaths	Average duration in days	No. off duty over 7 days	Case-rate per 100 of selected population
Business firms:							
A (factory)	♀	2296	294	—	14·1	203 (69·1 %)	12·8 ± 0·5
B (departmental store)	♀	1250	225	—	9	123 (54·6 %)	18·0 ± 0·7
C ,,	♀	450	87	—	7	30 (34·5 %)	19·3 ± 1·3
D (printers)	♂ > ♀	500	50	—	15	34 (68·0 %)	10·0 ± 0·9
E (wholesale chemists)	♀ > ♂	162	23	—	9	16 (69·6 %)	14·2 ± 1·9
F (sweet factory)	♀ + +	400	59	—	18	59 (100 %)	14·7 ± 1·1
G (bank)	♂ = ♀	162	66	—	7	15 (22·7 %)	40·7 ± 2·6
Official departments:							
H (*a*) Outdoor	♂	217	71	—	28	71 (100 %)	32·7 ± 2·2
(*b*) Clerical	♂ > ♀	45	12	—	10	9 (75·0 %)	26·7 ± 4·4
I Clerical	♂ > ♀	338	101	2	6·6	39 (38·6 %)	29·8 ± 1·7
†J Clerical and executive	♂	199	107	—	6	31 (29·0 %)	53·7 ± 2·4
K Mainly outdoor	♂	716	158	1	24·8	156 (98·7 %)	22·1 ± 3·3
L Outdoor and works	♂	1091	156	—	19·5	137 (87·8 %)	14·3 ± 0·7
M Mainly outdoor	♂	182	31	—	19	27 (87·1 %)	17·0 ± 1·9
N ,,	♂	3423	538	2	17	538 (100 %)	15·7 ± 0·4
O Outdoor and works	♂	1360	139	—	16·6	139 (100 %)	10·2 ± 0·1
P Outdoor	♂	315	62	—	21	56 (90·3 %)	19·7 ± 1·5
Q Clerical and nurses	♂ = ♀	965	135	—	11	96 (71·1 %)	14·0 ± 0·9
R Clerical	♀ > ♂	112	24	—	10	10 (41·6 %)	21·4 ± 2·6
S Clerical	♀ > ♂	341	46	—	13	32 (69·5 %)	13·5 ± 1·2
Schools (Staffs):							
T (*a*) Elementary	♀ = 75 % ♂ = 25 %	2175	330	—	10·5	182 (55·2 %)	15·2 ± 0·5
(*b*) Secondary	♂ = ♀	496	58	—	9·5	32 (55·2 %)	11·7 ± 1·0
	Totals	17,195	2772	5			16·1 ± 0·2

* Where only one sex is stated it is understood that either (*a*) the particular population consists entirely of this sex, or (*b*) that the other sex is very much in a minority.

† There is some evidence that in this group many cases of colds were included along with cases of influenza.

estimates in this column serve merely to give a broad indication of the sex constitution of the selected population.

At this point it may be briefly stated that only five deaths were reported in this selected population. This is equivalent to a death-rate of 0·29 per 1000, and to a case-mortality rate of 0·18 per cent. The case-rate for the selected population as a whole was 16·1 per cent.

Table I shows that the different groups can be combined into four main categories: (*a*) factory workers (groups A, D, F); (*b*) shop workers (groups B, C); (*c*) clerical workers and teachers (groups G, H(*b*), I, R, S, T(*a*), T(*b*); (*d*) outdoor workers (groups H(*a*), K, M, N, P). (In groups J, L, O and Q the data could not be subdivided to fit into this grouping; these groups have therefore been omitted from this classification.) If the incidence of influenza in these four main categories of workers is now investigated separately, some interesting features emerge. Table II summarises the essential points.

Table II

Type of work	Total persons at risk	Cases of influenza	Case-rate %
(i) Factory workers (groups A, D, F)	3196	403	12·6 ± 0·4
(ii) Shop-attendants (groups B, C)	1700	312	18·4 ± 0·6
(iii) Clerks, etc. and teachers (groups G, H(*b*), I, R, S, T(*a*), T(*b*))	3669	637	17·4 ± 0·4
(iv) Outdoor workers (groups H(*a*), K, M, N, P)	4853	860	17·7 ± 0·4

The difference in the last column between categories (ii) and (iii) is 1·0 ± 0·7; between categories (ii) and (iv) it is 0·7 ± 0·7; and between (iii) and (iv), 0·3 ± 0·6. None of these differences is significant. On the other hand, there is a significant difference in the case-rate in category (i) from that in the other three categories. This is shown as follows:

Difference in case-rate between categories (i) and (ii)	...	5·8 ± 0·7
,, ,, (i) and (iii)	...	4·8 ± 0·6
,, ,, (i) and (iv)	...	5·1 ± 0·6

It would seem, therefore, that in this selected population the workers in factories were less liable to contract influenza than were assistants in large shops, outdoor workers of various types, clerks and office workers, and school teachers. The data are insufficient to offer any explanation of these differences, but it may be mentioned that the three factories are among the best of their respective types in the city. Further, it is of interest to note that the employees in all three factories (A, D, F) had frequently had talks by members of the Health Department on the subject of general hygiene, with special reference to colds and influenza; and also, that these were the only groups of employees in the selected population which had ever had such propaganda, at least within recent years. At the present time, when so much emphasis is placed on personal attention in the prophylaxis of influenza, such observations are not without interest.

COURSE OF THE EPIDEMIC IN THE SELECTED POPULATION

The total cases returned for each week from each establishment are set out in Table III. It will be seen that, while many of the groups showed a regular increase of cases to a maximum as the epidemic continued, others did not. In some of these the outbreak appeared to start abruptly. This phenomenon was probably due to the fact that the earlier cases were not reported to the respective authorities, or were reported as other conditions. On the other hand, there is a possibility that many of the workers in these groups were infected outside their places of business, so that the appearance of a number of cases was the first indication of the presence of the disease.

Table III. *Weekly distribution of cases of influenza in selected population.*

Designation of firm or department (see Table I)	Week ending Dec. 3	Dec. 10	Dec. 17	Dec. 24	Dec. 31	Jan. 7	Jan. 14	Jan. 21	Jan. 28	Feb. 4	Feb. 11	Feb. 18	Feb. 25	Totals	Duration of outbrea in week
A	6	3	5	8	43	75	68	31	29	15	9	2	—	294	12
B	4	1	3	8	16	48	75	24	16	16	8	4	2	225	13
C	—	—	10	3	4	20	15	13	10	6	4	—	2	87	11
D	3	—	—	1	1	6	23	7	4	2	3	—	—	50	11
E	—	1	—	—	1	5	3	3	4	3	2	1	—	23	11
F	—	—	—	—	3	15	23	11	3	2	1	—	1	59	9
G	1	5	1	1	4	9	15	12	8	3	2	4	1	66	13
H (*a*) and (*b*)	2	—	—	—	2	11	11	13	23	15	4	1	1	83	13
I	1	4	4	4	14	22	21	11	6	9	1	—	4	101	13
J	5	2	10	2	8	10	21	19	15	6	2	4	3	107	13
K	3	2	1	2	11	36	27	28	18	18	5	5	2	158	13
L	3	—	1	3	16	41	36	34	10	7	1	1	3	156	13
M	—	—	—	—	—	6	8	8	5	2	1	—	1	31	8
N	4	12	6	7	6	96	153	97	62	47	19	20	9	538	13
O	2	1	1	2	2	23	36	40	15	9	4	1	3	139	13
P	1	1	—	—	1	6	22	12	13	3	2	—	1	62	13
Q	2	2	4	2	5	28	29	38	10	8	1	4	2	135	13
R	—	—	—	—	—	2	5	4	1	4	4	2	2	24	8
S	—	—	—	—	—	7	17	10	4	5	3	—	—	46	6
T (*a*) and (*b*)	—	1	1	—	1	1	61	145	85	48	27	14	4	388	12
Totals	37	35	47	43	138	467	669	560	341	228	103	63	41	2772	

Mean duration = 11·55 ± 0·29 weeks. σ = 1·92 weeks.

When the cases are summed for each week, however, an orderly sequence is obtained, which shows the course of events week by week for the selected population as a whole. Plotted out as a graph (Fig. 1) these totals form a curve of the typical epidemic type. There is no suggestion from this curve that the outbreak was other than a solitary one, showing a single peak. The observed distribution approximates closely enough to a smooth curve to suggest that the course of events in the selected population gives a fair idea of the course of events in the population as a whole. Fig. 2 shows the same figures plotted on an arithlog scale. The graph suggests that the change from ascent to descent *was not nearly so abrupt as Fig. 1 indicates, and that it was possibly effected gradually during the week ending January 14th, which was the peak week* for the selected population. It is also seen from Fig. 2 that, with the exception of the first four weeks, the rate of ascent and descent of the curve was surprisingly smooth.

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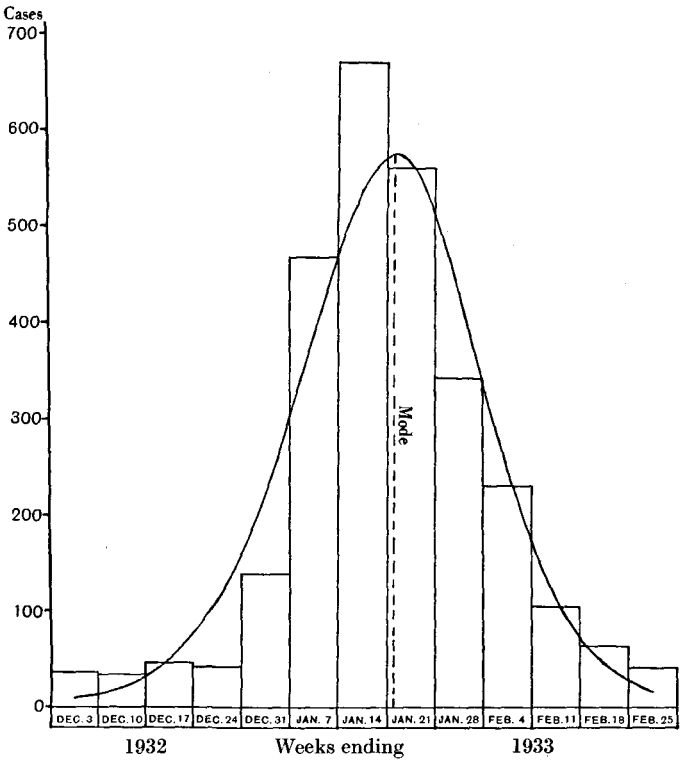

Fig. 1. Incidence of influenza in selected population (Arithmetic scale) Leeds, 1932–33. Type IV.

$$y = 552\left(1+\frac{x^2}{33{\cdot}358}\right)^{-5{\cdot}389} e^{-1{\cdot}048\tan^{-1}\frac{x}{5{\cdot}776}}.$$

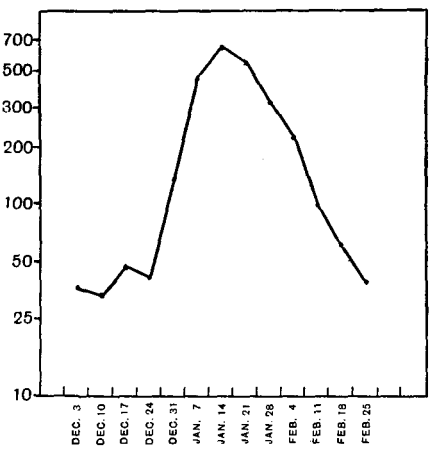

Fig. 2. Incidence of influenza in selected population (Logarithmic scale).

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An attempt was made to fit a curve to the data. The value of the criterion, k_2, being 0·0138, *i.e.* $>0<1$, indicated that the appropriate curve was a Pearson's Type IV for which the equation is:

$$y = y_0 \left(1 + \frac{x^2}{a^2}\right)^{-m} e^{-\nu \tan^{-1} \frac{x}{a}}.$$

Inserting the values obtained from the data, the equation becomes

$$y = 552 \left(1 + \frac{x^2}{33{\cdot}358}\right)^{-5{\cdot}389} e^{-1{\cdot}048 \tan^{-1} \frac{x}{5{\cdot}776}}.$$

Table IV gives the observed and calculated frequencies week by week:

Table IV

Week ending	Actual cases	Cases as calculated from curve	Week ending	Actual cases	Cases as calculated from curve
Dec. 3	37	9·2	Jan. 21	560	562·0
,, 10	35	21·4	,, 28	341	430·9
,, 17	47	49·4	Feb. 4	228	248·2
,, 24	43	109·8	,, 11	103	114·1
,, 31	138	222·7	,, 18	63	45·2
Jan. 7	467	387·3	,, 25	41	16·6
,, 14	669	537·9			

It will be readily seen that the curve does not fit the observed distribution very well. The discrepancy is found especially towards the peak, and is considerable. The occurrence of two epidemic waves in the city might explain the higher peak of the curve of observed frequencies, but when we take into consideration the smoothness of the logarithmic curve, this explanation does not seem at all likely. On the other hand, examination of Table III shows that the notification of cases from certain establishments started only in the weeks ending December 31st and January 7th. This suggests that a number of cases occurred during the first four weeks of the outbreak which were never reported as influenza to the heads of the respective establishments.

In the last column in Table III is given in weeks the approximate duration of the outbreak in each establishment. Owing to the fact that cases of influenza probably occurred before the initial limiting date of the investigation, and that they continued to occur in small numbers in the city after the final limiting date, these estimates probably sometimes fall slightly short of the actual duration. It is noteworthy, however, that the general weekly death-rate for the city as a whole rose above the average for this period over the preceding ten years only during the week ending December 24th. If a period of two weeks is allowed for lag between onset of disease and deaths of patients, it is seen that the commencement of the chosen period is sufficiently early.

In the selected establishments the duration of the outbreak ranged from six to thirteen weeks (S.D. = 1·92 weeks). This gives a mean duration of 11·55 ± 0·29 weeks.

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COURSE OF THE OUTBREAK IN THE CITY AS A WHOLE

Influenza in the city as a whole followed closely the course which has been described in the selected population. Table V gives the main statistics for respiratory diseases in the city during the period from the week ending November 5th to the week ending April 1st. The gross weekly death-rates from all causes for the ten years 1922–33, over that portion of each year which corresponded to the period from December 3rd, 1932, to March 11th, 1933, are set out in Table VI. In addition, the actual number of deaths from all causes registered each week are given in detail for the years 1928–9, and 1923–4, since these were "influenza years." The mean weekly death-rate for this period during these ten years was 17·10.

From Table V it is seen that the general death-rate first exceeded this ten-year average during the week ending December 24th. During the week ending December 3rd the notifications of acute primary pneumonia showed an increase, and in the following week (ending December 10th) there was a distinct increase in the notifications of influenzal pneumonia. It is evident that during this period the "influenzal constitution" was becoming manifest. The death-rate showed no very marked changes until the beginning of January, when there was an evident upward tendency, the peak being reached during the week ending January 21st. These features fit in with the general tendency shown in the selected population, except that, as is to be expected, the death curve shows a slight time lag. Early in February the general death-rate fell rapidly below the ten-year average.

Sir George Newman (1920) stated that an increased incidence of pneumonia and bronchitis not infrequently precedes an increased incidence of influenza, and that "the true curve of influenza mortality can apparently be constructed by combining with it the simultaneous waves of pneumonia and broncho-pneumonia." In Leeds the deaths from influenzal pneumonia reached their maximum (forty-eight in each week) during the weeks ending January 21st and 28th. In each of these two weeks the deaths from broncho-pneumonia and from bronchitis reached their maxima, which were considerably above the normal range. On the other hand, the deaths from lobar pneumonia showed no very marked increase. *Pari passu* with these increased deaths, the notifications of acute primary pneumonia reached their maximum (seventy-five) in the second week preceding the occurrence of the maximum number of deaths from broncho-pneumonia, from bronchitis, and from influenza and influenzal pneumonia respectively—that is, during the week ending January 14th. Van Loghem (1928) showed that the curve for influenzal pneumonia followed broadly that from other respiratory affections. It would seem, nevertheless, that the influenza virus, directly or indirectly, was responsible for a large number of these deaths which were registered as "broncho-pneumonia" or as "bronchitis."

Another interesting point which is seen in Table V is that, while the deaths

from all respiratory diseases under consideration had reached minimal figures by April 1st, the notifications of acute primary pneumonia, which had fallen to very low figures during the second half of February, had again shown a rise, and by April 1st had reached significant figures. Whether this was simply a trailer in the wake of the influenza epidemic, a "sympathetic rise" of an entirely distinct condition; or whether it was due to the continued notification of non-fatal cases of influenzal pneumonia, cannot be determined.

The city of Glasgow suffered from a similar outbreak of influenza about the same period, and for this the main statistics have been given by Dr A. S. M. Macgregor (1933). From his figures it is evident that the infection became epidemic in Glasgow probably during the last week of November—that is, practically simultaneously with the Leeds outbreak. The peak of the Glasgow epidemic evidently occurred during the week ending December 24th, when 117 notifications of influenzal pneumonia were received: the peak death-rate for this condition occurred in the following week. In Leeds, on the other hand, the peak of the epidemic did not occur until about January 21st—that is, approximately four weeks after the Glasgow peak. Although the figures are given only up to January 28th, they suggest that the Glasgow epidemic had practically terminated by the time that the Leeds epidemic had developed its maximum force.

Pearl (1924), in his studies on the 1918–19 influenza epidemic as it affected different American cities, devised a series of six epidemicity indices ($I_1 \ldots I_6$) which are of value in comparing the explosiveness of outbreaks in different localities. For our present purpose the index I_6 is most suitable. The expression is:

$$I_6 = \frac{P - M'}{T'},$$

where P denotes the maximum peak mortality observed during the duration of the epidemic; and T' is the number of weeks which elapsed between (*a*) the date when the mortality curve first passed outside the range of fluctuation exhibited by the curve between a week preceding the epidemic rise by about six or eight weeks, and the end of the week immediately preceding the epidemic rise of the curve, and (*b*) the week in which the mortality curve attained its first epidemic peak. M' is the mean death-rate in the period noted under (*a*) above.

In the present outbreak the available figures for Glasgow and Leeds respectively are as follows:

	Nov. 5	Nov. 12	Nov. 19	Nov. 26	Dec. 3	Dec. 10	Dec. 17	Dec. 24	Dec. 31	Jan. 7	Jan. 14	Jan. 21	Jan. 28
Glasgow (general death-rate)	12·4	14·9	15·2	14·9	14·6	18·2	20·0	28·7	27·3	19·4	18·4	18·0	18·0
Leeds (general death-rate)	13·2	12·3	10·8	15·3	14·8	16·1	15·6	17·6	16·8	19·7	22·9	31·7	31·6

In both the Glasgow and the Leeds outbreaks it has already been stated that the commencement can in each case be taken as the beginning of the

Table V

City of Leeds	1932, week ending November 5	November 12	November 19	November 26	December 3	December 10	December 17	December 24	December 31	1933, week ending January 7	January 14	January 21	January 28	February 4	February 11	February 18	February 25	March 4	March 11	March 18	March 25	April 1
General death-rate	13·2	12·3	10·8	15·3	14·8	16·1	15·6	17·6	16·8	19·7	22·9	31·7	31·6	24·4	21·6	16·2	14·3	16·1	16·8	15·6	13·1	13·3
Notifications of:																						
(*a*) Influenzal pneumonia	1	—	1	—	1	6	3	3	3	11	32	31	26	23	6	9	—	3	1	1	1	3
(*b*) Acute primary pneumonia	7	11	14	11	20	34	39	39	22	41	75	43	52	43	29	4	7	12	18	12	12	22
Deaths from:																						
(*a*) Influenza and influenzal pneumonia	1	2	—	—	1	3	2	2	6	14	33	48	48	31	13	9	2	3	5	2	1	2
(*b*) Lobar pneumonia	8	3	6	5	3	3	—	7	2	7	16	11	9	9	3	1	4	—	3	7	1	2
(*c*) Broncho-pneumonia	4	3	2	5	8	5	9	11	13	16	15	26	28	13	10	6	6	3	10	1	3	2
(*d*) Other forms of pneumonia (excluding influenzal)	—	1	1	—	2	4	—	1	3	1	6	3	2	1	1	2	5	1	—	2	1	—
(*e*) Bronchitis	8	3	8	5	9	8	12	8	13	18	19	33	38	27	20	10	9	6	10	7	6	7

Table VI. *Gross weekly death-rates (city of Leeds) from all causes for certain weeks in* 1932–33, *and corresponding weeks for previous years.*

Mean weekly death-rate for period 1922–3 to 1931–2 (10 years)—17·10.

Period		Dec. 3	Dec. 10	Dec. 17	Dec. 24	Dec. 31	Jan. 7	Jan. 14	Jan. 21	Jan. 28	Feb. 4	Feb. 11	Feb. 18	Feb. 25	Mar. 4	Mar. 11	
1932–3	Rate	14·8	16·1	15·6	17·6	16·8	19·7	22·9	31·7	31·6	24·4	21·6	16·2	14·3	16·1	16·8	19·75
1931–2	Rate	11·9	15·3	14·9	16·3	15·8	16·3	16·3	15·3	13·5	17·5	16·2	14·3	17·8	15·9	18·0	15·70
1930–1	Rate	14·6	13·3	15·6	15·9	16·0	17·8	16·2	17·0	16·2	16·7	18·2	18·2	19·2	18·0	23·1	17·14
1929–30	Rate	14·7	11·1	14·1	12·9	11·6	14·4	16·6	14·2	15·0	11·6	14·0	14·4	12·2	16·1	17·8	14·05
1928–9	Deaths	119	123	136	169	167	174	185	164	142	177	223	328	625	539	374	3645
	Rate	12·9	13·3	14·7	18·3	18·1	19·1	20·3	18·0	15·5	19·4	24·4	35·9	68·4	59·0	41·0	26·44
1927–8	Rate	14·1	13·9	13·9	16·5	16·6	17·5	16·1	14·4	14·3	13·7	13·3	16·7	15·8	16·4	13·8	15·06
1926–7	Rate	14·2	17·0	13·2	12·9	15·8	14·8	16·2	15·5	16·0	17·7	20·1	22·5	20·6	23·0	21·8	17·43
1925–6	Rate	18·7	19·8	17·3	15·7	19·6	16·7	14·3	15·6	15·3	18·4	13·8	19·1	14·8	13·9	17·1	16·60
1924–5	Rate	12·7	11·4	14·1	12·0	12·9	15·5	14·3	14·6	14·1	19·6	15·5	16·3	16·7	16·8	14·3	14·72
1923–4	Deaths	110	142	127	118	146	128	133	180	145	140	154	175	217	270	346	2531
	Rate	12·3	15·9	14·2	13·2	16·3	14·2	14·8	20·0	16·1	15·5	17·1	19·4	24·1	30·0	38·4	18·80
1922–3	Rate	11·9	13·2	15·5	13·1	13·8	14·3	15·2	13·1	13·2	14·8	15·0	17·6	15·4	17·0	15·3	14·56

week ending November 26th. The figures available for the calculation of M' are rather few. With the available data, however, the indices give:

$$I_6 \text{ (Glasgow)} = \frac{28{\cdot}7 - 14{\cdot}2}{5} = 2{\cdot}9,$$

$$I_6 \text{ (Leeds)} = \frac{31{\cdot}7 - 12{\cdot}1}{8} = 2{\cdot}4.$$

It is thus seen that, despite the much longer rise of the Leeds outbreak, in epidemicity it did not fall far short of the Glasgow outbreak.

Age and sex distribution of deaths

Of the 228 patients who died in the city between the beginning of the week ending November 5th, 1932, and the end of the week ending April 1st, 1933, 226 were residents in the city; the other two were non-residents who died in city institutions. The age and sex distribution of the 226 cases is as follows:

Ages	Under 1	1–	2–	5–	10–	15–	20–	25–	30–	35–	45–	50–	55–	60–	65–	75–	85–	Totals
Males	4	3	2	—	—	2	2	2	3	12	9	12	14	7	17	18	3	110
Females	1	1	2	2	1	—	3	2	2	19	11	9	7	8	21	24	3	116
Totals	5	4	4	2	1	2	5	4	5	31	20	21	21	15	38	42	6	226

From the information supplied by the death returns it seems probable that there were no marked differences in the sex distribution of the disease.

Since the pandemic of 1918 the age incidence of influenza in different outbreaks has been a feature of considerable importance. The late Dr T. H. C. Stevenson (1919) showed that in London the age incidence of influenza had been more or less constant from 1890 until 1918. During the July outbreak of 1918 there was an abrupt change, the emphasis falling heavily on young adults, and persons over 45 years being relatively little affected. This peculiarity was even more marked in the October outbreak of 1918. It was suggested in the Ministry of Health's report on the pandemic that the toll taken at the young adult ages of life was without any known West European or North American precedent (*Ministry of Health Report*, 1920, p. 40).

The experience of Leeds since 1900 is shown in Fig. 3. The method is that employed by Stevenson to demonstrate the age incidence in the London outbreaks from 1890 to 1918. The peculiar age incidence of the 1918–19 outbreaks is evident. An interesting feature is, however, that, whereas the transition to the 1918–19 grouping was abrupt, the return to the *status quo* has been gradual. These features are most clearly seen in the age-groups embracing the extremes of life—0–25 years, and 65 years and over. The figures at the top of each column give the total number of deaths on which each set of percentages was calculated. The years 1918, 1919, 1924, 1929 and 1933 are marked X, since in these years influenza was evidently epidemic. (As the majority of the deaths from influenza during the epidemic which is under consideration occurred in the first quarter of 1933, for the purpose of discussing mortality figures this year has been considered to be the epidemic year in preference to

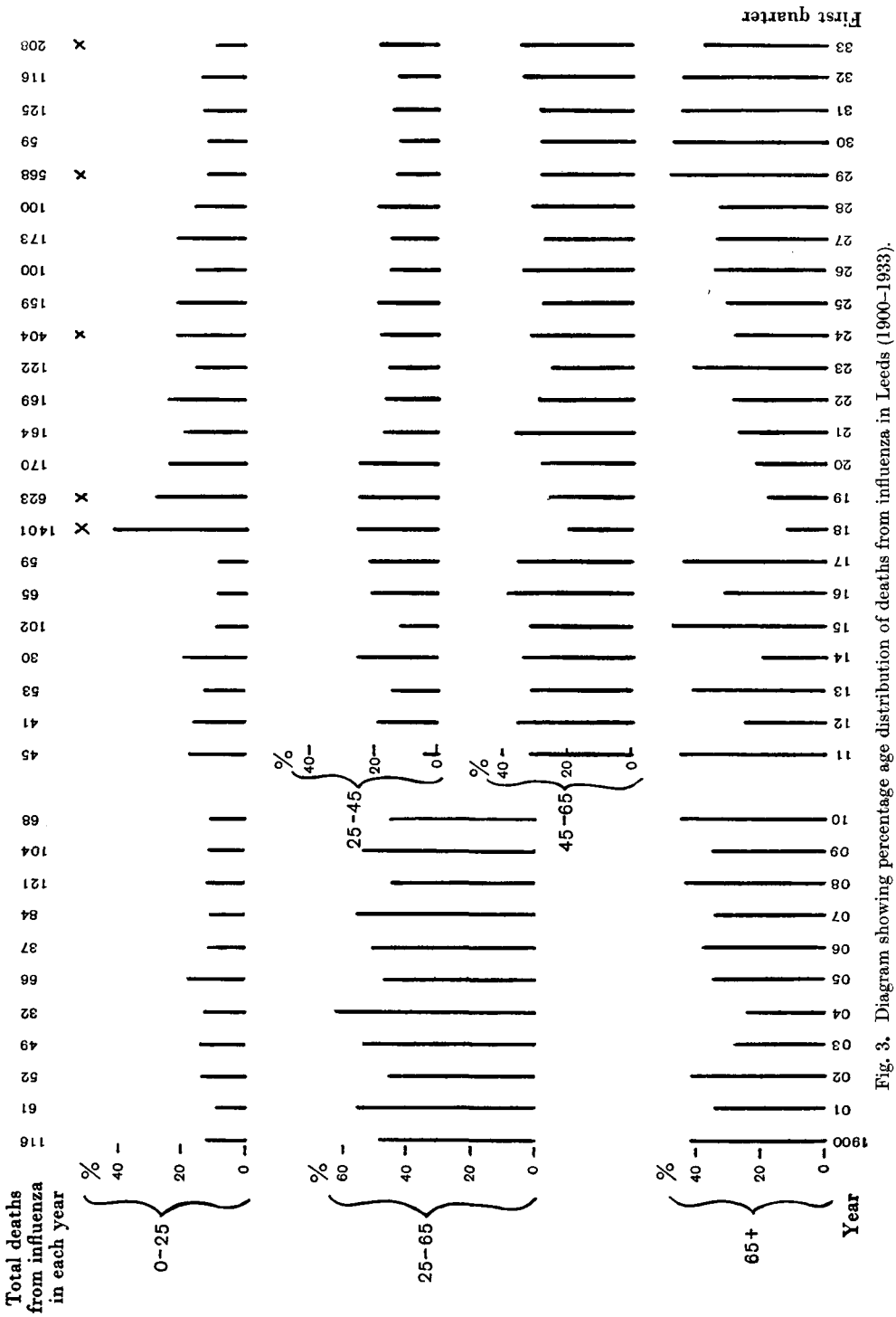

Fig. 3. Diagram showing percentage age distribution of deaths from influenza in Leeds (1900–1933).

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1932.) From the diagram it would appear that the normal balance of ages affected was reached in the 1929 epidemic. It is also seen from the diagram that these epidemic years fit in with the theory of the gradual return to the *status quo* better than some of the inter-epidemic years do. This feature may be due to the small number of deaths in some of these inter-epidemic years; or, on the other hand, some unknown factor may be responsible. At all events, there seems to be some justification for the assumption that the 1918–19 epidemic was not an isolated peak, entirely unrelated to the main waves of epidemic influenza which preceded and followed it. Granted that its onset was catastrophic and precipitated by influences which are not yet understood; in its wake there remained changes in the "influenzal constitution" which, so far as the age incidence is concerned, in round figures were effective in the city of Leeds for a period of ten years.

Distribution of deaths in the city

To obtain some idea of the mode of spread of the epidemic in the city as a whole the information furnished by the death certificates has had to be used, since no definite statement regarding morbidity was possible. This information is summarised in line 4 of Table V.

Each death from influenza which occurred in the city was plotted according to sex on a time-ward diagram. (The resulting diagram gives no information which warrants its reproduction.) It shows that generally the earliest deaths occurred in those wards of the city in which the mortality was afterwards highest. A number of deaths occurred in every ward, so that the infection certainly affected the city as a whole. It is noteworthy, however, that in those wards in which the mortality was greatest, the first deaths occurred earlier than in the other wards.

Table VII gives the density of population (persons per acre) in the twenty-six wards of the city, which are arranged in descending order of density. (The density is given to the nearest whole number, and in calculating these densities allowance was made for the various parks and open spaces in each

Table VII

Ward No.	15	19	10	2	4	5	3	17	21	22	12	23	8
Density of population	96	95	87	84	69	60	54	51	51	49	42	38	35
Persons per room	1·3	0·92	1·20	1·03	1·00	0·90	0·74	1·14	0·92	1·21	0·67	0·98	0·64
Actual deaths	11	6	18	17	14	10	15	7	8	13	14	3	5
Death-rate per 10,000	4·5	3·3	7·8	8·7	6·6	5·3	6·5	3·8	5·8	7·1	7·1	1·5	3·0
Ward No.	11	1	24	9	16	20	25	18	26	13	7	6	14
Density of population	32	29	21	19	16	14	9	9	7	5	4	3	3
Persons per room	0·77	1·14	0·82	0·84	1·00	0·76	0·86	0·98	0·89	0·59	0·67	0·63	0·76
Actual deaths	11	5	7	5	11	3	2	9	7	5	4	10	3
Death-rate per 10,000	5·6	3·2	4·1	2·6	5·1	2·0	1·1	4·5	3·8	3·3	2·2	6·4	2·1

ward.) The table also gives the actual number of deaths from influenza in each ward from the week ending November 5th, 1932, to the week ending April 1st, 1933; these figures are also shown as death-rates per 10,000 persons living in each ward.

From the table it is evident that there was no direct association between the incidence of death as a result of influenza and the density of the population in the ward. An important objection is that we are here dealing, not with actual cases, which were undoubtedly numerous, but with deaths, which were so few as not to warrant any satisfactory deduction being made from such evidence. Nevertheless, it may perhaps be said that the absence of any apparent association between density of population and death-rate from influenza bears out the negative results which were obtained for the 1918–19 epidemic. As a result of a minute analysis of the available data the conclusion was drawn that it was improbable that domestic overcrowding could be deemed a principal factor in the spread of epidemic influenza.

More interesting results are obtained when the ward death-rates are incorporated on a ward map (Fig. 4). It is seen that the wards with the heaviest death-rates are arranged in an inner ring round the centre of the city. Surrounding this inner ring is an intermediate zone, and on the outskirts of the city lie the wards in which the deaths were fewest. It might be thought from the map that ward 6 does not conform to this arragnement. It will be seen, however, that the innermost point of the boundary of this ward lies very near the centre of the city, and that the outermost boundary forms part of the boundary of the city itself. In this large area that part which is nearest to the centre of the city is very congested; the outer part is made up entirely of a residential area. In actual fact, however, only one of the ten deaths which were registered as having taken place in this ward occurred in what might be termed a "congested area."

The map (Fig. 4) also shows that ward 1, which forms the hub of the city, and ward 23, which forms part of the inner ring, both showed only a few deaths. No significant deduction can, of course, be made from the study of deaths alone; yet it is strange that these two wards showed so few deaths in comparison with the heavily affected wards which lie adjacent. The few deaths in ward 1 may perhaps be explained by the fact that this ward contains the business quarter of the city, and that, while there is a resident population of 15,778 persons, many of these are housed in fairly modern flats over business premises. The case of ward 23 is more difficult to explain away. It should be mentioned, however, that the north boundary of this ward is constituted by the River Aire. The main railway lines run close to the south boundary of the ward, and extensive railway sidings are situated on a large portion of the actual ward boundary. Stocks (Stocks and Karn, 1932) has shown that whooping-cough in London has been known to respect natural and artificial boundaries of this type; and it may be that with influenza, despite the tradi-

tional rapidity of spread and the posting effect, some similar but unknown factors are at work. It is perhaps significant that the first death in ward 23 occurred on January 12th, by which time practically every other ward in the city had suffered several deaths.

From a consideration of the map and the time-ward diagram it would appear that the influenza outbreak showed its effects earlier and more severely

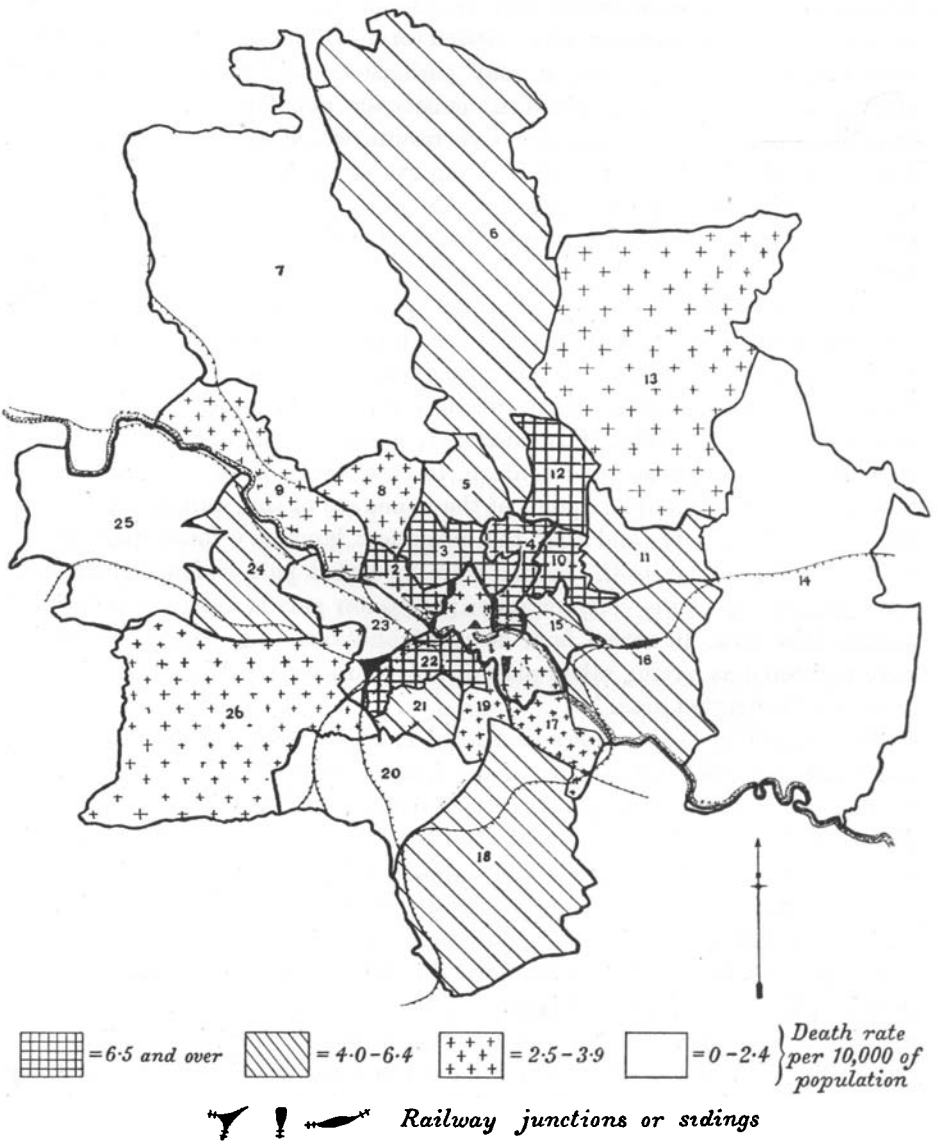

Fig. 4. Map showing death-rates from influenza in different wards of the city of Leeds.

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in the centre of the city, and that from there it extended outwards with decreasing "potential" towards the outskirts.

It is interesting to note that the figures in Table VII suggest no apparent association between the number of deaths from influenza and the average number of persons per room in each ward.

ASSOCIATION BETWEEN RESPIRATORY TUBERCULOSIS AND INFLUENZA

Many writers have called attention to the close association between influenza and other acute respiratory affections, but the possible connection between influenza and tuberculosis is less frequently commented on. Table V gives the weekly deaths from lobar pneumonia, broncho-pneumonia, and from chronic bronchitis during the period of the influenza epidemic. In each case there is an increase in the number of deaths from the respective conditions, and this increase, and the subsequent decline, proceed *pari passu* with the increase and decrease in the deaths from influenza and influenzal pneumonia. Records of various outbreaks, including the London epidemic of 1918–19, show that there is an increase in the number of deaths from phthisis during an influenza epidemic, and that this increase tends to reach its maximum about the time of the peak period of the influenza outbreak. It is mentioned in the *Ministry of Health Report* (1920, p. 26) that such records show that "the infection of influenza, if not specially attracted by the phthisical, is at least particularly deadly to them."

The position with regard to tuberculosis of the respiratory tract in Leeds is shown in Table VIII.

Table VIII

Year	No. of registered deaths from tuberculosis of respiratory system			
	1st quarter	2nd quarter	3rd quarter	4th quarter
1926	158	125	86	108
1927	154	126	97	80
1928	125	136	75	117
1929	180	130	102	96
1930	135	110	85	102
1931	130	103	100	106
1932	109	109	75	93
1933	129	107	77	99
Mean deaths in each quarter (8 years)	140	118	85	100

The influenza epidemic of 1929 reached its height during February and March of that year, and by the end of March it had practically died down. It is seen from the table that not only were the deaths from tuberculosis of the respiratory system distinctly above the average during the first quarter of 1929, but that they were actually the greatest registered in any quarter of the years 1926–33. On the other hand, the number of deaths registered as due to respiratory tuberculosis during the fourth quarter of 1932 and the first quarter of 1933 were distinctly below the average. These statements seem to hold even when the natural decrease in the death-rate from pulmonary

tuberculosis is taken into account. This unusual feature is difficult to explain. Taking into account the very low case-mortality rate in the selected population, it is possible that the particular type of influenza which was prevalent was of a non-killing variety and of a mild nature which was not prone to lead to a fatal flare-up of an already existing tuberculous condition. If this be the case, then the actual number of deaths registered as due to influenza in the city must have represented a very extensive epidemic of this mild form of the disease.

Meteorological conditions

The association between weather conditions and the incidence of respiratory infections has been examined on several occasions. During the 1919 influenza epidemic a report issued from the Direction d'Hygiène suggested that in Paris a sharp fall of temperature coincided with a rise in the curve of mortality, and that these periods were associated with a period of drought. This feature was examined in detail in the *Ministry of Health Report*, and it was shown that, when the death-rates in the three waves were plotted along with accumulated day-degrees of temperature, the onset of each wave of the epidemic was coincident with a rapid fall of temperature. It was further shown that, when the correlation between the pneumonia death-rate and the temperature during the previous week was worked out over a number of years, there was a significant increase in the correlation between these two variables during the 1918–19 epidemic. Dr Matthew Young (1924), in a very extensive analysis, concluded that there was a definite inverse relationship between the prevailing temperature and the mortality from respiratory diseases in children under five years of age. It is not intended in this communication to discuss the effects of meteorological conditions; but, since any report of an outbreak of respiratory disease would be incomplete without some description of these factors, the conditions which prevailed during the period of the outbreak will be briefly described.

The prevailing meteorological conditions during the period of the epidemic are shown graphically in Fig. 5, together with the notifications of influenzal pneumonia and primary pneumonia taken together, and the incidence of influenza in the selected population. Exception may be taken to the inclusion of cases of primary pneumonia with cases of influenzal pneumonia, especially in view of the fact that Macgregor (1933 *a*) has shown that there are grounds for considering lobar pneumonia to be a disease which is itself primarily associated with meteorological conditions. In favour of the method adopted in the figure, however, is the fact that during the epidemic there was an increase in cases of primary pneumonia at a time when this disease is not usually very prevalent in the city, and that the increase was associated quantitatively with the increase of influenzal pneumonia. In the light of these facts it would seem that a true idea of the incidence of pneumonia, arising directly from the prevalence of influenza in the city, is obtained by combining the deaths from the two forms of pneumonia.

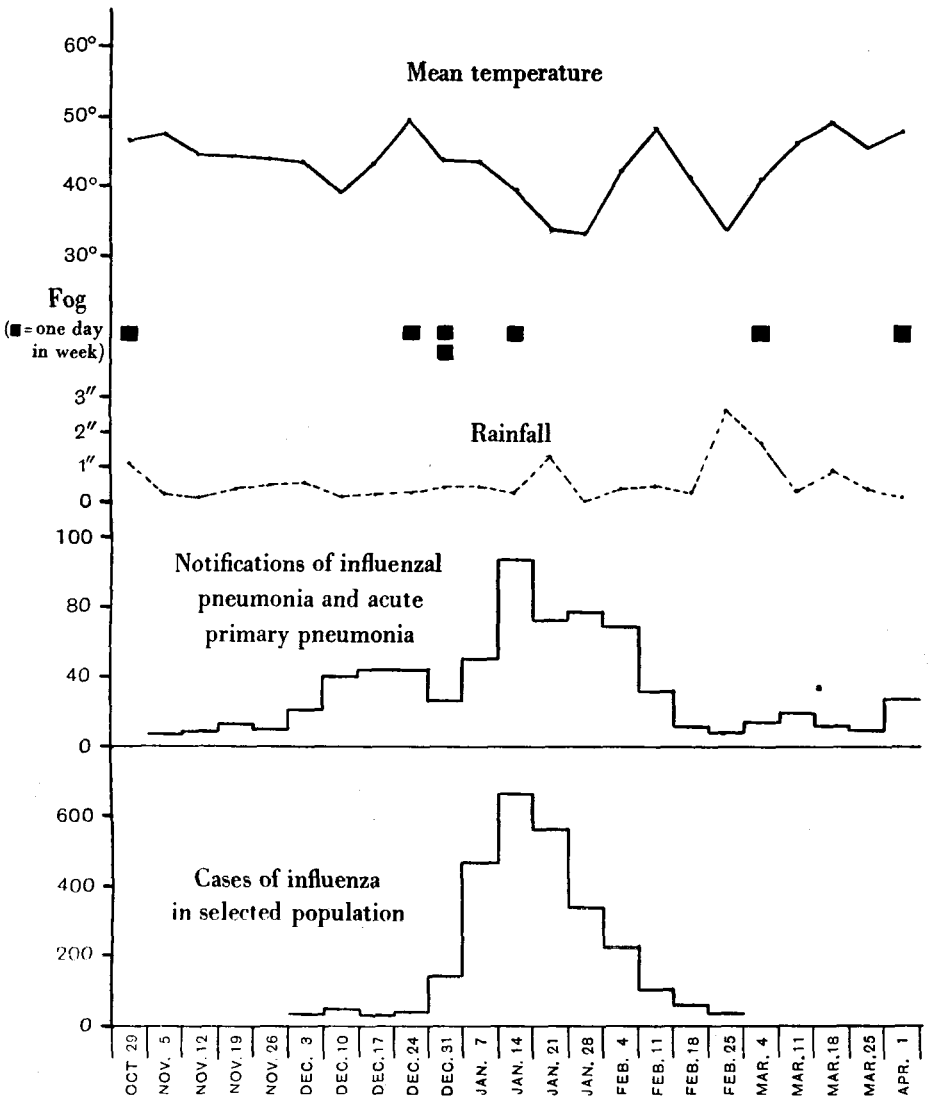

Fig. 5. Diagram showing meteorological conditions in relation to influenza.

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A curve based on influenzal pneumonia must necessarily show some lag so far as influenza itself is concerned, and probably a truer idea of the state of affairs is obtained by using the figures for influenza prevalence in the selected population. These figures are incorporated in the form of a histogram.

It is seen that the first appreciable increase of influenza and of influenzal pneumonia was accompanied by a definite fall in temperature. Thereafter, for two weeks the temperature rose, and there was no significant increase in the number of cases. During the weeks ending December 24th and 31st there were three days of fog and these were associated with a considerable fall in temperature; these features were accompanied by a very marked and sudden increase in the number of cases. The increase continued until the week ending January 14th, during which week the temperature was still falling and one day of fog was experienced. A succeeding fall of temperature (weeks ending February 11th to February 25th) was followed by a rise in the number of cases of pneumonia which were notified. The rise coincided at the start with one day of fog; and during the week ending April 1, when the temperature showed only slight variations, another day of fog coincided with a further increase in the notifications of pneumonia.

The association between rainfall and incidence of the disease is not so marked. It seems to be worth while to notice, however, that the first decrease from the peak of the epidemic coincided with a marked increase in rainfall.

These remarks suggest that there was some association between the meteorological conditions, especially mean temperature and presence of fog, and the course of the epidemic.

Clinical features

Some idea of the clinical aspects of the outbreak was obtained through the courtesy of various medical practitioners in the city. A series of questions was put to these gentlemen by the writer, and the following description collates their replies.

Respiratory type. The prevalent type of disease was respiratory and rather mild in nature. Generally, two forms of respiratory disorder were found, though not with equal frequency in different districts. The commonest form resembled the classical picture of influenza. The onset was usually sudden, without prodromal features. The patients complained of depression, shivering and pains in the back or in the body generally. In the early stages headache, sometimes frontal and sometimes occipital, was frequent. When the patient was first seen by the practitioner the temperature was high—often 102 or 103° F. These acute features lasted two to five days; thereafter, the temperature fell suddenly and profuse sweating brought relief from the symptoms. In many cases the disappearance of acute symptoms was followed by debility or depression which lasted for about a week.

The other form of the respiratory type appears to have been mainly a tracheitis. The onset was again sudden, and an important feature was sternal

pain. The throat was often raw and injected, and sputum was sometimes present. In certain districts of the city this seems to have been the prevalent form of the disease.

In both forms physical signs were few. If present, they were mainly of the nature of bronchial signs, such as moist rales, which were found at the lung bases only at the start of the disease.

Gastric type. Gastric cases were infrequent. Only one of the practitioners who was consulted had seen more than three cases of this type of the disease in his practice during the whole course of the epidemic, and several had not seen any gastric cases. On the whole, it seems that the gastric type tended to appear more towards the end of the outbreak. The condition simulated acute gastritis, with or without diarrhoea, and a common symptom was pain in the epigastrium just below the xiphisternum. Abdominal tenderness was usually absent. In a few cases diarrhoea was apparently practically the only symptom.

Complications. Apart from depression or prostration, which was noticed above to have been quite common, complications and sequelae were not frequent, and were mainly of two types:

(*a*) Influenzal pneumonia. None of the practitioners who were consulted had seen more than a few cases of this condition, so that the total notified cases (discussed previously) must have represented a widespread incidence of influenza. The clinical features of the influenzal pneumonia presented nothing unusual.

(*b*) Acute otitis media. This complication is recognised as being fairly frequent after influenza. In the present outbreak it was apparently much commoner than pneumonia. It affected both adults and children, but the complication was more frequent among children. Paracentesis was frequently not required.

(*c*) Other complications. Some practitioners had cases of cardiac complications—such as tachycardia, palpitation, "D.A.H."—following the acute attack. In other districts throat conditions supervened, and in one district at least acute skin conditions—such as seborrhoeic eczema—were not infrequent after, if they were not actually complications of, attacks of influenza.

It is of interest to compare the salient clinical features of the Leeds outbreak with the symptoms found elsewhere. In the Glasgow outbreak (Macgregor, 1933) the disease was apparently very similar to that seen in Leeds. The gastric type was not common, and the illness usually began with a sharp onset, followed by pyrexia with general and joint pains, which lasted a few days. Dr Macgregor notes that the acute symptoms were apt to be followed by cough and general debility. On the other hand, Marriott (1933) described forty-seven cases of influenza in the staff of the Middlesex Hospital, London. Of these seven (15 per cent.) were gastric cases. The respiratory cases very frequently complained of sternal pain, and the fauces were sometimes inflamed. Chest signs were few. The Leeds outbreak therefore seems

to have combined the clinical features of both the London and the Glasgow outbreaks.

Multiple cases in households. Most of the practitioners consulted had seen several examples of this occurrence. Commonly the infection appeared to be from husband to wife, or *vice versa*. These cases followed each other at intervals which varied from two to four days. In one remarkable instance a mother developed the disease first, then two daughters and a son were attacked successively; all of these persons developed influenzal pneumonia.

Duration of incapacity for work

In respect of the duration of incapacity the replies of the various practitioners could be divided roughly into two groups. Those practitioners whose clientèle consisted largely of clerical, administrative, and mental workers, stated that their patients had generally returned to their duties after an absence of about a week or ten days. On the other hand, practitioners who attended many persons of the artisan class stated that their patients were generally off work for more than ten days: the period was often a fortnight and sometimes three weeks.

This question was also considered from the point of view of the selected population. Particulars of two classes were furnished by the heads of the respective establishments: (*a*) the number of persons under their control who, owing to influenza, were off work for more than seven days; (*b*) the mean period of absence for all the employees which their returns had shown as having suffered from influenza. These particulars are set out in columns 6 and 7 of Table I.

For the purpose of comparing the duration of incapacity in the different types of workers, the same groups of establishments were taken as previously (see Table II). The mean period of absence for each group was calculated from the total cases in each establishment and the average period of absence for these cases. The results are given in Table IX.

Table IX

Type of work	Mean duration of absence in days
(i) Factory workers (groups A, D, F)	14·8
(ii) Shop workers (groups B, C)	8·4
(iii) Clerks, etc., and teachers (groups G, H(*b*), I, R, S, T(*a*), T(*b*))	9·6
(iv) Outdoor workers (groups H(*a*), K, M, N, P)	19·7

This inquiry therefore bears out the tentative statements made by individual doctors that brain workers and persons in the middle classes were off duty for a shorter time than were members of the artisan and poorer classes. From the above table it is seen that the difference is considerable. This difference may possibly be associated with the better care and attention which members of the middle classes presumably receive, so that they recover more quickly. Another alternative is that the members of the artisan class feel that

when they return to work, they will be called upon to undertake heavy duties, often in the open air, without any preliminary period in which to become thoroughly well. A third alternative, and one which must definitely be given consideration, is that the members of the artisan classes feel little responsibility towards their work and their employers, and that they therefore do not feel called upon to return to duty until their doctors take the initiative, and sign them up as fit. This alternative probably does not apply to all members or all groups of members of the artisan class. But, that the possibility is worth consideration is shown by the fact that certain practitioners are inclined to hold this view. As one doctor, whose practice embraces a large working-class clientèle, expressed it—"They will stay off work as long as I will let them." At any rate it would appear that a measure of the severity of any influenza outbreak which was based on the duration of incapacity for work of only one social section of the community would probably not be of much value.

SUMMARY AND CONCLUSIONS

1. This paper deals with the epidemiology of an outbreak of influenza which started in Leeds late in November 1932 and continued until the end of February 1933.

2. Returns of the actual cases which occurred each week in certain official departments and large firms made possible the investigation of a selected population. This consisted of 17,195 persons, and among its members there were 2772 cases of influenza with five deaths. The case-rate was therefore $16{\cdot}1 \pm 0{\cdot}2$ per 100 of the selected population. It is shown that in this population factory workers were less liable to contract influenza than were assistants in large shops, outdoor workers, clerks and office workers, and school teachers; and it is suggested that propaganda relating to respiratory infections may have had some effect in lessening the incidence of the disease among the workers in these factories. The mean duration of the outbreak in the selected establishments was $11{\cdot}55 \pm 0{\cdot}29$ weeks.

3. The total cases which occurred each week in the selected population were plotted as a graph; the resulting curve was of the typical epidemic type. A Pearson's Type IV curve was fitted to these data. The available evidence points to the fact that the outbreak consisted of a single wave.

4. From the data for the city as a whole it is shown that the Leeds outbreak took approximately twice as long to reach its peak as did the Glasgow epidemic, though both outbreaks started practically simultaneously. Nevertheless, in actual epidemicity, the Leeds outbreak did not fall far short of that which occurred in Glasgow.

5. An investigation of the age distribution of deaths from influenza in Leeds since 1900 shows that, though the 1918 epidemic produced a sudden change in the age distribution, in that there was an unprecedented toll of young adult life, the return to the *status quo* was not sudden, as is often assumed, but was effected gradually over a period of about ten years.

6. It is shown from an investigation of influenza deaths in different parts of the city that there was no direct association between these deaths and the density of population in the wards in which they occurred. Neither was there any association between the number of influenza deaths and the average number of persons per room in each ward. From a study of the distribution of the deaths in time and space it appeared that, with certain exceptions discussed in the paper, the outbreak started in the centre of the city and extended outwards from the centre with decreasing potential.

7. An investigation of the meteorological conditions suggested that there was a definite relationship between a fall of temperature, especially if accompanied by fog, and an increase in the incidence of influenza and of pneumonia.

8. The clinical features of the outbreak are discussed fully in the text. The disease was essentially of the respiratory type. Two forms of this were in evidence, (*a*) a form resembling the classical picture of influenza, and (*b*) a form in which the predominant feature was tracheitis. The gastric type of influenza was not common. Complications were not very frequent, but the commonest were influenzal pneumonia and acute otitis media. The duration of incapacity for work varied according to the social status of the individuals. Brain workers and persons in the middle classes were generally off duty for about nine days. On the other hand, the duration of incapacity in artisans and factory workers was usually about a fortnight or three weeks.

9. From the evidence which is adduced in this paper as a whole, including a consideration of the tuberculosis statistics of the city, it would seem that, though the outbreak of influenza in Leeds during the winter of 1932–3 was of a mild and non-killing type, infection was widespread, and the total incapacity must have resulted in a considerable economic loss to the community.

I am indebted to Prof. J. Johnstone Jervis for suggesting this investigation. My thanks are also due to the heads of the various departments and commercial firms, and to the Staff of the Public Health Department, without whose co-operation the data for this study could not have been obtained.

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