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I N F E C T I O U S   D I S E A S E

By

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A Series of Statistical Studies of the Epidemiological Behaviour of Scarlet Fever, Diphtheria, Measles, and Whooping Cough in Glasgow between 1916 and 1945, with special reference to Age-Incidence and to Social Environment.

PREFACE.

This work comprises a series of statistical investigations into certain aspects of the behaviour of Scarlet Fever, Diphtheria, Measles, and Whooping Cough in Glasgow between the years 1916 and 1945.

References in the literature to variations in the age-incidence of Diphtheria in various parts of the country, including Glasgow, prompted me to investigate changes in the age-distribution of cases and of deaths not only in Diphtheria but also in these three other common infectious diseases of childhood.

It will be shown that whereas an age-shift in morbidity towards a higher age has occurred not only in Diphtheria but also in Measles and Whooping Cough, in Scarlet Fever on the other hand the age-shift in morbidity has been in the opposite direction, that is towards a younger age.

The suggestion having been made by certain workers that age-shift in Diphtheria in London was associated with variations in social environment, I thereupon proceeded to study the relationships between the morbidity and mortality of the four diseases, age of attack, and social environment.

Here again, it will be shown that the behaviour of Scarlet Fever has differed in certain respects from that of the other diseases.

I have attempted as far as possible not only to present all the initial numerical data on which these studies are based but also to describe in detail the elementary statistical methods of analysis that have been employed. This has necessitated the inclusion of a large number of tables, the accompanying text being in the nature of a commentary upon these tables. In my final chapter I have discussed certain of the more notable features in the behaviour of the diseases as revealed in the earlier chapters, and I have offered some suggestions concerning the possible epidemiological processes that have been at work.

It is a limitation of the statistical method that while it may, by classification and analysis, reveal hitherto unrecognised trends and associations, it does not, of its own, explain these trends and associations. At the most, it can do no more than point out the probable direction in which we must look for the explanations we seek. Accordingly, in my discussion chapter, I am able to offer only the most tentative suggestions to explain the behaviour of the diseases, and, more particularly, the apparently abnormal behaviour of Scarlet Fever.

It is not suggested that as a result of these studies any revolutionary change in outlook on the problems of epidemiology will be achieved. This work is but one of those which individually contribute little of immediate value towards the advancement of medical knowledge, but which collectively may lead to a fuller understanding of the relationship between man and microbe, and so carry us a little further along the road towards victory over infectious disease.

It is with pleasure that I acknowledge the encouragement and advice that I have received from Dr. Thomas Anderson, Lecturer in Infectious Disease at the University of Glasgow. My thanks are due also to Dr R.A.Robb, Lecturer in the Mathematics Department of the University of Glasgow, who advised me on certain statistical matters, and to Miss Mary Knox, Librarian in the Public Health Department of Glasgow, who directed me towards the source of much of the statistical data that I have employed.

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CHAPTER 1

Introduction.

Section 1.

Morbidity, Mortality, and Fatality Rates in Scarlet Fever, Diphtheria, Measles, and Whooping Cough. (1916-1945)

This work opens with a general survey of the morbidity, mortality, and fatality rates in the four diseases in Glasgow from 1916 to 1945.

In Glasgow an annual register is maintained by the Medical Officer of Health of all cases of statutorily notifiable infectious diseases, and, in addition, of certain other infectious diseases not statutorily notifiable but of whose occurrence the Medical Officer of Health has become aware. Among the latter are included Measles and Whooping Cough, neither of which is as yet notifiable in Scotland.

The term "registered" cases is a convenient one wherewith to describe all the cases entered in the register. The term is not synonymous with "notifications" since it includes cases which have not been notified in the ordinary sense. Further, the register is amended for known errors of diagnosis. Throughout the course of this work numerical data concerning morbidity in Glasgow will be based upon "registered" cases.

The statistics both of morbidity and mortality which constitute the starting point of these studies have been obtained from two sources, (i) the published Annual Reports of the Medical Officer of Health of Glasgow, and (ii) the unpublished annual records of the Public Health Library, access to which was allowed me during a course of post-graduate study in the Institute of Hygiene of the University of Glasgow.

The actual annual numbers of "registered" cases and of deaths attributed to each of the four diseases are shown in Table 1. Table 2 expresses the same data as rates per million of the total city population for each year. The population figures on which these rates have been based have been obtained from the Annual Report of the Medical Officer of Health for 1945 in which are given annual population estimates since 1861.

In Table 3 the actual numbers of cases and of deaths have been aggregated for 5-year periods and for the whole 30 years, and in Table 4 these aggregates have been reduced to average annual rates per million total population for each 5-year period, and for the 30-year period.

Morbidity rates.

The case-rates for Scarlet Fever vary between 1,258 cases per million in 1918 and 8,315 cases per million in 1932.

Table 1.

Annual Cases and Deaths, Actual Numbers, Glasgow, 1916-45.

Year	Scarlet Fever		Diphtheria		Measles		Whooping Cough	
	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
1916	4073	161	1336	136	10435	516	1682	159
1917	1806	36	1267	153	12967	628	11027	854
1918	1327	25	1534	183	8630	369	4038	412
1919	2724	49	1812	161	9039	328	6709	628
1920	3767	59	2017	160	11797	311	2671	145
1921	3517	54	1856	129	3050	110	10748	690
1922	3475	75	1689	139	18868	1286	2850	198
1923	3568	72	1767	145	10305	560	4942	371
1924	3184	79	1899	137	8316	516	10048	648
1925	3812	68	1736	113	6507	118	12194	587
1926	4684	88	2294	132	16117	427	3818	182
1927	4117	44	3036	113	8983	307	9993	364
1928	3224	34	2581	140	10018	376	8055	381
1929	3331	40	2086	135	6421	80	5046	253
1930	4918	41	2580	145	12314	266	5726	225
1931	6980	74	2065	119	15268	416	9136	464
1932	9105	102	2100	119	5524	187	4623	128
1933	8339	83	2318	89	938	4	6412	227
1934	5917	77	2598	161	24423	514	5830	176
1935	4009	37	2409	115	890	8	7747	277
1936	4290	33	1923	54	20111	311	4174	117
1937	5563	29	2283	116	2244	29	8676	285
1938	4008	29	2790	132	15724	257	4102	88
1939	2934	11	3121	163	1452	2	6279	150
1940	1835	10	5142	226	10889	97	868	20
1941	1880	7	4008	155	1567	11	10917	286
1942	3060	9	3300	90	8255	65	1161	28
1943	3084	5	2893	81	7783	31	5515	90
1944	3355	7	2336	62	6299	16	3624	36
1945	3362	4	1943	33	5975	24	2744	35

Table 2.

Annual Case and Death Rates per Million Total Population.

Glasgow. 1916-45.

Year	Scarlet Fever		Diphtheria		Measles		Whooping Cough	
	Case Rate	Death Rate	Case Rate	Death Rate	Case Rate	Death Rate	Case Rate	Death Rate
1916	3910	155	1282	131	10014	495	1614	155
1917	1723	34	1209	146	12372	599	10521	815
1918	1258	24	1454	173	8180	350	3827	391
1919	2567	46	1706	151	8511	309	6317	591
1920	3527	55	1889	150	11046	291	2501	136
1921	3272	50	1727	120	2837	102	9998	642
1922	3233	70	1571	129	17552	1196	2651	184
1923	3322	67	1645	135	9595	521	4601	345
1924	2965	74	1768	128	7743	480	9356	603
1925	3552	63	1618	105	6064	110	11364	547
1926	4297	81	2105	121	14786	392	3503	167
1927	3777	40	2785	104	8241	282	9168	334
1928	2958	31	2368	128	9340	345	7390	350
1929	3061	37	1916	124	5896	73	4637	232
1930	4516	38	2369	133	11308	244	5258	207
1931	6415	68	1898	109	14033	382	8397	426
1932	8315	93	1918	109	5045	171	4222	117
1933	7560	75	2102	81	850	4	5813	206
1934	5302	69	2328	144	21884	461	5224	158
1935	3583	33	2153	103	795	7	6923	248
1936	3830	29	1717	48	17956	278	3727	104
1937	4967	26	2038	104	2004	26	7746	254
1938	3553	26	2473	117	13940	228	3637	78
1939	2601	10	2767	145	1287	2	5566	133
1940	1756	10	4921	216	10420	93	831	19
1941	1799	7	3835	148	1500	11	10447	274
1942	2928	9	3158	86	7900	62	1111	27
1943	2951	5	2768	78	7448	30	5278	86
1944	3195	7	2225	59	5999	15	3451	34
1945	3202	4	1850	31	5690	23	2613	33

Table 3.

Cases and Deaths, Actual Numbers, for 5-year Periods and for the 30 Years. Glasgow, 1916-45.

Years	Scarlet F.		Diphtheria		Measles		Whooping C.	
	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
1916-20	13697	330	7966	793	52868	2152	26127	2198
1921-25	17556	348	8947	663	47046	2590	40782	2494
1926-30	20274	247	12577	665	53853	1456	32638	1405
1931-35	34350	373	11490	603	47043	1129	33748	1272
1936-40	18630	112	15259	691	50420	696	24099	660
1941-45	14741	32	14480	421	29879	147	23961	475
1916-45	119248	1442	70719	3836	281109	8170	181355	8504

Table 4.

Case and Death Rates. Average Annual Rates for 5-Year Periods and for the 30 Years. Glasgow, 1916-45.

(Rates per Million Total Population)

Years	Scarlet F.		Diphtheria		Measles		Whooping C.	
	Case Rate	Death Rate	Case Rate	Death Rate	Case Rate	Death Rate	Case Rate	Death Rate
1916-20	2597	63	1510	150	10022	408	4953	417
1921-25	3269	65	1666	123	8760	482	7594	464
1926-30	3721	45	2309	122	9885	267	5991	258
1931-35	6221	68	2081	109	8519	204	6112	230
1936-40	3362	20	2754	125	9099	126	4349	119
1941-45	2815	6	2766	80	5707	28	4576	91
1916-45	3682	45	2183	118	8679	252	5599	263

The average annual rate for the whole period is 3,682. On the whole, there has been little variation between one year and the next, and only one period of high prevalence has occurred, from 1930 to 1934. Accordingly the average quinquennial rates show an almost symmetrical rise and fall to and from this period of high prevalence in the fourth quinquennium. There is no evidence that Scarlet Fever is tending to become either more or less prevalent.

The lowest annual case-rate for Diphtheria is 1,209 in 1917, and the highest 4,921 in 1940. The average annual rate over the 30 years is 2,183 per million total population. No marked fluctuations have occurred between one year and the next. The general trend is one of increasing prevalence towards the peak in 1940. Thereafter there has been a progressive annual fall. In 1945 the case-rate was below 2,000 for the first time since 1936.

An entirely different picture is presented by the annual Measles case-rates. Here the lowest annual rate is 795 in 1935, and the highest 21,884 in 1934. The average annual rate over the whole period is 8,679. Measles in Glasgow exhibits biennial periodicity, epidemics commencing typically towards the end of each odd-numbered year and carrying on into the first few months of the succeeding even-numbered year. When the period of epidemic prevalence balances itself between the end of the one year and the beginning of the next, the annual case-rates of each of the two calendar years will be similar, (e.g. 1927, 8241 cases per million, and in 1928, 9,340 cases per million). On some occasions the peak of the epidemic has occurred earlier than at the very end of the year, and on such occasions the odd-numbered year shows a higher case rate than the even-numbered year. This happened in 1917-18, in 1923-24, and in 1931-32. More often, however, the epidemic peak has been delayed to the spring months of the even-numbered year, with the result that a very low incidence has occurred in the odd-numbered year. Violent inter-annual fluctuations from this cause have occurred in 1921-22, 1933-4, 1935-36, 1937-38, 1939-40, and 1941-42. The quinquennial average rates do not altogether smooth out these fluctuations since the odd-numbered and even-numbered years interchange in preponderance in each 5-year period. The last quinquennium shows some fall in incidence from what had gone before.

As in Measles, biennial periodicity also occurs in Whooping Cough, and inter-annual fluctuations in case-rates are frequently seen. The lowest annual rate is 831 per million in 1940, and the highest 11,364 in 1925. The 30-year average annual rate is 5,599 cases per million. The periodic epidemics of Whooping Cough tend on the whole to alternate with those of Measles and occur at the end of each even-numbered year and the beginning of each odd-numbered year. The balance between the two years is more complete than in Measles, and inter-annual fluctuations are therefore less violent. The quinquennial average rates indicate that Whooping Cough has been rather less prevalent in the last two quinquennia than in the earlier ones.

On the whole, looking at all four diseases, we may say that apart from periodic fluctuations, the general trend of incidence for all four diseases shows little evidence of increase or of decrease over the course of the 30 years.

Mortality Rates.

The position with regard to death-rates from these diseases is entirely different from that of case-rates.

With Scarlet Fever the highest death-rate, 155 per million total population, occurred in 1916, and the lowest 4 per million occurred in 1945. The 30-year annual average was 45 per million. The period of high case-prevalence kept the death-rates at a higher level, but in the last two quinquennia there is evidence of a substantial fall, a fall which has been fairly progressive from year to year since 1932.

The highest annual death-rate from Diphtheria, 216 per million, occurred in 1940, and the lowest, 31 per million occurred in 1945. The 30-year annual average was 118 per million. The Diphtheria death-rates remained fairly steady up to 1939, rose sharply during the 1940-41 epidemic, and thereafter dropped very rapidly.

Measles had its highest death-rate in 1922, 1,196 per million, and its lowest, 2 deaths per million in 1939. The annual average was 252 per million. The death-rates fluctuate with the case-rates, but there has been a progressive fall in death-rate throughout the period, more especially in the last quinquennium.

The Whooping Cough death rate was highest in 1917 with a rate of 815 per million, lowest in 1940 with a rate of 19 per million, and averaging over the 30 years, 263 per million. As with the other diseases, death-rates fluctuate with case-rates, but there has been a progressive fall in death-rates over the whole period.

Fatality Rates.

During the course of this work the expression "fatality rate" will be employed to indicate the number of deaths per 100 registered cases.

The fatality rate in each disease for each year is shown in Table 5, while the average fatality rates for each quinquennium and for the 30 year period are given in Table 6.

In each disease there is an almost progressive reduction in fatality rate, year by year, from the beginning of the

Table 5.

Annual Fatality Rates, Glasgow, 1916-45.

Year	Scarlet Fever	Diphtheria	Measles	Whooping Cough
1916	4.0	10.2	4.9	9.5
1917	2.0	12.1	4.8	7.7
1918	1.9	11.9	4.3	10.2
1919	1.8	8.9	3.6	9.4
1920	1.6	7.9	2.6	5.4
1921	1.5	7.0	3.6	6.4
1922	2.2	8.2	6.8	6.9
1923	2.0	8.2	5.4	7.5
1924	2.5	7.2	6.2	6.4
1925	1.8	6.5	1.8	4.8
1926	1.9	5.8	2.6	4.8
1927	1.1	3.7	3.4	3.6
1928	1.1	5.4	3.8	4.7
1929	1.2	6.5	1.2	5.0
1930	0.8	5.6	2.2	3.9
1931	1.1	5.8	2.7	5.1
1932	1.1	5.7	3.4	2.8
1933	1.0	3.8	0.4	3.5
1934	1.3	6.2	2.1	3.0
1935	0.9	4.8	0.9	3.6
1936	0.8	2.8	1.5	2.8
1937	0.5	5.1	1.3	3.3
1938	0.7	4.7	1.6	2.1
1939	0.4	5.2	0.1	2.4
1940	0.5	4.4	0.9	2.3
1941	0.4	3.9	0.7	2.6
1942	0.3	2.7	0.8	2.4
1943	0.2	2.8	0.4	1.6
1944	0.2	2.7	0.3	1.0
1945	0.1	1.7	0.4	1.3

Table 6.

Quinquennial and 30-year Fatality Rates, Glasgow, 1916-45.

Years	Scarlet Fever	Diphtheria	Measles	Whooping Cough
1916-20	2.4	10.0	4.1	8.4
1921-25	2.0	7.4	5.5	6.1
1926-30	1.2	5.3	2.7	4.3
1931-35	1.1	5.2	2.4	3.8
1936-40	0.6	4.5	1.4	2.7
1941-45	0.2	2.9	0.5	2.0
1916-45	1.2	5.4	2.9	4.7

period to the end. The Scarlet Fever fatality rate has fallen from 4.0 in 1916 to 0.1 in 1945. The Diphtheria fatality rate has fallen from 12.1 in 1917 to 1.7 in 1945. The fatality rate of Measles was highest, 6.8, in 1922, and lowest, 0.1, in 1939. Whooping Cough had a fatality rate of 10.2 in 1918, and of 1.0 in 1944.

For the purpose of more readily comparing the general trend of the diseases, one with another, Table 7 has been prepared from the foregoing tables to show the relative trends of the case, death, and fatality rate in each quinquennium, all the rates for 1916-20 being taken as 100 and the rates for the succeeding quinquennia being expressed as percentages of the 1916-20 rates.

It becomes apparent that the fall in death rate and in fatality rate has not occurred to the same extent in each disease. Measles shows the greatest fall in death-rate, followed closely by Scarlet Fever; the Whooping Cough death-rate has in the last quinquennium dropped to rather less than one quarter of what it was in the first quinquennium, and the Diphtheria death-rate has just failed to halve itself.

Scarlet Fever shows the greatest reduction in fatality rate, followed closely by Measles. The reduction in the fatality rate of Whooping Cough and Diphtheria are not quite

Table 7.

Proportionate Case, Death, and Fatality Rates.

1916-20 Rates = 100.

Years	Scarlet Fever	Diphtheria	Measles	Whooping Cough
Case Rates				
1916-20	100	100	100	100
1921-25	126	110	87	153
1926-30	143	153	99	121
1931-35	240	138	85	123
1936-40	129	182	91	88
1941-45	108	183	57	92
Death Rates				
1916-20	100	100	100	100
1921-25	103	82	118	111
1926-30	71	81	65	62
1931-35	108	73	50	55
1936-40	32	83	31	29
1941-45	10	53	7	22
Fatality Rates				
1916-20	100	100	100	100
1921-25	83	74	134	73
1926-30	50	53	66	51
1931-35	46	52	59	45
1936-40	25	45	34	32
1941-45	8	29	12	24

so great, though they are, nevertheless, considerable.

Undoubtedly the outstanding feature of the general trend of the four diseases during the 30-year period is the almost unbroken succession of diminishing fatality rates.

Section 2.

Factors influencing the epidemiological behaviour of these four diseases.

We shall now very briefly review some of the factors which, it is probable, have been influencing the behaviour of the four diseases so as to produce the trends that have just been described.

Before discussing separate factors, it should be noted that variations in the prevalence and severity of infectious disease are well-recognised phenomena, and that the waxing and waning of various infectious diseases have been observed throughout the centuries. Long term or 'secular' variations in prevalence or severity are those which spread themselves out over many years, the full cycle of rise and fall taking perhaps a hundred years or more. This is well illustrated by Scarlet Fever which was prevalent and severe throughout the country in the latter half of the 18th century, subsided by the beginning of the last century, and again rose in intensity just after the middle of the century. Since about 1870, however, there has been a progressive diminution in the severity of the disease.

Superimposed upon these long-term variations there are short-term, 'periodic' or 'cyclical' variations occurring every few years and lasting one or more years. Scarlet Fever shows such variations during the course of the 30 years that we are studying. In Table 2, we see the rise and fall of case-rates over short numbers of years. There was a minimum incidence in 1918 rising to a maximum in 1926, followed by a fall in 1928 and thereafter an increasing incidence reaching a peak in 1932. After this a fall comes, up to 1940, after which incidence begins to rise again. There is no regular periodicity about these variations though we may say that a period of increased prevalence of Scarlet Fever is to be expected in Glasgow every four to seven years,

A similar periodicity can be seen in Diphtheria. In Glasgow years of maximum prevalence occurred in 1920, 1927, 1930, 1934, and 1940. Reference has already been made in the last section to the biennial periodicity both of Measles and of Whooping Cough.

A third type of variation in prevalence also occurs, seasonal variation. We have already mentioned that both Measles and Whooping Cough are winter diseases, though the epidemics may come early or late. For Scarlet Fever the season of maximum prevalence is typically the late autumn and early winter with a tendency towards a secondary peak in the late spring. Diphtheria spreads its maximum prevalence over the whole course of the winter months.

To illustrate these seasonal variations, the total monthly city cases for certain years have been tabulated in Table 8. It should be noted that the time-series in each series starts in July. Also included are proportionate monthly rates, the total number of cases in each month being expressed as a percentage of the January total for each series. Both the 1936-7 Whooping Cough epidemic and the 1937-38 Measles epidemic offer examples of the epidemic being delayed to the spring months.

The secular, the periodic, and the seasonal variations must all be taken into account when studying the general trend of the infectious diseases. But there are many other factors which we must consider. As Harries and Mitman say (1947, page 89), "Many complex and variable factors are concerned in the dispersability and fatality of infectious disease. The two primary ones are the resistance of the hosts and the prevalence and virulence of the causative organism but both are influenced by the environment of the herd. Environment includes weather, seasonal and geographical influences, social conditions such as poverty, nutrition and housing, sanitation, hygiene, and density and movement of populations".

It is not intended here, in what is merely an introductory chapter, to enter into a full discussion of these "many complex and variable factors" that are concerned.

Table 8.

Monthly Case Incidence.

Actual Monthly Cases, and Monthly Cases Expressed as Percentages of the January Cases. Glasgow.

	Scarlet Fever				Diphtheria			
	1923-24		1937-38		1923-24		1937-38	
Month	Cases	%	Cases	%	Cases	%	Cases	%
July	169	72	174	42	76	34	113	47
August	229	98	368	90	74	33	203	85
September	267	114	431	105	123	55	221	93
October	363	154	560	136	150	66	246	103
November	309	131	636	155	155	69	252	105
December	219	93	462	113	195	86	240	100
January	235	100	410	100	226	100	239	100
February	184	78	358	87	203	90	209	88
March	204	87	379	93	180	80	275	115
April	213	91	339	83	118	52	244	102
May	226	97	366	90	157	70	193	81
June	260	111	329	80	132	59	218	91

	Measles				Whooping Cough			
	1923-24		1937-38		1924-25		1936-37	
Month	Cases	%	Cases	%	Cases	%	Cases	%
July	215	8	63	2	450	22	83	5
August	306	11	18	1	804	39	214	14
September	352	12	49	1	551	27	437	29
October	1274	45	155	4	680	33	495	32
November	2181	77	546	14	1069	52	755	50
December	2866	101	1121	30	1049	51	786	51
January	2836	100	3767	100	2062	100	1523	100
February	1894	67	4875	130	1445	70	1793	118
March	1468	52	4748	128	1835	89	1841	121
April	940	33	1453	39	1700	83	1850	121
May	693	24	639	17	1516	74	669	44
June	280	10	208	6	1093	53	424	28

It will be sufficient to refer to some of these well recognised factors and to demonstrate by a means of a few tables how these factors have been operating.

A. Variation in the prevalence and virulence of the causative organism.

Little can be said at present about possible variations in the Measles virus or in the Haemophilus pertussis. Much has been written about the types of streptococci responsible for Scarlet Fever, but we are far from having heard the last word on this intricate problem. Recent work on the Corynebacterium diphtheriae, however, with regard to the three main types - gravis, intermedius, and mitis, their sub-types, and the significance of "atypical" strains, offers us at least a strong lead towards an explanation of periodic variation in the prevalence and virulence of Diphtheria. In Leete's review (1944) of six years of bacteriological typing in Hull, his account of the rise and fall of different gravis sub-types and of the transient predominance in 1941 of the atypical and deadly Edinburgh-Christison strain No. 4, (E.C.4.), is of profound epidemiological interest.

In Glasgow, the bacteriological types of C.diphtheriae have been described by Carter in three reports, the third of which covers the years 1934 to 1942 and deals with the results of typing some 12,000 strains. In 1934 gravis contributed 5.2% of the strains that were investigated, but by 1942, 68.2% of the recovered strains were of gravis type. Over the same period the intermedius type had fallen from 61.1% in 1934 to 18.6% in 1942, and mitis from 31.4% to 13%. The actual changeover in predominance from intermedius to gravis took place in 1938 and was fairly sudden, the preceding years and succeeding years showing a smaller degree of change of type. There is, however, no evidence of any substantially increased fatality-rate accompanying the changeover. In Glagow gravis has been scarcely more lethal than the intermedius type. As Carter has said "the arresting feature of the gravis strain in Glasgow has been not its lethality but its communicability".

While it is feasible that periods of increased prevalence of Scarlet Fever, such as occurred from 1931 to 1933, may similarly be attributed to a change in type of the pathogen it is improbable that such a change in type is responsible for the biennial epidemics of Measles and Whooping Cough. Such evidence as there is seems to suggest that epidemics of the two latter diseases occur when a sufficient number of susceptible persons have accumulated in the population, and that the epidemics wane when the remaining susceptibles are diluted by persons who have acquired in one way or another immunity to the disease.

B. Resistance of the Hosts.

Under this head we shall discuss those factors which influence the resistance of the individual as distinct from the resistance of the herd.

1. Age and Resistance.

It is probable that most persons are susceptible to each of the four diseases, regardless of age, if they have not previously been in contact in any way with the diseases. Accordingly it is only correct to speak of the diseases as "diseases of childhood", when we mean by that diseases which, in this country at any rate, concentrate their attack upon children not because of any inherent susceptibility among children, but because adults have had an opportunity to acquire immunity by previous exposure or attack.

There have been numerous epidemics of Measles among adult populations, such as the Faroe Islands epidemic of 1846 and the Fiji Islands epdemic of 1875. In both of these epidemics it was evident that children were no more susceptible to attack than were the adults of the same population.

In Glasgow, however, each of the four disease especially attacks children. Table 9, prepared from data which will be presented in the next chapter, shows the percentage distribution of cases and deaths and the fatality rates for various age-groups, consolidated for the whole 30-year period, 1916-45. Most of the cases in each disease occur in the

Table 9.

Percentage Distribution of Cases and Deaths, and Fatality Rates for Various Age-Groups. Glasgow, 1916-45.

Age-group	-1	-2	-5	-10	-15	15-	All Ages
Scarlet Fever							
Cases	0.7	3.6	23.2	40.9	16.8	14.8	100
Deaths	5.3	16.1	34.1	25.2	6.2	13.1	100
Fatality Rate	9.2	5.4	1.8	0.7	0.4	1.1	1.2
Diphtheria							
Cases	2.0	4.9	24.0	35.2	14.5	19.4	100
Deaths	8.6	17.0	37.4	27.9	4.3	4.8	100
Fatality Rate	23.6	18.8	8.5	4.3	1.6	1.3	5.4
Measles							
Cases	6.1	11.9	36.1	42.7	1.8	1.4	100
Deaths	28.5	44.9	22.9	3.2	0.1	0.4	100
Fatality Rate	13.7	10.9	1.8	0.2	0.2	0.8	2.9
Whooping Cough							
Cases	10.3	11.2	34.7	42.2	1.4	0.2	100
Deaths	41.9	35.9	19.3	2.7	0.1	0.1	100
Fatality Rate	19.0	15.0	2.6	0.3	0.2	1.4	4.7

5-10 age-group, and this is followed by the 2-5 age-group. Very few cases of Scarlet Fever and Diphtheria occur in the first year of life, but these two disease have a considerable proportion of adult cases.

In Scarlet Fever and Diphtheria most of the deaths occur in the 2-5 age-group, in Measles in the 1-2 age-group, and in Whooping Cough in the 0-1 age-group.

In each disease the fatality rate is high in the first year of life, and falls progressively during child-hood to be followed by a slight rise in adult life, except in Diphtheria.

It is generally admitted that there is some degree of resistance to specific infections during the early months of life. This we may presume to be some form of passive immunity acquired during intra-uterine life and possibly sustained after birth by antibodies in the maternal milk. The mechanism of this congenital immunity however is not altogether clear. It is apparent, however, from Table 9, that if an infant does acquire one of these diseases in the first year of life the risk of a fatal outcome is considerable.

2. Sex.

Differences in morbidity, mortality, and fatality rates occur between the two sexes. To exemplify these differences, Table 10 shows, for the three year period 1930-32,

Table 10.

Sex Distribution, All Ages. 1930-32.

		Scarlet Fever	Diphtheria	Measles	Whooping Cough
Cases	Male	9211	2962	16298	8987
	Female	11792	3783	16808	10498
	Female Cases as Percentage of Male	128	128	103	117
Deaths	Male	98	197	452	377
	Female	119	186	417	440
	Female Deaths as Percentage of Male	122	95	92	117
Fatality Rate	Male	1.1	6.6	2.8	4.2
	Female	1.0	4.9	2.5	4.2
	Female Fatality Rate as Percentage of Male	91	74	89	100

Table 11.

Sex Distribution in Age-Groups, 1930-32. Cases.

	-1	-2	-5	-10	-15	-20	-25	-35	-45	-55	-65	65-	All Ages
Scarlet Fever													
Male	93	355	2252	3853	1428	524	246	290	121	36	11	2	9211
Female	68	354	2368	4752	2047	822	515	567	210	58	27	4	11792
% of Male	73	100	105	124	143	157	209	196	174	161	245	200	128
Diphtheria													
Male	72	179	807	1199	383	137	70	67	29	10	6	3	2962
Female	48	139	815	1481	571	282	196	162	52	27	28	2	3783
% of Male	67	78	101	124	149	206	280	242	179	270	133	67	128
Measles													
Male	1126	1958	5804	7200	155	15	16	20	2	1	1	-	16298
Female	1049	1984	5934	7326	224	75	129	68	13	5	-	1	16808
% of Male	92	102	102	102	144	500	809	340	650	500	-	-	103
Whooping Cough													
Male	932	1008	3072	3856	108	4	-	4	2	1	-	-	8987
Female	1029	1182	3598	4531	135	5	2	13	1	-	1	1	10498
% of Male	110	118	117	118	125	125	-	325	50	-	-	-	117

the sex distribution of cases and of deaths, the female totals expressed as a percentage of the male totals, and the fatality rate for each sex. The period 1930-32 was selected only by reason its being near the middle of the complete thirty year period. It will be observed that for each disease there are more female cases than male. In deaths from Scarlet Fever and Whooping Cough females predominate, but the opposite occurs in deaths from Diphtheria and Measles. The male fatality rate is markedly higher than the female in Diphtheria, slightly higher in Scarlet Fever and Measles, and the same as the female rate in Whooping Cough.

In Table 11, the total cases for each sex have been analysed into age-groups and the female totals in each age-group have been expressed as a percentage of the male totals. It is evident that under one year of age there are more male cases than female except in Whooping Cough where the opposite occurs. In the -2 and -5 age-groups there is little difference between the sexes except in Whooping Cough where there is again a definite preponderance of female cases. At later ages, and especially in adult life, female cases in each disease far outnumber the male.

The picture with regard to deaths (Table 12) is less uniform. In Scarlet Fever, female deaths predominate in the lower age-groups, and male deaths in adult life. In Diphtheria, male cases predominate in all age-groups except

Table 12.

Sex Distribution in Age-Groups, 1930-32. Deaths.

Scarlet Fever	-1	-2	-5	-10	-15	-20	-25	-35	-45	-55	-65	65-	All Ages
Male	8	9	29	24	5	6	-	8	5	3	1	-	98
Female	9	18	48	19	9	3	2	6	2	1	2	-	119
Female as % of Male	112	200	166	79	180	50	-	75	40	33	200	-	122
Diphtheria													
Male	21	36	63	48	13	4	3	1	3	3	2	-	197
Female	16	28	60	63	11	3	1	-	1	1	1	1	186
Female as % of Male	76	78	95	132	85	75	33	-	33	33	50	-	95
Measles													
Male	164	201	76	9	1	-	-	-	-	1	-	-	452
Female	132	186	86	11	-	1	1	1	-	-	-	-	417
Female as % of Male	81	93	114	122	-	-	-	-	-	-	-	-	92
Whooping Cough													
Male	190	124	62	1	-	-	-	-	-	-	-	-	377
Female	183	158	92	6	-	-	-	-	1	-	-	-	440
Female as % of Male	96	127	148	600	-	-	-	-	-	-	-	-	117

Table 13.

1930-32 Fatality Rates. Sexes and Age-Groups.

Scarlet Fever	-1	-2	-5	-10	-15	-20	-25	-35	-45	-55	-65	65-	All Ages
Male	8.6	2.5	1.3	0.6	0.4	1.1	-	2.8	4.1	8.4	9.1	-	1.1
Female	13.2	5.1	2.0	0.4	0.4	0.4	0.4	1.1	1.0	1.7	7.4	-	1.0
Diphtheria													
Male	29.2	20.1	7.8	4.0	3.4	2.9	4.3	1.5	10.3	30.0	33.3	-	6.6
Female	33.3	20.1	7.4	4.3	1.9	1.1	0.5	-	1.9	3.7	12.5	50.0	4.9
Measles													
Male	14.5	10.3	1.3	0.13	0.6	-	0.8	-	-	100.0	-	-	2.8
Female	12.6	9.4	1.5	0.15	-	1.3	-	-	-	-	-	-	2.5
Whooping Cough													
Male	20.4	12.3	2.0	0.026	-	-	-	-	-	-	-	-	4.2
Female	17.8	13.3	2.6	0.13	-	-	-	-	100.0	-	-	-	4.2

the -10 age-group. In Measles, male deaths exceed female deaths in the first two age-groups and the reverse occurs in the next two. Thereafter only four deaths occur, two in each sex. In Whooping Cough there are slightly more male deaths than female in the first year of life, but in the next three age-groups female deaths are in the majority. Only one adult death occurs.

It follows from the fore-going, as is seen in Table 13, that the male fatality rate in Scarlet Fever is lower than the female in the earlier age-groups, but considerably in excess of it at later ages. Much the same occurs in Diphtheria. In Measles the male fatality rate exceeds the female in the first two age-groups, but thereafter the two rates are similar. In Whooping Cough the female fatality rate slightly exceeds the male except in the first year of life.

Only the barest of general conclusions can be drawn from such limited data as has been here presented, expecially in view of the small number of deaths in adult life. It seems justifiable, however, to conclude that adult females show much greater liability to attack by each of the diseases than adult males; that male infants are relatively more susceptible to attack than female infants except in Whooping Cough; and that for both sexes the fatality rate rises in later adult life.

3. The Susceptibility of Immigrants.

We have already indicated that susceptibility to attack by each of these diseases is a function not of age but of previous experience of the disease. Accordingly, among those who have not previously been exposed to infection the age-distribution of cases may be found to differ markedly from that occurring among the native city population.

In the Annual Report of the Medical Officer of Health of Glasgow for the year 1926, a statistical analysis of the 1925-26 Measles epidemic yields some interesting information concerning the susceptibility of immigrants into the city. Table 14 is reproduced from this Annual Report. It clearly shows how markedly the age-distribution of Measles cases among immigrants differs from that among the Glasgow-born population, and, in addition, the definite preponderance of female immigrant cases. To the original table I have added the three last columns to indicate the percentage of the total cases in each age-group that occurred among natives and among immigrants. It is of course impossible to come to a definite conclusion about the relative susceptibility between the native and immigrant population unless we are able to consider the relative numbers at the risk in each of the two groups. At the 1931 Census approximately 62% of the total population had been born in the city. As most immigrants presumably come to the city in adult life

Table 14.

Age-Incidence of Measles among the Native and Immigrant Populations.

Glasgow, 1925-26.

	Born in Glasgow				Born outside Glasgow			
Age	Male	Female	Total	% of Total	Male	Female	Total	% of Total
-5	5699	5598	11297	57.0	65	95	160	21.9
-10	4015	4197	8212	41.4	203	232	435	59.6
-15	97	150	247	1.2	19	16	35	4.8
-20	10	18	28	0.1	3	15	18	2.5
-25	3	22	25	0.1	10	32	42	5.8
25-	3	25	28	0.1	6	33	39	5.3
?	14	6	20	0.1	1	-	1	0.1
All Ages	9841	10016	19857	100.0	307	423	730	100.0

All Cases

	Total	Percentage Native-born	Percentage Immigrant
-5	11457	98.6	1.4
-10	8647	95.0	5.0
-15	282	87.6	12.4
-20	46	60.9	39.1
-25	67	37.4	62.6
25-	67	41.8	58.2
?	21	95.2	4.8
All Ages	20587	96.5	3.5

there is probably a relative preponderance of immigrant cases at all ages.

C. The Environment of the Herd.

Under this heading we may review those social and environmental factors which tend to make the diseases more prevalent or more severe in one area or in one group of persons than in another. It is often not possible to draw a clear line between the factors influencing individual resistance, and factors influencing "herd" resistance, so that some of the factors here discussed such as nutrition, and economic position, might have been discussed in the preceeding sub-section. But as these two factors tend in a general way to be associated with the social-environmental factors of housing, overcrowding, hygiene, and the like, it seems reasonable to consider them here.

1. Geographical and Climatic Factors.

a) Scarlet Fever.

Hilda A. Woods (1933) in her "Epidemiological Study of Scarlet Fever in England and Wales" illustrated, by means of two tables, the geographical distribution of attack rates and of fatality rates in Scarlet Fever for the North of England, the Midlands, the South of England, and for Wales in two time-periods 1911-13 and 1927-29, (See Tables 15a and 15b). A distinction is made between the rates for London,

Table 15.

Scarlet Fever. Geographical Distribution of Attack Rate and Fatality Rate. England and Wales, 1911-13 and 1927-29. (After Woods).

A. Attack Rate per 10,000 Population aged 0-15 years.

		North	Midlands	South	Wales	England & Wales
London	1911-13	-	-	101	-	-
	1927-29	-	-	137	-	-
County Boroughs	1911-13	109	135	114	125	119
	1927-29	128	104	94	49	113
Other urban areas	1911-13	113	94	76	131	101
	1927-29	104	104	98	60	98
All rural areas	1911-13	102	83	55	85	80
	1927-29	87	85	82	46	80
All areas	1911-13	110	103	87	115	102
	1927-29	114	99	111	54	104

B. Fatality Rate per 1,000 Notified Cases.

		North	Midlands	South	Wales	England & Wales
London	1911-13	-	-	13.3	-	-
	1927-29	-	-	4.0	-	-
County Boroughs	1911-13	23.8	19.4	15.4	18.8	21.2
	1927-29	6.6	3.9	7.3	6.7	5.9
Other urban areas	1911-13	21.7	13.1	10.3	15.3	16.3
	1927-29	7.7	5.3	5.4	6.3	6.2
All rural areas	1911-13	19.4	13.7	8.6	15.2	14.6
	1927-29	7.8	7.5	7.6	10.0	7.5
All areas	1911-13	22.5	15.7	12.4	16.0	17.5
	1927-29	7.1	5.3	5.5	7.3	6.1

for urban areas, and for rural areas. In both of the time-periods the attack rate is in general higher in the North than in the Midlands, and higher in the Midlands than in the South. The attack rate for Wales comes highest in the first period and lowest in the second. Throughout the country, urban attack rates are higher than rural attack rates. Fatality rates in the first period are in a descending order from North to Wales to Midlands to South, and from urban to rural areas. In the second period the order of fatality rates, from highest to lowest, is Wales, North, South, Midlands. As before the urban fatality rates are higher than the rural. For London the attack rate occupies an intermediate position in the first time-period, but the highest in the second period. The London fatality rate is, however, the lowest of all areas at both periods.

Turning our attention now to Glasgow, we should expect on the basis of its geographical position and urban condition both the attack rate and the fatality rate to be high. Taking Woods' figures for London 1916-29, and the figures that have already been given in earlier tables for Glasgow, it is possible to compare the experience of the two cities over these fourteen years, (Table 16). The fatality rates for London, which Woods does not give, have been calculated from the death-rate / attack rate ratic , and while not therefore completely accurate, may be regarded as accurate

Table 16.

Annual Case, Death, and Fatality Rates, Glasgow and London.

1916 - 1929. Scarlet Fever.

(Cases per thousand, Deaths per million total population)

	Case-Rates		Death-Rates		Fatality Rates	
Year	Glasgow	London	Glasgow	London	Glasgow	London
1916	3.9	3.9	155	34	4.0	0.9
1917	1.7	2.1	34	22	2.0	1.0
1918	1.3	1.5	24	30	1.9	2.0
1919	2.6	1.7	46	34	1.8	2.0
1920	3.5	3.0	55	46	1.6	1.5
1921	3.3	5.0	50	65	1.5	1.3
1922	3.2	7.3	70	66	2.2	0.9
1923	3.3	3.8	67	25	2.0	0.7
1924	3.0	2.2	74	28	2.5	1.3
1925	3.6	2.5	63	22	1.8	0.9
1926	4.3	2.7	81	18	1.9	0.7
1927	3.8	2.7	40	14	1.1	0.5
1928	3.0	3.4	31	18	1.1	0.5
1929	3.1	3.6	37	17	1.2	0.5

Table 17.

Measles Mortality and Latitude. 1922-29. (After Brincker).

(Deaths per 100,000 living at ages 0 - 5 in England and Wales)

	North	Midlands	South	Wales	England & Wales
London	-	-	198	-	198
County Boroughs	200	130	89	141	164
Other Urban Districts	126	76	53	112	93
Rural Districts	88	37	28	47	48
All Areas	161	84	117	99	120

enough for the purposes of a general comparison. During the years that are illustrated the attack rate in Glasgow is on the whole lower than that of London. The death rate and fatality rate, however, are considerably higher. In fact looking again at the geographical distribution of fatality rates in England and Wales for 1927-29 (Table 15b) it is evident that the Glasgow fatality rate is higher than in any of the English areas. It would be unjustifiable, however, to attribute the high fatality rate experienced in Glasgow solely to the effect of latitude and climate. As we shall see later, the influence of social conditions is of importance.

There is an interesting meteorological phenomenon in connection with Scarlet Fever to which reference can appropriately be made in this section. This is the relationship between the prevalence of Scarlet Fever and rainfall. The tendency, it cannot be said to be more, is for Scarlet Fever to be, during dry years, more prevalent than it might otherwise have been, and to be less prevalent during wet years.

Woods has calculated coefficients of correlation (based on annual changes in the variables in order to elimate trend) for four cities for years 1900 to 1929; her results are:-

London	-0.50 ± 0.09	Liverpool	-0.08 ± 0.12
Birmingham	+0.13 ± 0.12	Manchester	-0.19 ± 0.12

For Glasgow I have calculated a coefficient of correlation, also by the variate - difference method, for the years 1916-

1945. This has a value of -0.0844 $\pm$0.1861. It is evident that it is only in London that significant negative correlation has occurred. In the other cities the correlation is negligible.

b). Diphtheria.

In his review of the epidemiology of Diphtheria during this century, Russell (1943) gives a table (not reproduced) showing the incidence of Diphtheria per 100,000 population in various areas of England and Wales for the period 1921-37. Selecting a few of these, we may compare them with the Glasgow case-rate for the same period, approximately 200 cases per 100,000 population:-

London	254	Croydon	135
Birmingham	186	Coventry	122
Liverpool	253	Birkenhead	176
Manchester	145	Salford	241

England and Wales 140

In general, case-rates are higher in urban than in rural districts, but there is quite definitely no regular gradation from North to South. It seems probable that prevalence in Diphtheria is dependent more upon social conditions and the type of prevailing organism than upon geographical or climatic factors.

c) Measles.

Brincker (1938) has shown that the mortality of Measles at ages 0-5 years in England for the period 1922-30 is considerably higher in the North than in the Midlands, and higher in the Midlands than in the South. This descending scale of Mortality holds both in urban and rural areas (see Table 17). The mortality in London however, is practically the same as that in the Northern County Boroughs. By analogy, we might expect the mortality of Measles to be, in general, higher still in Scotland, and, in particular, highest of all in Glasgow. We can readily compare the death rate per 1000 total population for Glasgow and for London using Brincker's rates for London, and the rates given in Table 2 for Glasgow. This comparison is made in Table 18, where it is seen that the death-rates from Measles in Glasgow are almost invariably higher than those of London. How much this is due to differences in latitude and climate, and how much is due to differences in social conditions between the two cities is difficult to determine.

In Glasgow we have already indicated that the peak of the biennial Measles epidemic may come at any time during the winter or spring months. In the spring the temperature is likely to be higher and the fatality rate to be lower. For instance in the 1923-24 epidemic the peak occurred in December; the mean temperature during that month was 34.5°F. During the next epidemic 1925-26, the peak month was February, when the mean temperature was 40.8°F. For the 1923-24 epidemic the fatality rate was in the region of 6% and for the 1925-26 epidemic just over 2%. How far the fall in fatality

Table 18.

Measles Mortality, Glasgow and London.

Annual Deaths per 1,000 living. 1916-37.

Year	Glasgow	London
1916	0.50	0.19
1917	0.60	0.50
1918	0.35	0.42
1919	0.31	0.08
1920	0.29	0.22
1921	0.10	0.05
1922	1.20	0.34
1923	0.52	0.08
1924	0.48	0.29
1925	0.11	0.07
1926	0.39	0.20
1927	0.28	0.04
1928	0.35	0.30
1929	0.07	0.05
1930	0.24	0.23
1931	0.38	0.03
1932	0.17	0.19
1933	0.01	0.02
1934	0.46	0.20
1935	0.01	0.01
1936	0.28	0.14
1937	0.03	0.01

Table 20.

Death Rates in the Different Social Classes, Age Group 1-2 years. England and Wales, 1930-32. (Rates expressed as percentages of the national rate).

Class	Diphtheria	Measles	Whooping Cough
I (Upper Professional)	47	10	22
II (Lower Professional)		29	41
III (Skilled & Clerical)	89	80	86
IV (Semi-skilled)	106	102	110
V (Unskilled)	153	194	165
All Classes	100	100	100

rate was due to the higher temperature during the latter epidemic, and how far it was due to other factors it is impossible to say.

2. The Effect of Urbanization.

The differences both in prevalence and mortality between urban and rural districts have already been mentioned in the preceding section, and it is not proposed to go much further into the matter. It may be of interest, however, to reproduce a table by Stallybrass (1931) in which the differences in mortality between the two types of district is very clearly demonstated.

Table 19.

Mortality per 100,000, England & Wales 1922-23.

	Scarlet Fever	Diphtheria	Measles	Whooping C.
County Boroughs	3.4.	7.8.	18.8.	16.2.
Rural Districts	1.7.	4.3.	6.4.	10.2.

3. Economic Factors.

The importance of these factors is well exemplified by a table, (Table 20), quoted by Harries & Mitman (1947) from the Decennial Supplement of the Registrar-General for England

and Wales, 1931. The table brings out very clearly the excessive mortality found among the poorer classes.

But poverty is a condition which brings in its train a number of concomitant conditions which will influence the behaviour of infectious disease more than will the bare economic factor of having or not having a sufficiency of money. In the poorer districts, and more especially in the poorer districts of large cities, we may expect to find an associated array of conditions such as bad housing, large families, overcrowding, malnutrition, inadequate or unsuitable clothing, lack of hygiene and sanitation, ignorance, negligence, and vermin. All these conditions are factors influencing to a greater or less extent the prevalence and course of the various types of infectious disease. But to attempt to separate out the individual factors and to estimate the influence of each would be a difficult and probably impossible task. Wright and Wright (1942) however, have shown (Table 21) with data relating to the London Boroughs, by means of coefficients of partial correlation, the relative importance of social position and of overcrowding as factors influencing the mortality of Measles and Whooping Cough.

Table 21

Coefficients of Partial Correlation

Mortality from	Substandard Housing excluding Social Index	Social Index excluding Substandard Housing
Measles	+0.741 sig.	-0.088 not sig.
Whooping Cough	+0.657 sig.	-0.192 not sig.

The "Social Index" is based on the number of persons in the lower paid occupations at the 1931 Census, while "Substandard Housing" is based on the percentage of the population in each borough living more than 2 persons per room. A high Social Index in the nomenclature of Wright and Wright therefore indicates a low economic position. The coefficient of total correlation between this Social Index and Substandard Housing was found to be +0.741. Incidentally, the coefficient of total correlation between "Social Index and "Children per Family" was +0.859.

It is to be assumed from these coefficients of partial correlation that the economic level by itself does not influence to any extent the mortality of Measles and Whooping Cough. But the overcrowding that is found in association with a low economic level is a factor of considerable importance.

A mass of evidence has been produced by a large number of investigators to indicate the association between the morbidity and mortality of the four diseases we are studying and housing conditions, especially overcrowding. As we shall be looking closely into this matter again in Chapter 3, it is unnecessary to discuss it further at this stage.

With regard to nutrition it is reasonably safe to assume that the nutritional state of the poorer classes was, at any rate prior to 1939, at a much lower level than that of the more prosperous sections of the population.

Marion Watson, (1937), showed that in mice exposed to infection by B.typhimurium, variations in the resistance of mice to the disease could be produced by modification of diet. She attributed an increased resistance to infection to the inclusion of dried separated milk in the mouse diet. It is also recognised that the resistance of epithelial tissues to bacterial invasion can be diminished by a deficiency of Vitamin A in the dietary, though this diminished resistance is possibly an indirect effect due to atrophy of the epithelial cells.

Conversely, well-nourished guinea-pigs, it is said, develop experimental Foot-and-mouth Disease more readily than do under-nourished ones, and there is, to quote Burnet, (1940) "a general impression that Infantile Paralysis is more liable to attack a well-nourished 'healthy' child than one who is not thriving; the evidence for this statement, however, is not quite convincing".

So far as I am aware, there is no evidence that under-nourished children are more, or less, susceptible to attack by either Scarlet Fever, Diphtheria, Measles, or Whooping Cough than are well-nourished children. There is, however, a very general impression, which is no doubt a true one, that, once the disease has started, the patient's previous nutritional state may be a factor of supreme importance in deciding the course of the illness. The well-nourished child will have, in general, though not invariably, a shorter and less complicated illness than the under-nourished one. Accordingly, we may perhaps say that fatality but not prevalence is a function of nutritional state.

4. The Influence of Schools.

We saw in Table 9 that the largest proportion of cases in each of the four diseases occurs in the 5-10 years age-group, i.e. the primary school age-period, and it is a reasonable assumption that many of the children of school age who become infected do so during their attendance at school. In his annual report for 1934 the Medical Officer of Health for Glasgow describes the following interesting morbidity state in one class of a city school. The average age of pupils in the class was 6 years. The school premises were described as modern and well ventilated.

Class Roll. 47. Present 17. Absent 30.

Reason for Absence:-

Diphtheria	2
Scarlet Fever	6
Scarlet Fever Contact	1
Post-Scarlet Fever Nephritis	1
Measles	17
"Cold"	2
Toothache	1

Throat swabbing of the 17 children still present revealed 3 carriers of a virulent Diphtheria organism.

From time to time writers have attempted to show an association between the prevalence of infectious diseases and the periods of the school vacations. As an example the two tables, Tables 22 and 23, are reproduced from Chalmers' book "TheHealth of Glasgow" (1930). How far we are justified in drawing definite conclusions from these two tables is doubtful. It may be that school closure and re-opening come at times when seasonal conditions are producing variations in the incidence of the diseases. But in that case we might expect some uniformity in the proportionate attack upon the different age-groups. It seems that with Scarlet Fever the summer holiday period is attended by an increased

Table 22.

Scarlet Fever and School Summer Holidays.

Age-Group	Before Holidays.	During Holidays.	After Holidays
Pre-school ages	20.4%	25.3%	19.0%
School ages	61.3%	61.3%	68.0%
Above school ages	18.3%	13.4%	13.0%
All ages	100.0%	100.0%	100.0%
Total numbers of cases	2161	1836	3180
% distribution of grand total	30.1%	25.6%	44.3%

Table 23.

Measles and School Christmas Holidays.

Age-Group	Before Holidays.	During Holidays.	After Holidays
Pre-school ages	61.5%	67.0%	72.0%
School ages	37.3%	31.5%	26.2%
Above school ages	1.2%	1.5%	1.8%
All ages	100.0%	100.0%	100.0%
Total numbers of cases	2821	3288	2240
% distribution of grand total	33.7%	39.2%	27.1%

Table 24.

Percentages of Glasgow Children Immunised.

Date	Pre-school	School
July, 1941	46%	55%
December, 1941	26%	52%
December, 1942	25%	50%
December, 1943	23%	60%

incidence among the pre-school group, but that after the holidays the incidence among the school age-group rises. With Measles, children of school age show a decreasing incidence during and after the Christmas Holidays, while incidence among the pre-school group rises both during and after the holidays. In other words, for both diseases the school holidays seem to cause some transfer of infection from school-children to the younger children at home.

5. Public Health and Medical Measures.

It is intended here to indicate only in the barest outline the general features of some of the more important measures directed towards the prevention and mitigation of the four diseases and to mention some of the changes in procedure that have taken place in Glasgow during the thirty years from 1916 to 1945.

a) Notification.

Statutory notification of Scarlet Fever and Diphtheria has been in force throughout the period. Measles has not been notifiable. Whooping Cough was made notifiable during a period of three years from 10th July, 1924 to 10th July, 1927. The object of this measure was "to obtain early information with a view to prevention of subsequent cases and to achieve early treatment by home nursing or removal to hospital", (M.O.H. An.Rep.1926). Scrutiny of the annual

Whooping Cough case, death, and fatality rates for the 3-year period do not, however, reveal any marked divergence from the experience of neighbouring years nor any break in the general trend.

The normal method of ascertainment of the existence of cases of Measles and Whooping Cough has been by information coming to the Medical Officer of Health via schools, sanitary inspectors, health visitors, general practitioners, and parents. It is debatable whether statutory notification would have increased the numbers of known cases. What it might have done, however, would have been to allow a more justifiable comparison with other areas where statutory notification has been in operation.

It may be added that it is very doubtful whether the statutory notification of Measles and Whooping Cough, due to their high infectivity in the early, unrecognised stage, would be helpful in reducing the spread of infection, while all or nearly all of the serious cases come under notice through the existing means of ascertainment.

b) Hospitalisation.

The policy with regard to hospitalisation is in great measure dependent upon the number of beds available at any one time in the Isolation hospitals of the city. It would be impracticable to provide hospitals beds for over 12,000 cases of Measles in one month - the incidence of May 1934, but at non-epidemic periods a considerable proportion of cases can be accommodated in hospital.

With Scarlet Fever there has been a growing policy to leave cases at home unless the home circumstances are unsuitable. For instance, during the years following the first war, about 6% of cases remained at home. By 1938, this figure had risen to 13% and is still rising. On the other hand the opposite policy has been adopted with Diphtheria, and as far as possible every suspected case is removed to hospital as soon as information about the case reaches the Public Health Department. Thus early adequate treatment is ensured, diagnosis is rendered more certain, and the risk of a fatal outcome is reduced. In 1923, 4% of Diphtheria cases remained at home; in 1938, only 1.4%.

In Measles and Whooping Cough about 90% of cases every year have been treated at home. As long as beds are available serious cases, or cases occurring in unsuitable homes, are removed to hospital.

c) Treatment.

A full discussion concerning recent advances in the treatment of these diseases would here be out of place, and will not be attempted. Scarlet Fever Antitoxin is used as a routine therapeutic measure in one city Fever Hospital (Knightswood) in all but very mild or late recovering cases. The general mildness of the disease renders difficult the assessment of the value of the antitoxin as a preventive of death. It is felt however, that the administration of the antitoxin brings about a more rapid reduction in toxic symptoms and is, therefore a useful procedure.

Sulphonamides have been used in recent years for the invasive complications of Scarlet Fever, and penicillin for pyogenic complications.

The administration of Diphtheria antitoxin in adequate dosage as early in the disease as possible has been the aim in the treatment of Diphtheria. The use of Penicillin as a therapeutic agent, so far as I am aware, has not been attempted in Glasgow, though it has been used with doubtful success in the clearing up of convalescent carriers.

The introduction of Sulphonamide therapy has considerably enhanced the physician's armamentarium in the treatment of Measles, and more especially of the respiratory complications. In at least one Fever Hospital a moderate four- hourly dose of Sulphadiazine is given to all children suffering from the uncomplicated disease with a view to preventing the development of complications. In addition 2,000units of A.D.S. is given routinely to these children in view of their excessive susceptibility to Diphtheria.

In Whooping Cough too, Chemotherapy is employed in cases with respiratory complications, though with less success than in Measles due to the pulmonary condition being primarily a "Collapse" rather than a true pneumonic process.

d) Immuno-prophylaxis.

Preventive inoculation against each of the four diseases is a practicable procedure under certain conditions and within certain limitations.

Prophylaxis against Scarlet Fever has not been employed in Glasgow except on isolated and unrecorded occasions. The mildness of disease, the numerous injections required, and doubt about the duration of the immunity produced has rendered mass immunisation undesirable.

The special conditions associated with present day immuno-prophylaxis against Measles have prevented any attempt at widespread immunisation. Only passive immunisation is so far practicable, and to be successful in preventing or mitigating an attack, the reagent — convalescent serum, placental extract, or gamma globulin — should be given within the first half of the incubation period. Immunisation in this way has a definite place in preventing attacks in infants and young children, and the procedure has been used in institutions and hospitals where young children have been exposed to the risk of infection. As an example of the results achieved, the Superintendent of Knightswood Fever Hospital, using convalescent Measles Serum during the 1937 epidemic, reported as follows (M.O.H. An.Rep.1937):-

No. of patients receiving serum ...	330
No. of patients who developed ordinary Measles	0
No. of patients who developed modified Measles	66
No. of patients who did not develop Measles	264

Prophylaxis with Whooping Cough Vaccine has only been adopted on a limited scale in Glasgow, chiefly among young children attending day nurseries. Opinions are divided at present on the efficiency of present vaccines, though beneficial results have been claimed when large dosage has been employed.

I have left Diphtheria immunisation to last since it alone has been practised on a wide scale. The campaign in Scotland, including Glasgow, was begun in December 1940 at the height of the Diphtheria epidemic. Prior to this, immunisation had been performed only in institutions and on nurses in Fever Hospitals, among whom favourable results had been achieved.

From the figures published in the Annual Reports of the Medical Officer of Health, it is possible to express in tabular form the percentage of children in the city who had been immunised by the date shown, (Table 24).

It appears that the initial response to the campaign was not maintained; in the pre-school group the return of children from evacuation and the addition of newborn children have lowered the percentage of the immunised.

It is of interest to refer to Table 2, to see whether the general trend of Diphtheria has radically altered since mass immunisation was introduced. The annual case-rates have diminished progressively since 1940, but this might well be merely a return to normal after a period of epidemicity. The death-rates have declined steadily since 1940, and are now lower than they have ever been. A similar decline has also occurred in fatality rates, but falls in death and fatality rates have occurred at the same time in Scarlet Fever, Measles, and Whooping Cough, and the improvement in Diphtheria is no greater than in these other diseases.

If we confine ourselves to Diphtheria alone, and do not look further back than 1940, the effect of mass immunisation seems magnificent, but a wider and more comparative view does not support this first impression. Several years will have to elapse, and probably a much higher percentage of children will have to be immunised, before we can say that Diphtheria in Glasgow has been defeated by mass immunisation.

It is not intended by any means to give the impression that immunisation against Diphtheria is not a valuable procedure. In 1943, there were no deaths from Diphtheria among immunised pre-school children. Among pre-school children not immunised there were 48 deaths. Similarly in children of school ages, 3 deaths occurred in children who had been immunised, and 22 deaths in children who had not been immunised. Among the children who have been immunised, the risk of attack is appreciably reduced; the risk of death is rendered remote.

Section 3

Glasgow Population, Housing and Municipal Wards.

a) Population.

Glasgow is the second largest city of the British Isles. Both a major sea-port and a centre of heavy industry, its prosperity has fluctuated with the production demands of war and the industrial depressions of peace.

Following an extension of the city in 1913 the population has remained at rather over 1 million persons. The estimated population, birth rate, death rate, and infant mortality rate for each "census year" from 1861 are shown in Table 25.

The last census was taken in 1931. It is, therefore, a matter of extreme difficulty to estimate with accuracy the population of the city in recent years, and an error of many thousands may be present in the estimates of the last ten or so years.

In 1921 the census was taken in June, a month during which a number of Glasgow people are absent from the city on holiday. The census estimate of total population was 1,034,174. The Medical Officer of Health, however, estimated the figure at 1,075,000. This discrepancy renders difficult the estimation of the child population of the city during the earlier part of the 30-year period, 1916-45, since there is no way of knowing whether the proportion of the population alleged to be absent from the city on holiday had the same age-constitution as the actual census population.

It will be apparent from Table 25 that during the past 30 years the total population of the city has varied little. At the same time, there has been a drop in birth rates of roughly one-third. The death rate and the infant mortality rates seem to have remained fairly steady during the last two or three decades. The infant mortality rate, it should be explained, was unduly high in 1941 compared with neighbouring years, and since 1941 it has fallen rapidly. In 1945 it was 68 per thousand births.

The effect of a stationary total population combined with a falling birth rate and a stationary death rate is to age the population; i.e. the proportion of children in the population becomes smaller and the proportion of adults and old persons becomes larger. How far this alteration in the age-constitution of the population has influenced the age-incidence of the four diseases will be examined later.

Meanwhile we shall look at the age-constitution of the populationat the three censuses, 1911, 1921, and 1931, and the Medical Officer of Health's estimates for 1941 and 1945. These figures are given in Table 26. Below the number of persons in each age-group is shown the percentage of the total population constituted by that age-group. The Medical Officer of Health's estimates for the child populations are

Table 25.

Glasgow. Population, Birth Rate, Death Rate, and Infant Mortality Rate.

Year	Population	Birth Rate per 1,000 of population	Death Rate per 1,000 of population	Infant Mortality Rate per 1,000 births
1861	397,673	41.6	27.5	154
1871	491,900	38.4	32.1	191
1881	512,034	37.3	25.2	144
1891	567,143	35.0	25.3	148
1901	761,925	31.8	21.2	149
1911	784,680	27.7	17.7	139
1921	1,075,000	27.6	14.5	106
1931	1,088,461	21.1	14.2	105
1941	1,045,333	18.5	15.6	111

Table 26.

Actual and Percentage Age-Distribution of Population. Glasgow.

Year	-1	-2	-5	-10	-15	15-	Total
1911	18449	19006	50690	81368	72245	538738	784496
	2.4	2.4	6.5	10.4	9.7	68.6	100
1921	24967	25092	51514	100337	101576	730688	1034174
	2.4	2.4	5.0	9.7	9.8	70.7	100
1931	20852	19725	58400	104136	94483	790865	1088461
	1.9	1.8	5.4	9.6	8.7	72.6	100
1941	18559	19159	57745	94632	95000	760238	1045333
	1.8	1.8	5.5	9.1	9.1	72.7	100
1945	19504	20159	55726	92000	93000	769611	1050000
	1.8	1.9	5.3	8.8	8.9	73.3	100

based on births and deaths for the first three age-groups, and on school population estimates for the two school age-groups. The 15- age-group has been calculated as the residue of the total estimated population. These figures clearly show the relative reduction in the child (under 15 years) population, from 31.4% in 1911 to 26.7% in 1945, and the relative increase in the adult (over 15 years) population, from 68.6% in 1911 to 73.3% in 1945. While the table indicates in a general way that there has been some transfer of population from the child to the adult age-groups during these 34 years, the figures for certain of the age-groups cannot be regarded as accurate. We shall be returning, however, to this matter in the next chapter.

b) Housing.

Newsholme (1923) gives an interesting table, here reproduced as Table 27, which, while not of very recent date, clearly shows us what the housing position of Glasgow was in 1911, compared with certain other cities in the same year.

In 1921 the percentage of persons living more than two per room in Glasgow was 54%, and in 1931 42.3%. No later figures are available, and the only earlier figure that I have found was 59% in 1891. Evidently the situation was improving only very slowly up to 1921, and thereafter began to improve more rapidly. A similar trend is shown in Table 28 giving figures for the number of persons per room, (M.O.H. An. Rep., 1932).

The next table (Table 29) allows us to compare the percentage distribution of houses of various sizes in Glasgow with that of three other cities in 1931. One of the reasons for the high degree of overcrowding in Glasgow now becomes apparent, namely the very high percentage of small houses.

A high percentage of small houses is not, however, the only problem. We must consider also the type of house. In Glasgow the prevailing type of dwelling is the tenement. In England the word "tenement" frequently retains its original meaning and implies a house or an apartment. In Scotland this meaning is unknown and "tenement", to quote Halliday, "signifies a block or building consisting of several storeys on each of which are resident one or more families, each occupying a separate suite of rooms, entered from a common landing or lobby. The dwelling place of each family is known as a 'house' ".

It seems probable that up until 1931, 80% or more of the population of Glasgow lived in tenements. Since then there has been, up to 1939, a transfer of a proportion of the population to suburban housing schemes, in which the cottage type, and the flatted type of house predominate.

Table 27.

Percentage of the Population Living More Than 2 Persons per Room in Various Cities, 1911. (Newsholme).

Manchester	Liverpool	Birmingham	London	Edinburgh	Glasgow
7.0%	9.5%	9.8%	16.8%	31.1%	53.6%

Table 28.

Average Number of Persons per Room at Various Years. Glasgow.

1881	1891	1901	1911	1921	1931
2.040	2.033	1.846	1.827	1.766	1.536

Table 29.

Percentage of Houses of Different Sizes in Various Cities, 1931.

Size of House	Glasgow	Edinburgh	Birmingham	Liverpool
1 Apartment	14.8%	6.7%	0.2%	0.3%
2 Apartments	43.7%	31.8%	1.1%	2.7%
3 Apartments	23.7%	25.5%	17.1%	9.7%
4 Apartments	9.1%	14.8%	19.8%	21.8%
5 or more Apartments	8.7%	21.2%	61.8%	65.5%
All Sizes	100.0%	100.0%	100.0%	100.0%

The older tenement housing, due to the close propinquity of families, and the fact that children play in the common "close", and run into one another's houses, must be regarded as a potent cause of the rapid dissemination of infection from one family to another. In addition, light and air in these older tenements is deficient; and the high narrow flights of stairs to be navigated to and from the houses on the upper storeys act as a deterrent upon mothers to take infants out for fresh air and sunshine.

The slums of Glasgow are invariably old and decrepit tenement buildings. Many of the newer tenements, however, are well constructed, well ventilated buildings, containing houses of three, four, or more spacious rooms, and equipped to the best standards of modern sanitation. These modern tenements cannot be regarded as being detrimental to health.

c) Municipal Wards.

The City of Glasgow is, for administrative purposes, divided into 38 municipal wards, each designated by number and by name. Ward 38, Yoker and Knightswood, was constituted in 1933; the others, in their present form, in 1921. Previous to that the wards were fewer, and had different numbers, names, and boundaries. Accordingly, in the serial presentation of ward data, it is not possible to go further back than 1921.

The wards are grouped geographically into five divisions, Eastern, Central, Northern, South-West, and South-East.

There are considerable differences in the size of population in these wards, varying, in 1931, from 13,705 in Ward 13 (Blythswood) to 56,430 in Ward 25 (Whiteinch), from which Ward 38 was split off two years later. The average size of the wards is, however, about 30,000.

Between the inhabitants of the separate wards, there exist well-marked differences in social position, occupation, housing, over-crowding, birth-rates, infant mortality rates, and death rates. The study of differences in the behaviour of the four infectious diseases among these different groups of the population will be taken up in Chapters 3 and 4.

CHAPTER 2

Variations in Age-Incidence.

Section 1

Age-Shift in Morbidity, Mortality and Fatality.

In 1907 Sir Shirley Murphy addressed the Royal Society of Medicine on the subject of variations in age-mortality in several diseases, one of which was Diphtheria. Using London data from 1860 to 1905, he suggested that the age-mortality in Diphtheria varied rhythmically, moving up to the school ages during periods of high prevalence, and returning to the pre-school ages in non-epidemic periods, and that these variations might be connected, in part, with the aggregation of children in schools.

Chalmers in an appendix to his annual report, (M.O.H. An.Rep. 1913), reviewed the age-mortality in Diphtheria in Scotland from 1860 to 1911, and demonstrated a relative transfer of deaths from the 0-5 to the 5-10 years age-groups. He also studied age-distribution of notified cases in Glasgow from 1903 to 1912, and demonstrated a relative transfer of cases from the -5 age-group to the -10 and -15 age-groups. Table 30 is from his report and gives the percentage distribution of cases in age-groups for each year from 1903 to 1912.

In 1934, the Registrar-General demonstrated a relative transfer of Diphtheria from the pre-school to the school age-groups in England and Wales from 1901 to 1934.

Picken (1937) confirmed the age-shift in mortality and

Table 30.

% Age-Distribution of Notified Cases of Diphtheria, 1903-1912.
Glasgow. (Chalmers).

Year	-5	-10	-15	15-	All Ages
1903	53.8	20.4	6.5	19.3	100
1904	50.4	22.4	7.0	20.2	100
1905	51.0	25.3	7.2	16.5	100
1906	43.3	31.8	9.4	15.5	100
1907	41.6	29.6	10.1	18.7	100
1908	47.3	30.8	7.8	14.1	100
1909	44.2	31.3	9.4	15.1	100
1910	42.9	30.9	11.4	14.8	100
1911	41.2	33.8	11.0	14.0	100
1912	42.7	31.4	10.6	15.3	100

attributed it to relative differences in the reduction in fatality rates at different ages, rather than to variations in the age-incidence of cases. Coming at a time when interest was closely centred on the recently discovered "types" of C.Diphtheriae, it was perhaps natural that Picken should suggest, as a possible reason for variations in the age-fatality rates, changes of strain of Corynebacterium diphtheriae.

Cheeseman, Martin & Russell (1939) carried matters a stage further when they demonstrated that the age-shift in Diphtheria had occurred in the poorer London Boroughs but not in the better-class ones. They suggested that a reduction in family size was responsible for the age-shift, a reduction which had occurred to a greater extent in the poorer, than in the better-class boroughs.

Finally, Carter (1943) in his bacteriological review of Diphtheria in Glasgow from 1934, indicated by means of several tables, that the age-shift in Diphtheria in Glasgow, had continued during the years subsequent to Chalmer's observations of 1913.

Possible variations in the age-incidence of the other three diseases has received much less attention. Woods (1933), comparing the age-distribution of Scarlet Fever cases in London, for 1901-5 with 1926-29, demonstrated an age-shift of cases from the 0-5 to the 5-10 age-groups, an age-shift which she attributed to the altered age-constitution of the population at risk. Similarly, Butler (1945) was able to demonstrate an age-shift in the incidence of measles from an earlier to a later age.

It is the object of this section to analyse the experience of Glasgow from 1916 to 1945 with respect to Scarlet Fever, Diphtheria, Measles, and Whooping Cough, and to demonstrate age-shifts in Morbidity, Mortality, and Fatality in each of these diseases.

Data concerning the age-distribution of cases was obtained from the Public Health Department records. These records, available from 1916 onwards, group the cases into the following age-groups:- -1 year, -2, -5, -10, -15, -25, -35, -45, -55, -65, -75, and 75+ years. The two sexes are shown separately, and for some but not all years, a distinction is made between home and hospital-treated cases. Having abstracted these case-records in the above grouping, I then re-grouped the cases into the following groups:- -1 year, -2, -5, -10, -15, and 15- years, without regard to sex or place of treatment. For each of the new age-groups the percentage of the total number of cases at all ages was then calculated. This was done for each disease for each of the thirty years. Next, the cases within each age-group were added in six five-years periods, 1916-1920, 1921-25, and so on. The percentage of the total within each age-group was calculated for each five-year period. Finally all the cases for the whole thirty years were added in age-groups and calculated as percentages of the total number of cases at all ages.

It will be realised that this representation of the percentage age-distribution of cases is equivalent to assuming that exactly one hundred cases of each disease had occurred in each year, then in each five years, and then in the whole thirty years; therefore, the calculated percentages in the age-groups represent the proportion of cases that would have occurred in each age-group had the total number of cases been constant for each time-period.

The number of deaths at diffent ages for each of the infectious diseases is published in the Annual Reports of the Medical Officer of Health. These deaths were re-grouped into the same age-groups as for cases, again without distinction of sex; and exactly as with the cases, the percentage age-distribution of deaths for single years, and for five-year and thirty-year periods were calculated.

The percentage age-distributions of cases and of deaths for each individual year are shown in Tables 31 and 32.

The actual and percentage age-distribution of cases and of deaths in quinquennia are shown in Tables 33 and 34. Earlier, in Table 9, we saw the percentage age-distributions for the consolidated 30 years.

Before we discuss these tables, we must complete the

Table 31.

Annual Percentage Age-Distribution of Cases. Scarlet Fever.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	1.3	3.9	21.1	35.2	17.6	20.9	100
1917	0.8	2.6	20.2	41.9	18.0	16.5	100
1918	0.9	3.5	22.1	42.0	16.7	14.8	100
1919	0.7	2.8	20.2	41.4	18.6	16.3	100
1920	0.8	2.0	18.4	42.3	19.9	16.6	100
1921	0.9	2.2	17.2	44.2	20.0	15.5	100
1922	0.9	3.1	22.0	43.4	17.6	13.0	100
1923	1.1	3.8	22.3	41.5	17.5	13.8	100
1924	1.2	2.7	22.7	39.1	19.8	14.5	100
1925	1.0	3.5	22.1	38.8	20.3	14.3	100
1926	0.9	3.4	22.7	40.5	17.0	15.5	100
1927	0.6	3.1	19.4	40.3	19.0	17.6	100
1928	0.4	2.1	20.7	41.6	15.8	19.4	100
1929	0.5	2.4	19.2	43.4	16.1	18.4	100
1930	0.9	3.8	22.9	42.8	14.7	14.9	100
1931	0.8	3.0	21.7	41.6	16.5	16.4	100
1932	0.6	3.5	21.7	39.4	17.6	17.2	100
1933	0.6	3.6	23.6	41.6	17.0	13.8	100
1934	0.5	3.8	24.3	39.6	16.4	15.4	100
1935	0.5	4.4	25.0	39.1	15.0	16.0	100
1936	0.5	4.1	24.5	39.5	16.0	15.4	100
1937	0.5	3.8	26.3	41.1	15.7	12.6	100
1938	0.5	5.0	27.7	40.0	13.7	13.1	100
1939	0.5	5.3	26.7	39.5	14.0	14.0	100
1940	0.8	5.7	31.8	36.2	12.3	13.2	100
1941	0.7	5.0	27.7	39.5	13.7	13.4	100
1942	0.5	4.1	24.7	42.3	17.1	11.3	100
1943	0.5	3.3	24.8	43.1	18.7	9.6	100
1944	0.4	4.8	27.9	44.5	15.2	7.2	100
1945	0.4	5.2	30.2	44.4	13.9	5.9	100

Table 31 (continued).

Annual Percentage Age-Distribution of Cases. Diphtheria.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	3.7	10.2	31.9	26.8	9.6	17.8	100
1917	3.0	9.4	28.4	28.8	10.6	19.8	100
1918	2.4	7.9	30.5	33.7	9.7	15.8	100
1919	1.9	6.0	26.5	36.2	12.5	16.9	100
1920	3.1	5.7	23.0	36.0	13.4	18.8	100
1921	3.2	6.1	21.3	35.8	14.3	19.3	100
1922	3.9	8.4	25.2	32.1	12.6	17.8	100
1923	4.2	7.5	27.0	31.0	12.6	17.7	100
1924	3.3	7.3	28.2	29.7	13.5	18.0	100
1925	3.0	6.6	26.3	31.3	12.2	20.6	100
1926	3.0	7.5	23.4	32.5	13.2	20.4	100
1927	2.8	6.0	22.5	35.0	11.9	21.8	100
1928	2.4	7.0	24.7	36.0	12.2	17.7	100
1929	2.6	5.5	25.2	38.5	12.3	15.9	100
1930	1.9	4.4	24.1	40.6	14.1	14.9	100
1931	2.0	5.7	24.4	39.3	12.4	16.2	100
1932	1.5	4.2	23.6	39.3	15.7	15.7	100
1933	1.5	3.1	20.2	40.7	18.8	15.7	100
1934	1.2	3.4	22.1	38.5	17.1	17.7	100
1935	1.9	3.6	20.8	38.7	17.5	17.5	100
1936	1.5	4.1	19.9	36.0	17.3	21.2	100
1937	1.1	3.5	20.0	35.3	16.6	23.5	100
1938	1.1	3.4	23.9	37.8	16.7	17.1	100
1939	1.1	2.7	24.3	36.8	16.7	18.4	100
1940	0.7	3.2	24.9	36.1	14.9	20.2	100
1941	1.5	3.4	23.5	32.2	13.8	25.6	100
1942	1.3	3.3	22.8	31.4	15.5	25.7	100
1943	1.8	3.6	22.9	33.1	15.5	23.1	100
1944	1.3	3.8	22.8	33.3	16.7	22.1	100
1945	1.1	3.9	25.8	35.2	16.4	17.6	100

Table 31 (continued).

Annual Percentage Age-Distribution of Cases. Measles.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	7.2	15.5	40.0	32.3	2.4	2.6	100
1917	6.4	13.2	40.6	34.7	2.0	3.1	100
1918	5.0	12.6	39.9	36.8	2.0	3.7	100
1919	5.7	11.3	39.8	40.4	1.2	1.6	100
1920	6.3	11.3	36.0	43.1	1.5	1.8	100
1921	6.4	10.4	35.3	43.4	2.0	2.5	100
1922	6.7	14.9	37.9	38.1	1.2	1.2	100
1923	6.8	14.7	40.4	35.4	1.5	1.2	100
1924	7.8	14.0	40.7	33.6	2.1	1.8	100
1925	6.1	11.4	34.0	45.5	1.8	1.2	100
1926	6.0	12.2	39.2	40.1	1.5	1.0	100
1927	6.2	11.9	36.9	42.9	1.0	1.1	100
1928	6.9	13.2	39.2	38.6	1.0	1.1	100
1929	5.7	9.9	31.6	50.1	1.7	1.0	100
1930	6.2	11.9	35.9	43.7	1.1	1.2	100
1931	6.2	11.6	35.7	44.8	0.9	0.8	100
1932	8.3	12.5	34.0	41.7	2.0	1.5	100
1933	7.3	6.0	16.6	59.2	9.5	1.4	100
1934	5.4	11.6	37.2	44.0	1.1	0.7	100
1935	7.2	4.3	17.5	64.8	4.3	1.9	100
1936	5.7	11.3	33.3	45.8	2.8	1.1	100
1937	5.5	9.8	27.9	53.9	1.6	1.3	100
1938	6.0	11.5	35.4	44.3	1.3	1.5	100
1939	4.5	4.1	14.9	66.4	8.2	1.9	100
1940	5.1	11.6	37.2	44.1	1.0	1.0	100
1941	8.0	8.9	29.4	47.8	2.6	3.3	100
1942	5.0	9.4	29.8	52.2	2.3	1.3	100
1943	4.5	7.2	24.2	57.0	5.7	1.4	100
1944	5.3	9.6	33.1	47.4	3.2	1.4	100
1945	5.4	9.9	32.3	49.2	2.4	0.8	100

Table 31 (continued).

Annual Percentage Age-Distribution of Cases. Whooping Cough.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	10.1	11.7	36.8	39.2	2.0	0.2	100
1917	9.7	10.4	34.8	43.1	1.9	0.1	100
1918	9.6	10.3	37.0	40.8	2.2	0.1	100
1919	8.5	9.8	34.0	45.2	2.2	0.3	100
1920	11.5	9.4	30.3	46.8	1.6	0.4	100
1921	11.1	10.3	33.9	43.1	1.4	0.2	100
1922	11.1	11.8	35.4	40.3	1.2	0.2	100
1923	11.2	12.3	34.2	41.1	1.0	0.2	100
1924	12.8	12.6	39.6	33.7	1.0	0.3	100
1925	14.3	13.6	40.2	30.2	1.1	0.6	100
1926	14.4	13.3	35.2	35.7	0.9	0.5	100
1927	12.2	13.3	36.1	36.9	1.0	0.5	100
1928	11.2	12.6	38.3	36.8	0.8	0.3	100
1929	10.2	12.0	36.7	40.3	0.6	0.2	100
1930	9.9	11.2	34.7	43.2	0.9	0.1	100
1931	10.6	11.4	34.2	42.2	1.4	0.2	100
1932	9.2	10.9	34.0	44.3	1.4	0.2	100
1933	9.4	11.7	33.6	43.7	1.4	0.2	100
1934	8.7	10.4	32.4	47.3	1.0	0.2	100
1935	10.0	11.2	33.7	43.6	1.3	0.2	100
1936	8.2	10.8	31.9	47.6	1.3	0.1	100
1937	8.9	10.0	32.6	47.0	1.4	0.1	100
1938	8.4	10.5	34.6	45.4	0.9	0.2	100
1939	8.8	10.6	32.3	46.5	1.7	0.1	100
1940	6.8	9.0	29.9	52.6	1.4	0.3	100
1941	8.4	10.4	34.0	45.6	1.5	0.1	100
1942	7.5	10.1	33.2	47.2	1.6	0.4	100
1943	8.1	9.2	30.8	49.9	1.9	0.1	100
1944	9.1	9.6	29.4	49.8	1.9	0.2	100
1945	8.5	8.7	29.4	50.9	2.3	0.2	100

Table 32.

Annual Percentage Age-Distribution of Deaths. Scarlet Fever.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	3.1	16.2	34.8	34.1	3.7	8.1	100
1917	11.1	5.6	27.8	36.1	11.1	8.3	100
1918	4.0	20.0	40.0	32.0	-	4.0	100
1919	6.1	16.3	36.8	22.5	2.0	16.3	100
1920	1.7	17.1	37.2	28.7	5.1	10.2	100
1921	9.3	3.7	37.0	24.1	9.3	16.6	100
1922	1.3	20.0	38.7	24.0	4.0	12.0	100
1923	2.8	19.5	37.4	27.8	6.9	5.6	100
1924	6.3	11.4	40.4	24.3	7.6	10.0	100
1925	4.4	23.6	35.1	23.6	7.4	5.9	100
1926	6.8	20.5	33.0	21.6	4.6	13.5	100
1927	6.8	18.1	34.2	25.0	2.3	13.6	100
1928	-	23.5	32.5	17.6	5.8	20.6	100
1929	2.5	12.5	27.5	35.0	7.5	15.0	100
1930	14.6	19.5	39.1	14.6	4.9	7.3	100
1931	5.4	9.4	39.2	25.6	4.0	16.4	100
1932	6.9	11.8	31.3	17.7	8.8	23.5	100
1933	3.6	18.1	31.3	21.7	13.3	12.0	100
1934	5.1	18.2	29.9	29.9	3.9	13.0	100
1935	5.4	10.8	29.8	27.0	10.8	16.2	100
1936	3.0	9.2	33.3	27.3	6.0	21.2	100
1937	-	17.2	41.4	17.2	3.5	20.7	100
1938	6.9	20.7	31.1	13.7	3.5	24.1	100
1939	18.2	27.2	18.2	18.2	-	18.2	100
1940	30.0	30.0	10.0	20.0	10.0	-	100
1941	14.3	14.3	14.3	28.5	14.3	14.3	100
1942	-	22.2	-	44.5	-	33.3	100
1943	-	-	20.0	-	60.0	20.0	100
1944	14.3	28.6	14.3	28.6	-	14.3	100
1945	-	25.0	75.0	-	-	-	100

Table 32 (continued).

Annual Percentage Age-Distribution of Deaths. Diphtheria.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	14.7	25.8	36.0	16.9	0.7	5.9	100
1917	8.5	28.8	33.3	20.9	3.3	5.2	100
1918	10.4	16.4	40.4	26.2	2.2	4.4	100
1919	8.1	15.5	39.2	32.9	1.2	3.1	100
1920	12.5	19.4	32.4	26.9	2.5	6.3	100
1921	14.0	23.3	29.4	24.7	3.9	4.7	100
1922	11.5	31.7	30.2	20.8	2.2	3.6	100
1923	14.4	17.2	34.7	28.2	4.1	1.4	100
1924	8.0	24.0	43.1	19.8	2.2	2.9	100
1925	7.2	20.1	41.6	28.3	2.8	-	100
1926	15.9	28.7	36.4	15.2	1.5	2.3	100
1927	9.7	24.8	32.8	26.4	-	6.3	100
1928	14.3	26.5	31.4	17.9	2.1	7.8	100
1929	10.4	21.5	34.1	28.1	2.2	3.7	100
1930	8.3	15.9	35.8	27.6	7.6	4.8	100
1931	11.8	19.3	29.4	26.0	5.9	7.6	100
1932	9.1	15.2	30.3	33.7	5.0	6.7	100
1933	1.1	10.1	39.3	29.2	15.8	4.5	100
1934	4.4	13.1	35.4	34.1	5.6	7.4	100
1935	10.4	9.6	33.9	33.1	7.8	5.2	100
1936	1.9	7.4	31.4	46.3	7.4	5.6	100
1937	3.5	10.3	30.2	34.5	12.9	8.6	100
1938	3.8	9.0	36.4	41.0	6.8	3.0	100
1939	1.8	4.9	50.4	39.3	1.2	2.4	100
1940	2.7	8.4	49.2	31.8	4.4	3.5	100
1941	5.2	7.7	43.9	32.2	4.5	6.5	100
1942	5.6	5.6	48.8	21.1	13.3	5.6	100
1943	13.6	8.7	37.0	27.1	3.7	9.9	100
1944	4.8	24.2	43.6	19.4	4.8	3.2	100
1945	3.0	9.1	63.7	21.2	-	3.0	100

Table 32 (continued).

Annual Percentage Age-Distribution of Deaths. Measles.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	25.0	44.0	26.9	3.7	-	0.4	100
1917	22.3	42.4	29.9	4.9	0.2	0.3	100
1918	18.4	47.2	28.2	5.4	0.3	0.5	100
1919	22.0	39.9	30.5	6.7	-	0.9	100
1920	35.5	40.0	21.6	2.9	-	-	100
1921	20.9	47.3	22.7	9.1	-	-	100
1922	27.0	44.6	25.3	2.8	-	0.3	100
1923	26.0	48.0	22.2	3.0	0.4	0.4	100
1924	28.3	49.5	20.5	1.3	0.4	-	100
1925	28.0	49.1	19.5	3.4	-	-	100
1926	28.8	47.1	21.8	1.9	0.2	0.2	100
1927	27.1	45.9	25.2	1.5	-	0.3	100
1928	31.4	48.4	18.1	1.3	0.3	0.5	100
1929	27.5	53.9	14.9	3.7	-	-	100
1930	39.8	43.7	14.6	1.1	0.4	0.4	100
1931	31.3	43.2	22.6	2.9	-	-	100
1932	32.1	48.7	15.4	2.7	-	1.1	100
1933	50.0	50.0	-	-	-	-	100
1934	31.3	43.3	19.9	4.9	-	0.6	100
1935	50.0	25.0	12.5	12.5	-	-	100
1936	35.0	45.3	17.1	2.6	-	-	100
1937	24.2	48.4	20.6	6.8	-	-	100
1938	28.8	45.9	21.0	2.7	-	1.6	100
1939	100.0	-	-	-	-	-	100
1940	43.4	39.1	14.4	1.0	-	2.1	100
1941	54.5	9.1	27.3	9.1	-	-	100
1942	36.9	35.4	23.1	3.1	-	1.5	100
1943	61.2	25.9	6.5	3.2	3.2	-	100
1944	56.2	18.8	25.0	-	-	-	100
1945	54.2	20.8	25.0	-	-	-	100

Table 32 (continued).

Annual Percentage Age-Distribution of Deaths. Whooping Cough.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	32.7	39.0	25.2	3.1	-	-	100
1917	34.5	35.5	25.3	4.7	-	-	100
1918	34.0	34.4	27.5	4.1	-	-	100
1919	30.7	34.6	28.4	5.9	0.2	0.2	100
1920	47.6	32.4	14.5	5.5	-	-	100
1921	45.1	40.8	11.8	2.3	-	-	100
1922	37.3	38.5	22.7	1.5	-	-	100
1923	34.9	44.9	18.3	1.6	-	0.3	100
1924	37.6	42.1	18.8	1.5	-	-	100
1925	46.4	36.4	15.3	1.5	0.2	0.2	100
1926	40.1	31.8	23.6	3.9	0.6	-	100
1927	50.6	33.2	13.7	2.5	-	-	100
1928	41.6	38.4	18.1	1.6	-	0.3	100
1929	45.0	32.4	19.4	3.2	-	-	100
1930	44.1	36.5	18.6	0.4	-	0.4	100
1931	48.9	33.2	16.8	1.1	-	-	100
1932	36.6	36.0	26.6	0.8	-	-	100
1933	51.5	34.9	12.8	0.4	-	0.4	100
1934	39.3	35.2	24.4	1.1	-	-	100
1935	48.1	35.0	14.0	2.9	-	-	100
1936	41.9	40.2	12.8	5.1	-	-	100
1937	48.8	30.2	17.9	3.1	-	-	100
1938	46.5	42.1	11.4	-	-	-	100
1939	52.7	26.6	18.0	2.7	-	-	100
1940	60.0	15.0	25.0	-	-	-	100
1941	46.5	33.2	17.2	3.1	-	-	100
1942	53.6	32.1	10.7	3.6	-	-	100
1943	64.4	18.9	16.7	-	-	-	100
1944	61.1	22.2	13.9	2.8	-	-	100
1945	40.0	37.1	20.0	-	2.9	-	100

Table 33.

Quinquennial Actual and Percentage Age-Distribution of Cases.

Years	-1	-2	-5	-10	-15	15-	All Ages
Scarlet Fever							
1916-20	129	403	2755	5476	2522	2412	13697
	0.9	2.9	20.2	40.0	18.4	17.6	100
1921-25	177	540	3739	7260	3348	2492	17556
	1.0	3.1	21.3	41.3	19.1	14.2	100
1926-30	141	616	4296	8434	3356	3431	20274
	0.7	3.0	21.2	41.6	16.6	16.9	100
1931-35	214	1220	7900	13878	5736	5402	34350
	0.6	3.6	23.0	40.4	16.7	15.7	100
1936-40	98	843	5009	7399	2744	2537	18630
	0.5	4.5	26.9	39.7	14.8	13.6	100
1941-45	69	666	3995	6336	2340	1335	14741
	0.5	4.5	27.1	43.0	15.9	9.0	100
Diphtheria							
1916-20	220	601	2198	2621	910	1416	7966
	2.8	7.6	27.5	32.9	11.4	17.8	100
1921-25	314	640	2293	2861	1169	1670	8947
	3.5	7.2	25.6	31.9	13.1	18.7	100
1926-30	315	766	3008	4578	1604	2306	12577
	2.5	6.1	23.8	36.4	12.8	18.4	100
1931-35	182	452	2541	4515	1888	1912	11490
	1.6	3.9	22.1	39.4	16.4	16.6	100
1936-40	156	499	3545	5560	2469	3030	15259
	1.0	3.3	23.2	36.4	16.2	19.9	100
1941-45	209	513	3387	4749	2220	3402	14480
	1.4	3.5	23.4	32.8	15.4	23.5	100
Measles							
1916-20	3280	6770	20722	19775	961	1360	52868
	6.2	12.8	39.2	37.4	1.8	2.6	100
1921-25	3232	6565	17980	17899	724	646	47046
	6.9	14.0	38.2	38.0	1.5	1.4	100
1926-30	3314	6469	20013	22808	668	581	53853
	6.2	11.9	37.2	42.4	1.2	1.1	100
1931-35	2868	5387	16717	21020	654	397	47043
	6.1	11.5	35.5	44.7	1.4	0.8	100
1936-40	2831	5640	17163	23139	1022	625	50420
	5.6	11.2	34.0	46.0	2.0	1.2	100
1941-45	1539	2670	8830	15409	1019	412	29879
	5.1	8.9	29.6	51.6	3.4	1.4	100

Table 33 (continued).

Quinquennial Actual and Percentage Age-Distribution of Cases.

Whooping Cough

Years	-1	-2	-5	-10	-15	15-	All Ages
1916-20	2506	2670	9039	11341	518	53	26127
	9.6	10.2	34.6	43.4	2.0	0.2	100
1921-25	5092	4985	15203	14876	479	147	40782
	12.4	12.2	37.3	36.5	1.2	0.4	100
1926-30	3748	4111	11869	12523	287	100	32638
	11.5	12.6	36.4	38.3	0.9	0.3	100
1931-35	3278	3769	11346	14844	438	73	33748
	9.7	11.2	33.6	44.0	1.3	0.2	100
1936-40	2069	2498	7873	11293	334	32	24099
	8.6	10.3	32.7	46.9	1.4	0.1	100
1941-45	2013	2343	7671	11481	420	33	23961
	8.4	9.8	32.0	48.0	1.7	0.1	100

Table 34.

Quinquennial Actual and Percentage Age-Distribution of Deaths.

Scarlet Fever

Years	-1	-2	-5	-10	-15	15-	All Ages
1916-20	14	51	116	104	14	31	330
	4.2	15.4	35.2	31.6	4.2	9.4	100
1921-25	16	56	132	86	24	34	348
	4.6	16.1	37.9	24.7	6.9	9.8	100
1926-30	16	47	82	56	12	34	247
	6.5	19.0	33.2	22.7	4.9	13.7	100
1931-35	20	52	121	88	30	62	373
	5.4	13.9	32.4	23.6	8.1	16.6	100
1936-40	8	20	35	22	5	22	112
	7.1	17.9	31.3	19.6	4.5	19.6	100
1941-45	2	6	6	8	4	6	32
	6.1	18.8	18.8	25.0	12.5	18.8	100

Table 34 (continued).

Quinquennial Actual and Percentage Age-Distribution of Deaths.

Years	-1	-2	-5	-10	-15	15-	All Ages
Diphtheria							
1916-20	85	165	289	199	16	39	793
	10.7	20.8	36.4	25.2	2.0	4.9	100
1921-25	74	155	236	161	20	17	663
	11.1	23.3	35.7	24.3	3.0	2.6	100
1926-30	78	155	227	153	19	33	665
	11.7	23.3	34.1	23.0	2.9	5.0	100
1931-35	45	82	202	190	45	39	603
	7.5	13.5	33.6	31.5	7.4	6.5	100
1936-40	19	55	293	255	40	29	691
	2.7	8.0	42.3	37.0	5.8	4.2	100
1941-45	28	42	190	110	25	26	421
	6.7	10.0	45.1	26.1	5.9	6.2	100
Measles							
1916-20	520	922	598	101	2	9	2152
	24.2	42.8	27.8	4.7	0.1	0.4	100
1921-25	696	1207	603	74	4	6	2590
	26.9	46.6	23.3	2.8	0.2	0.2	100
1926-30	452	683	289	24	3	5	1456
	31.0	47.0	19.8	1.7	0.2	0.3	100
1931-35	357	498	226	43	-	5	1129
	31.6	44.1	20.1	3.8	-	0.4	100
1936-40	234	311	127	18	-	6	696
	33.6	44.7	18.2	2.6	-	0.9	100
1941-45	71	40	30	4	1	1	147
	48.3	27.2	20.4	2.7	0.7	0.7	100
Whooping Cough							
1916-20	749	771	569	107	1	1	2198
	34.0	35.1	25.8	4.9	0.1	0.1	100
1921-25	1030	1010	407	44	1	2	2494
	41.3	40.4	16.3	1.8	0.1	0.1	100
1926-30	629	489	253	31	1	2	1405
	44.8	34.8	18.0	2.2	0.1	0.1	100
1931-35	593	438	223	17	-	1	1272
	46.7	34.4	17.5	1.3	-	0.1	100
1936-40	320	213	108	19	-	-	660
	48.4	32.3	16.4	2.9	-	-	100
1941-45	242	142	79	11	1	-	475
	51.0	29.9	16.6	2.3	0.2	-	100

Table 35.

Annual Age-Fatality Rates. Scarlet Fever.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	9.1	16.4	6.5	3.8	0.8	1.5	4.0
1917	26.6	4.3	2.8	1.7	1.2	1.0	2.0
1918	8.3	10.6	3.4	1.4	-	0.5	1.9
1919	16.7	10.7	3.3	1.0	0.2	1.8	1.8
1920	3.5	13.3	3.2	1.1	0.4	1.0	1.6
1921	15.6	2.6	3.3	0.8	0.7	1.7	1.5
1922	3.2	14.2	3.8	1.2	0.5	2.0	2.2
1923	5.3	10.0	3.4	1.4	0.8	0.8	2.0
1924	13.5	10.5	4.4	1.5	0.9	1.7	2.5
1925	7.7	12.0	2.8	1.1	0.6	0.7	1.8
1926	13.6	11.4	2.7	1.0	0.5	1.7	1.9
1927	12.5	6.3	1.9	0.7	0.1	0.8	1.1
1928	-	11.8	1.7	0.4	0.4	1.1	1.1
1929	6.7	6.3	1.7	1.0	0.6	1.0	1.2
1930	13.3	4.3	1.4	0.3	0.3	0.4	0.8
1931	6 .9	3.4	1.9	0.7	0.3	1.0	1.1
1932	12.1	3.8	1.6	0.5	0.6	1.5	1.1
1933	6.1	5.1	1.3	0.5	0.8	0.9	1.0
1934	14.8	6.3	1.6	1.0	0.3	1.1	1.3
1935	9.1	2.3	1.1	0.6	0.7	0.9	0.9
1936	5.0	1.8	1.0	0.5	0.3	1.1	0.8
1937	-	2.4	0.8	0.2	0.1	0.9	0.5
1938	9.5	3.0	0.8	0.3	0.2	1.3	0.7
1939	13.3	1.9	0.3	0.2	-	0.5	0.4
1940	21.4	2.9	0.2	0.3	0.4	-	0.5
1941	7.7	1.1	0.2	0.3	0.4	0.4	0.4
1942	-	1.6	-	0.3	-	0.9	0.3
1943	-	-	0.1	-	0.5	0.3	0.2
1944	7.7	1.2	0.1	0.1	-	0.4	0.2
1945	-	0.6	0.3	-	-	-	0.1

Table 35 (continued).

Annual Age-Fatality Rates. Diphtheria.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	40.0	25.5	11.5	6.1	0.8	3.4	10.2
1917	34.4	37.0	14.2	8.8	3.7	3.2	12.1
1918	52.8	24.6	15.8	9.3	2.7	3.3	11.9
1919	38.4	22.9	13.1	8.1	0.9	1.6	8.9
1920	32.3	27.1	11.2	5.9	1.5	2.6	7.9
1921	30.5	26.5	9.6	4.8	1.9	1.7	7.0
1922	24.3	31.2	9.9	5.3	1.4	1.7	8.2
1923	28.5	18.8	10.5	7.5	2.7	0.6	8.2
1924	17.4	23.7	11.0	4.8	1.2	1.2	7.2
1925	15.4	20.2	10.3	5.9	1.4	-	6.5
1926	30.9	22.0	9.0	2.7	0.7	0.6	5.8
1927	13.1	15.4	5.4	2.8	-	1.1	3.7
1928	32.8	20.3	6.9	2.7	1.0	2.4	5.4
1929	26.0	25.0	8.8	4.7	1.2	1.5	6.5
1930	25.0	20.3	8.4	3.8	3.0	1.8	5.6
1931	34.2	19.7	6.9	3.8	2.7	2.7	5.8
1932	35.3	20.4	7.2	4.8	1.8	2.4	5.7
1933	28.7	12.5	7.5	2.8	3.2	1.1	3.8
1934	23.4	23.6	9.9	5.5	2.0	2.6	6.2
1935	26.7	12.8	7.8	4.1	2.1	1.4	4.8
1936	35.8	5.1	4.5	3.6	1.2	0.7	2.8
1937	15.4	15.2	7.7	5.0	4.0	1.9	5.1
1938	16.7	12.5	7.2	5.1	1.9	0.8	4.7
1939	8.8	9.6	10.7	5.6	0.4	0.7	5.2
1940	15.8	11.6	8.7	3.9	1.3	0.8	4.4
1941	13.1	8.8	7.2	3.9	1.3	1.0	3.9
1942	11.6	4.6	5.9	1.8	2.3	0.6	2.7
1943	20.8	6.7	4.5	2.3	0.7	1.2	2.8
1944	9.7	16.9	5.1	1.5	0.8	0.4	2.7
1945	4.8	4.0	4.2	1.0	-	0.3	1.7

Table 35 (continued).

Annual Age-Fatality Rates. Measles.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	17.2	14.0	3.3	0.6	-	0.7	4.9
1917	16.8	15.8	3.6	0.7	0.4	0.5	4.8
1918	15.8	16.0	3.0	0.6	0.6	0.6	4.3
1919	14.0	12.8	2.8	0.6	-	2.1	3.6
1920	14.9	9.3	1.6	0.2	-	-	2.6
1921	11.7	16.2	2.3	0.8	-	-	3.6
1922	27.3	20.4	4.5	0.5	-	1.8	6.8
1923	20.4	17.7	3.0	0.5	1.3	1.6	5.4
1924	22.5	21.9	3.1	0.3	1.2	-	6.2
1925	8.3	7.8	1.0	0.1	-	-	1.8
1926	12.7	10.2	1.5	0.1	0.4	0.6	2.6
1927	15.0	13.2	2.3	0.1	-	1.1	3.4
1928	17.1	13.7	1.7	0.1	1.0	1.8	3.8
1929	6.5	6.7	0.6	0.1	-	-	1.2
1930	13.9	7.9	0.9	0.1	0.8	0.7	2.2
1931	13.6	10.1	1.7	0.2	-	-	2.7
1932	13.2	13.1	1.5	0.2	-	2.4	3.4
1933	2.9	3.6	-	-	-	-	0.4
1934	12.1	7.9	1.1	0.2	-	1.8	2.1
1935	6.2	5.3	0.6	0.2	-	-	0.9
1936	9.5	6.2	0.8	0.1	-	-	1.5
1937	5.7	6.4	1.0	0.2	-	-	1.3
1938	7.8	6.5	1.0	0.1	-	1.7	1.6
1939	3.1	-	-	-	-	-	0.1
1940	7.6	3.0	0.3	0.02	-	1.9	0.9
1941	4.8	7.2	0.7	0.1	-	-	0.7
1942	5.9	2.9	0.6	0.05	-	0.9	0.8
1943	5.5	1.4	0.1	0.02	0.2	-	0.4
1944	2.7	0.5	0.2	-	-	-	0.3
1945	4.0	0.9	0.3	-	-	-	0.4

Table 35 (continued).

Annual Age-Fatality Rates. Whooping Cough.

Year	-1	-2	-5	-10	-15	15-	All Ages
1916	30.6	31.5	6.5	0.8	-	-	9.5
1917	27.6	26.4	5.6	0.8	-	-	7.7
1918	36.9	34.1	7.6	1.3	-	-	10.2
1919	33.7	32.7	7.9	1.2	0.7	5.3	9.4
1920	22.4	18.8	2.6	0.6	-	-	5.4
1921	26.2	25.3	2.2	0.3	-	-	6.4
1922	23.3	22.5	4.5	0.3	-	-	6.9
1923	23.3	27.4	4.0	0.3	-	9.1	7.5
1924	18.9	21.5	3.1	0.3	-	-	6.4
1925	15.6	12.9	1.8	0.2	0.7	1.4	4.8
1926	13.3	11.5	3.2	0.5	3.0	-	4.8
1927	15.0	9.2	1.4	0.2	-	-	3.6
1928	17.8	14.3	2.2	0.2	-	5.0	4.7
1929	22.2	13.5	2.7	0.4	-	-	5.0
1930	17.5	12.7	2.1	0.4	-	16.7	3.9
1931	23.2	14.8	2.5	0.1	-	-	5.1
1932	11.1	9.1	2.2	0.05	-	-	2.8
1933	19.4	10.6	1.3	0.04	-	6.7	3.5
1934	13.7	10.2	2.3	0.1	-	-	3.0
1935	17.2	11.2	1.5	0.2	-	-	3.6
1936	14.4	10.4	1.1	0.3	-	-	2.8
1937	18.0	9.9	1.8	0.2	-	-	3.3
1938	11.9	8.6	0.7	-	-	-	2.1
1939	14.3	6.0	1.3	0.1	-	-	2.4
1940	20.4	3.8	1.9	-	-	-	2.3
1941	14.6	8.4	1.3	0.2	-	-	2.6
1942	17.3	7.7	0.8	0.2	-	-	2.4
1943	13.0	3.3	0.9	-	-	-	1.6
1944	6.6	2.3	0.5	0.06	-	-	1.0
1945	6.0	5.4	0.9	-	1.6	-	1.3

Table 36.

Quinquennial Age-Fatality Rates.

Years	-1	-2	-5	-10	-15	15-	All Ages
	Scarlet Fever						
1916-20	10.9	12.7	4.2	1.9	0.6	1.3	2.4
1921-25	9.0	10.4	3.5	1.2	0.7	1.4	2.0
1926-30	11.3	7.6	1.9	0.7	0.4	1.0	1.2
1931-35	9.3	4.3	1.5	0.6	0.5	1.1	1.1
1936-40	8.2	2.4	0.7	0.3	0.2	0.9	0.6
1941-45	2.9	0.9	0.2	0.1	0.2	0.4	0.2
	Diphtheria						
1916-20	38.6	27.5	13.1	7.6	1.8	2.8	10.0
1921-25	23.6	24.2	10.3	5.6	1.7	1.0	7.4
1926-30	24.8	20.2	7.5	3.3	1.2	1.4	5.3
1931-35	24.7	18.1	7.9	4.2	2.4	2.0	5.2
1936-40	12.2	11.0	8.3	4.6	1.6	1.0	4.5
1941-45	13.4	8.2	5.6	2.3	1.1	0.8	2.9
	Measles						
1916-20	15.9	13.6	2.9	0.5	0.2	0.7	4.1
1921-25	21.5	18.4	3.4	0.4	0.6	0.9	5.5
1926-30	13.6	10.6	1.4	0.1	0.4	0.9	2.7
1931-35	12.4	9.2	1.4	0.2	-	1.3	2.4
1936-40	8.3	5.5	0.7	0.08	-	1.0	1.4
1941-45	4.6	1.5	0.3	0.03	0.1	0.2	0.5
	Whooping Cough						
1916-20	29.9	28.9	6.3	0.9	0.2	1.9	8.4
1921-25	20.2	20.3	2.7	0.3	0.2	1.4	6.1
1926-30	16.8	11.9	2.1	0.2	0.3	2.0	4.3
1931-35	18.1	11.6	2.0	0.1	-	1.4	3.8
1936-40	15.5	8.5	1.4	0.2	-	-	2.7
1941-45	12.0	6.1	1.0	0.1	0.2	-	2.0

picture by calculating fatality rates for the various age-groups for the various time-periods. These calculations were performed by dividing the actual number of deaths in each age-group in each time-period by the corresponding number of cases, and multiplying the quotient by 100; i.e. the deaths are expressed as a percentage of the cases. The annual age-fatality rates are given in Table 35, while Table 36 gives the quinquennial age-fatality rates.

We are now in a position to examine the changing age-distribution of cases, deaths, and fatality over the six quinquennia. It will, however, simplify the comparison of the proportions of cases and deaths in the different age-groups in Tables 33 and 34 if we add an additional pair of tables, Tables 37 and 38, in which the percentage age-distributions of cases and deaths for each quinquennium are expressed in proportion to the 1916-20 distribution, this being taken as 100 for each age-group. It is desirable that it be kept clearly in mind exactly what we are doing: we assumed, in the first place, that the total cases for all ages for each quinquennium are constant, (Table 33); we are now further assuming that the proportion of the constant total occurring within each age-group in 1916-20 has been brought up to 100, and we have shown what the corresponding proportion in the same age-group would have

Table 37.

Quinquennial Age-Distribution of Cases. Relative Changes within Age-Groups. 1916-20 = 100.

Years	-1	-2	-5	-10	-15	15-
Scarlet Fever						
1916-20	100	100	100	100	100	100
1921-25	111	107	106	103	104	81
1926-30	78	103	105	104	90	96
1931-35	67	124	114	101	91	89
1936-40	56	155	133	99	80	77
1941-45	56	155	134	108	86	52
Diphtheria						
1916-20	100	100	100	100	100	100
1921-25	125	95	93	97	115	105
1926-30	89	80	87	111	112	103
1931-35	57	51	80	120	144	93
1936-40	36	43	84	111	142	112
1941-45	50	46	85	100	135	132
Measles						
1916-20	100	100	100	100	100	100
1921-25	111	109	97	102	83	54
1926-30	100	93	95	113	67	42
1931-35	98	90	91	120	78	31
1936-40	90	88	87	123	111	46
1941-45	82	70	76	138	189	54
Whooping Cough						
1916-20	100	100	100	100	100	100
1921-25	129	120	108	84	60	200
1926-30	120	124	105	88	45	150
1931-35	101	110	97	101	65	100
1936-40	90	101	95	108	70	50
1941-45	88	96	92	111	85	50

Table 38.

Quinquennial Age-Distribution of Deaths. Relative Changes within Age-Groups. 1916-20 = 100.

Years	-1	-2	-5	-10	-15	15-
Scarlet Fever						
1916-20	100	100	100	100	100	100
1921-25	110	104	108	78	164	104
1926-30	155	123	95	72	117	146
1931-35	129	91	92	75	193	177
1936-40	169	116	89	62	107	209
1941-45	145	122	53	79	298	200
Diphtheria						
1916-20	100	100	100	100	100	100
1921-25	104	112	98	96	150	53
1926-30	109	112	94	91	145	102
1931-35	70	65	92	125	370	133
1936-40	25	38	116	147	290	86
1941-45	63	48	124	104	295	127
Measles						
1916-20	100	100	100	100	100	100
1921-25	111	109	84	60	200	50
1926-30	128	110	72	36	200	75
1931-35	131	103	73	81	-	100
1936-40	139	104	66	55	-	225
1941-45	200	64	73	58	700	175
Whooping Cough						
1916-20	100	100	100	100	100	100
1921-25	122	115	63	37	100	100
1926-30	132	99	70	45	100	100
1931-35	138	98	68	27	-	100
1936-40	142	92	64	59	-	-
1941-45	150	85	64	47	200	-

been in succeeding quinquennia. In other words, we have adopted a simple method of showing how the proportion of cases within each age-group has varied. Similarly we have shown how the proportion of deaths within each age-group has varied.

Considering cases first, we observe that the relative incidence of Scarlet Fever has diminished in the first year of life, has risen in the -2 and -5 age-groups, is fairly steady in the -10 age-group, falls slightly in the -15 age-group, and falls steeply in the 15- age-group.

In Diphtheria there is a fall in the -1, -2 and -5 age-groups. The -10 age-group rose, but returned again to its original level; there is a rise in the -15 and the 15- age-groups.

Measles shows a fall in the first three age-groups, a rise in the next two, and a fall in the 15- age-group.

The 1916-20 age-distribution of Whooping Cough is abnormal, inasmuch as, if we follow the trend of the succeeding five quinquennia, the age-distribution of the 1916-20 is such that it might be expected to come about the middle of these twenty-five years instead of before them. Present data is insufficient to show whether the 1916-20 age-distribution is as markedly different from preceeding periods as it is from the following ones. It cannot, therefore, be determined here whether it is the 1916-20 or the 1921-25 age-distribution that departs from the regular trend. Be that as it may, the trend of Whooping Cough seems to proceed regularly from 1921-25 onwards, showing a progressive fall in the first three age-groups, a rise in the next two, and a fall in the 15- age-group, i.e. ignoring the 1916-20 age-distribution, succeeding changes are similar to those of Measles.

We have therefore demonstrated, apart from a diminishing proportion of cases in all four diseases in the first year of life , 1) in Scarlet Fever a rising proportion of cases in the early age-groups and a falling proportion in the later age-groups; and 11) in each of the other three diseases, a falling proportion in the early age-groups, and a rising proportion in the later childhood age-groups. While Diphtheria, Measles, and Whooping Cough each show a relative transfer of cases from an earlier to a later age, the opposite has occurred in Scarlet Fever.

Considering now the changes in age-distribution of deaths we see that in Scarlet Fever there has been a rise in the two lowest age-groups, a fall in the two middle groups, and a substantial rise in the -15 and 15- age-groups.

Diphtheria shows a fall in the first two age-groups and a rise in all the higher age-groups, especially in the -15 age-group. The trend of Diphtheria deaths is, therefore, similar to that of Diphtheria cases.

The proportion of Measles deaths in the first year of life has been rising; in the -2 age-group it has remained fairly steady, though dropping in the last quinquennium; in the -5 and -10 age-groups, it has fallen between the first and second quinquennia, and has since been fairly steady; and shows a rise in the -15 and 15-age-groups.

The proportion of Whooping Cough deaths in the -1 age-group has risen progressively. From 1921-25 there has been a progressive fall in the -2 age-group, but little change has occurred in the later age-groups.

In contra-distinction to the age-shift of cases, all the diseases, except Diphtheria, show an increasing proportion of deaths occurring in the first year of life. In Scarlet Fever this is shared also by the -2 age-group. Diphtheria is again exceptional in showing arise in the -5 and -10 age-groups, Both Scarlet Fever and Diphtheria show a considerable increase in the proportion of deaths in the -15 age-group, and a smaller increase in the 15- age-group. Only one Measles death occurred in the 15- age-group in 1941-45, so that the comparative rate of 700 compared with 100 in 1916-20 is of little significance.

While the general movement of cases was easy to describe the picture with regard to deaths is confusing, and each disease must be considered on its own. A point of considerable importance emerges however. Changes in age-mortality, do not necessarily parallel changes in age-morbidity. The assumption frequently made that the age-distribution of deaths reflects the age-distribution of cases, is unjustified in the present instance.

Third, we come to the consideration of Table 36, the age-distribution of fatality rates. We have already seen in Chapter 1, that a progressive fall in total (all ages) fatality rates has taken place. Table 36, shows us how much each age-group has contributed towards the lowering of the total fatality rate for each disease. Comparison of the trend is simplified by expressing the fatality rate of each age-group in 1916-20 as 100 and calculating the corresponding rates for subsequent quinquennia. This has been done in Table 39. Only one age-group in only one disease, the -15 age-group in Whooping Cough, has failed to show a fall.

In Scarlet Fever, Measles, and Whooping Cough, the fall in fatality is greatest in the -2, -5, and -10 age-groups with a less marked fall in the -1, -15 and 15- age-groups. In Diphtheria, the reductions in the different age-groups are similar to one another, though the -15 age-group shows a smaller reduction than the others.

These wide differences between age-groups in the reduction in fatality for each of the diseases except Diphtheria at once explains the difference between the trend of age-morbidity and age-mortality. Especially it explains the rising proportion of deaths in the -1 age-group, where the falling proportion of cases is more than counter-balanced by a smaller reduction in fatality rates than at later

Table 39.

Quinquennial Fatality Rates. Relative Changes within Age-Groups. 1916-20 = 100.

Years	-1	-2	-5	-10	-15	15-	All Ages
Scarlet Fever							
1916-20	100	100	100	100	100	100	100
1921-25	83	82	83	63	117	108	83
1926-30	104	60	45	37	67	77	50
1931-35	85	34	36	32	83	85	46
1936-40	75	19	17	16	33	69	25
1941-45	27	7	5	5	33	31	8
Diphtheria							
1916-20	100	100	100	100	100	100	100
1921-25	61	88	79	74	95	36	74
1926-30	64	74	57	43	67	50	53
1931-35	64	66	60	55	133	72	52
1936-40	32	40	63	61	89	36	45
1941-45	35	30	43	30	61	29	29
Measles							
1916-20	100	100	100	100	100	100	100
1921-25	136	135	117	80	300	129	134
1926-30	86	78	48	20	200	129	66
1931-35	78	68	48	40	-	186	59
1936-40	52	41	24	16	-	143	34
1941-45	29	11	10	6	50	29	12
Whooping Cough							
1916-20	100	100	100	100	100	100	100
1921-25	68	70	43	33	100	74	73
1926-30	56	41	33	22	150	105	51
1931-35	61	40	32	11	-	74	45
1936-40	52	29	22	22	-	-	32
1941-45	40	21	16	11	100	-	24

childhood ages. The marked rise in the proportion of Scarlet Fever deaths in the 15 age-group is also explained by a failure of fatality to drop as much as in earlier age-groups. As the reduction in fatality rates in Diphtheria has not varied widely between the age-groups, the trends of age-morbidity and age-mortality are similar.

We have already seen that the fatality rate in the first year of life is higher than at later ages. We have also just seen that this fatality rate has failed to come down as rapidly as that of the next three age-groups. The comparative behaviour of the fatality rate within the first year of life is strikingly demonstrated in a further table (Table 40). In this table, which is derived from Table 36, the total fatality rate for "all ages" in each quinquennium is represented as 100, and the fatality rate for each age-group is represented as a proportion of this value. That is to say, the fatality rate for each age-group is expressed as a percentage of the total fatality rate for "all ages" in the same quinquennium. Since we are holding the total fatality rate constant thoughout the six quinquennia, a rise in the proportionate fatality rate in any age-group indicates that the fatality rate within that age-group has failed to fall to the same extent as has the total fatality rate.

Another way of looking at Table 40 is to imagine two series of cases, one occurring in persons of "all ages" and one in persons of only one-age group, say "under 1 year".

Table 40.

Quinquennial Age-Fatality Rates. Relative Changes within Age-Groups. "All Ages" = 100.

Years	-1	-2	-5	-10	-15	15-	All Ages
Scarlet Fever							
1916-20	455	530	175	79	25	54	100
1921-25	450	520	175	60	35	70	100
1926-30	942	633	158	58	33	83	100
1931-35	845	391	136	55	45	100	100
1936-40	1367	400	117	50	33	150	100
1941-45	1450	450	100	50	100	200	100
Diphtheria							
1916-20	386	275	131	76	18	28	100
1921-25	320	328	139	76	23	14	100
1926-30	469	382	141	62	23	26	100
1931-35	476	349	152	81	46	39	100
1936-40	272	245	184	102	36	22	100
1941-45	463	283	194	79	38	28	100
Measles							
1916-20	389	332	71	12	5	17	100
1921-25	392	335	62	7	11	16	100
1926-30	504	393	52	4	15	33	100
1931-35	518	384	58	8	-	54	100
1936-40	593	394	50	6	-	71	100
1941-45	920	300	60	6	20	40	100
Whooping Cough							
1916-20	356	344	75	11	2	23	100
1921-25	332	334	44	5	3	23	100
1926-30	392	277	49	5	7	47	100
1931-35	477	306	53	3	-	37	100
1936-40	576	315	52	7	-	-	100
1941-45	600	305	50	5	10	-	100

Then if we express e.g. the Scarlet Fever fatality rate, for "all ages" as 100, the corresponding rate in the -1 age-group would have been 455 in the 1916-20, but would have been 1450 in 1941-45; i.e. in 1916-20 the "under one year" fatality rate was 4.55 times the total fatality rate, but in 1941-45 it was 14.50 times the total fatality rate.

Naturally this table tells us no more that we already know, but it demonstrates, in perhaps a more convincing manner, the increasing weight which, in each disease, the high fatality rate in the "under one year" age-group contributes to the total fatality rate.

These relative trends in case, death, and fatality rates between several age-groups, and for four separate diseases, are perhaps difficult to follow when presented concurrently. It may help to elucidate the position and to show what are the major trends if we reduced the number and enlarge the size of the age-groups. We shall compare first, the 2-5 with the 0-2 years age-groups, and then the 5—15 with the 0-5 years age-groups.

From the percentage age-distributions of cases and deaths in quinquennia, (Tables 33 and 34), the relative incidence of cases and of deaths for the 0-2 age-group is obtained by adding together the percentages in the -1 and -2 age-groups. The 2-5 age-group percentages are already given in the tables. The two series of percentages are now shown under their headings in Table 41, and the third column expresses the ratio of the 2-5 percentage to the 0-2 percentage, each ratio for convenience being multiplied by 100. In other words, the proportion of cases and deaths in the 2-5 age-group are shown as a percentage of the proportion of cases and deaths in the 0-2 age-group.

Looking in the first place at the cases, it is seen that no marked change in ratio occurred in Scarlet Fever or in Measles. In Diphtheria, there has been a definite rise in the 2-5 group as compared with the 0-2 age-group. In Whooping Cough, the ratio shows a slight rise from 1926-30 onwards. We may say, therefore, that definitely in Diphtheria, and to a less extent in Whooping Cough, there has been a relative transfer of cases from the 0-2 to the 2-5 age-group.

With regard to deaths, again there is some evidence in Diphtheria of a transfer to the later age-group. On the other hand, after the first quinquennium, no change has occurred in the Whooping Cough ratios. Scarlet Fever and Measles, however, both show the opposite trend to that of Diphtheria, and the ratio of deaths in the higher to deaths in the lower age-groups is decreasing. These results are very much what we would expect to find from what we have already seen.

To calculate the fatality rates for the 0-2 age-group it has been necessary to go back to the original numerical data, add the actual deaths in the -1 and -2 age-groups and divide

Table 41.

Age-Shift in Morbidity, Mortality, and Fatality between the 0 - 2 and 2 - 5 Age-Groups.

Years	Percentage of Cases			Percentage of Deaths			Fatality Rates		
	0-2	2-5	100(2-5)/(0-2)	0-2	2-5	100(2-5)/(0-2)	0-2	2-5	100(2-5)/(0-2)
Scarlet Fever									
1916-20	3.8	20.2	532	19.6	35.2	180	12.2	4.2	34
1921-25	4.1	21.3	520	20.7	37.9	183	10.0	3.5	35
1926-30	3.7	21.2	573	25.5	33.2	130	8.3	1.9	23
1931-35	4.2	23.0	547	19.3	32.4	168	5.0	1.5	30
1936-40	5.0	26.9	538	25.0	31.3	125	3.0	0.7	23
1941-45	5.0	27.1	542	24.9	18.8	76	1.1	0.2	18
Diphtheria									
1916-20	10.4	27.5	264	31.5	36.4	116	30.5	13.1	43
1921-25	10.7	25.6	239	34.4	35.7	104	24.0	10.3	43
1926-30	8.6	23.8	277	35.0	34.1	97	21.6	7.5	35
1931-35	5.5	22.1	402	21.0	33.6	160	20.0	7.9	40
1936-40	4.3	23.2	540	10.7	42.3	395	11.3	8.3	73
1941-45	4.9	23.4	478	16.7	45.1	270	9.7	5.6	58
Measles									
1916-20	19.0	39.2	206	67.0	27.8	42	14.3	2.9	20
1921-25	20.9	38.2	183	73.5	23.3	32	19.4	3.4	18
1926-30	18.1	37.2	206	78.0	19.8	25	11.6	1.4	12
1931-35	17.6	35.5	202	75.7	20.1	27	10.4	1.4	13
1936-40	16.8	34.0	202	78.3	18.2	23	6.4	0.7	11
1941-45	14.0	29.6	211	75.5	20.4	27	2.6	0.3	12
Whooping Cough									
1916-20	19.8	34.6	175	69.1	25.8	37	29.4	6.3	21
1921-25	24.6	37.3	152	81.7	16.3	20	20.2	2.7	13
1926-30	24.1	36.4	151	79.6	18.0	23	14.2	2.1	15
1931-35	20.9	33.6	161	81.1	17.5	22	14.6	2.0	14
1936-40	18.9	32.7	173	80.7	16.4	20	11.7	1.4	12
1941-45	18.2	32.0	176	80.9	16.6	21	8.8	1.0	11

this sum by the sum of the total cases in the two age-groups, multiplying the quotients by 100. The fatality rates for the 2-5 age-group are already known (Table 36). We now express the 2-5 age-group fatality rate as a percentage of that of the 0-2 age-group. These fatality rates and their percentage ratios are also shown in Table 41.

The fatality rate in the higher age-group relative to that in the lower age-group has, as we would expect, fallen in Scarlet Fever, Measles, and Whooping Cough, but has, on the whole, risen in Diphtheria.

An exactly similar process has been carried out to compare the 5-15 age-group with the 0-5 age-group. The three sets of ratios, for cases, deaths, and fatality rates, are given in Table 42.

It will be remembered, that, as we saw in Table 37, the trend in the Scarlet Fever age-distribution of cases was exceptional in that it showed a transfer of cases from the higher to the lower age-groups, the other three diseases, showing a transfer in the opposite direction. This anomalous behaviour of Scarlet Fever is even more clearly brought out now, the 5-15 to 0-5 case-ratio showing a very definite progressive fall in Scarlet Fever, while each of the other diseases shows just as definite a rise. The Scarlet Fever deaths, however, do not, as we know, follow the cases, and no definite trend in the death-ratio is apparent. In Diphtheria, the ratio of deaths between

Table 42.

Age-Shift in Morbidity, Mortality, and Fatality between the 0 - 5 and 5 - 15 Age-Groups.

Years	Percentage of Cases			Percentage of Deaths			Fatality Rates		
	0-5	5-15	100(5-15)/(0-5)	0-5	5-15	100(5-15)/(0-5)	0-5	5-15	100(5-15)/(0-5)
Scarlet Fever									
1916-20	24.0	58.4	244	54.8	35.8	66	5.5	1.5	27
1921-25	25.4	60.4	238	58.6	31.6	54	4.6	1.0	22
1926-30	24.9	58.2	235	58.7	27.6	47	2.9	0.6	21
1931-35	27.2	27.1	210	51.7	31.7	61	2.1	0.6	29
1936-40	31.9	54.5	171	56.3	24.1	43	1.1	0.3	27
1941-45	32.1	58.9	183	43.7	37.5	86	0.3	0.1	33
Diphtheria									
1916-20	37.9	44.3	117	67.9	27.2	40	17.9	6.1	34
1921-25	36.3	45.0	124	70.1	27.3	39	14.3	4.5	31
1926-30	32.4	49.2	152	69.1	25.9	37	11.2	2.8	25
1931-35	27.6	55.8	202	54.6	38.9	71	10.4	3.7	36
1936-40	27.5	52.6	191	53.0	42.8	81	8.7	3.7	43
1941-45	28.3	48.2	170	61.8	32.0	52	6.3	1.9	30
Measles									
1916-20	58.2	39.2	67	94.8	4.8	5.1	6.6	0.5	8
1921-25	59.1	39.5	67	96.8	3.0	3.1	9.0	0.4	4
1926-30	55.3	43.6	79	97.8	1.9	2.0	4.8	0.1	2
1931-35	53.1	46.1	87	95.8	3.8	4.0	4.3	0.2	5
1936-40	50.8	48.0	95	96.5	2.6	2.7	1.3	0.07	5
1941-45	43.6	55.0	126	95.9	3.4	3.5	1.1	0.03	3
Whooping Cough									
1916-20	54.4	45.4	83	94.9	5.0	5.3	14.7	0.9	6
1921-25	61.9	37.7	61	98.0	1.9	1.9	9.7	0.3	3
1926-30	60.5	39.2	65	97.6	2.3	2.4	6.9	0.2	3
1931-35	54.5	45.3	83	98.6	1.3	1.3	6.8	0.1	1
1936-40	51.6	48.3	94	97.1	2.9	3.0	5.2	0.2	4
1941-45	50.2	49.7	99	97.5	2.5	2.6	3.8	0.1	3

the two age-groups rises, though not quite in line with the case-ratio. In Measles and Whooping Cough the death-ratios show no definite trend in either direction. The fatality rate in the higher age-group compared with that in the lower shows no very definite change in any of the diseases. Scarlet Fever and Diphtheria show a higher ratio in the first quinquennium than in the two following ones, and, in Measles and Whooping Cough, the ratio in the first quinquennium is considerably higher than in any other of the succeeding ones. The contrast in the behaviour of the fatality rates between the 0-2 and 2-5 age-groups is not repeated between the 0-5 and 5-15 age-groups.

Before passing on to the next section of this chapter, it may be as well briefly to recapitulate the findings that have so far been made, and to emphasise those that may be regarded as of significance.

i. Variations in the age-incidence of deaths do not necessarily reflect variations in the age-incidence of cases, since the former is a compound function both of the latter and of the age-fatality rate.

ii. In each disease, the relative number of cases in the first year of life is becoming less. In each disease except Diphtheria, the relative number of deaths in the first year of life is becoming greater.

iii. In Diphtheria, Measles and Whooping Cough, there is a relative transfer of cases from an earlier to a later age-period, especially from the 0-5 to the 5-15 age-groups. In Scarlet Fever this relative transfer is in the opposite direction.

iv. Due to unequal rates of reduction in fatality rate in the different age-groups, deaths do not show a comparable transfer between the lower and the higher age-groups, except in Diphtheria, where the fall in fatality rates has been equally shared by most age-groups.

v. Except in Diphtheria, the fall in fatality rates has occurred especially among pre-school and younger school children. Among infants, children aged 10-15 years, and adults the fall in fatality rates has been less. In Diphtheria, the fatality rate in the 10-15 age-group has shown the least tendency to fall.

It is almost impossible to draw definite conclusions about the changes in fatality rate in the higher age-groups in Measles and Whooping Cough, as the number of cases is small, and deaths are rare.

Section 2

The Effect of Altered Age-Constitution of the Population upon Age-Incidence.

In Chaper 1, reference was made to the falling birth-rate, and to its influence upon the age-constitution of the population. Table 26 showed the age-distribution of the population at the three census years, and two later years, from 1911 to 1945. Using the percentage age-distributions of Table 26, we may interpolate for intervening years and so arrive at approximate percentage age-distributions for the six quinquennia with which we are concerned. This has been done in Table 43, which shows also the relative trend of the proportion of the population in each age-group, the 1916-20 percentage for each age-group being expressed as 100.

The fall in the proportion within the -1 age-group from 2.4 to 1.8%, i.e. 100 to 75, is in step with the fall in the birth rate from 26 per thousand in 1916 to 19.3. per thousand in 1945, and is, therefore, probably an accurate representation of what has been happening within that age-group.

Due to the sparing in infant life in recent years, the reduction in the -2 age-group we might expect to be very slightly less than in the -1 age-group.

A reduction in the proportions within the -10 and -15 age-groups of approximately 10 in each 100 is probably fairly

Table 43.

Quinquennial Percentage Age-Distribution of the Population of Glasgow, Based on Census Estimates.

(With Relative Changes within the Age-Groups).

Years	-1	-2	-5	-10	-15	15-	All Ages
1916-20	2.4	2.4	5.4	9.9	9.8	70.1	100
	100	100	100	100	100	100	
1921-25	2.3	2.2	5.1	9.7	9.6	71.1	100
	96	92	94	98	98	101	
1926-30	2.0	1.9	5.3	9.6	9.0	72.2	100
	83	79	98	97	92	103	
1931-35	1.9	1.8	5.4	9.4	8.8	72.7	100
	79	75	100	95	90	104	
1936-40	1.9	1.8	5.4	9.2	9.0	72.7	100
	79	75	100	93	92	104	
1941-45	1.8	1.8	5.4	9.0	9.0	73.0	100
	75	75	100	91	92	104	

Table 44.

"Smoothed" Relative Changes within the Age-Groups.

1916-20	100	100	100	100	100	100
1921-25	95	96	97	98	98	101
1926-30	90	92	94	96	96	102
1931-35	85	88	91	94	94	103
1936-40	80	84	88	92	92	105
1941-45	75	80	85	90	90	106

accurate. The indicated trend in the -5 age-group is, however, surely quite inaccurate. It is unreasonable that the earlier and later age-groups should show a fall in their relative proportions, and that the -5 age-group proportion should remain unchanged.

In an effort to overcome this serious discrepancy, I have constructed two hypothetical tables, which are intended to show more accurately, or at least more reasonably, the behaviour of each of the age-group proportions. Table 44 expresses the proportion in each age-group in 1916-20 as 100; the proportions in the succeeding quinquennia are calculated on the basis that the -1 age-group has progressively dropped to 75, the -10 and the -15 age-groups have each dropped to 90, and the intermediate -2 and -5 age-groups have dropped to 80 and 85 respectively by the 1941-45 quinquennium. Thereafter, Table 45 was constructed, substituting for the 1931-35 proportionate figures in Table 44, the percentages given for 1931-35 in Table 26. These percentages, closely similar to those of the 1931 Census, are probably fairly accurate. The percentages for the other quinquennia were then calculated from the proportionate figures of Table 44. The whole procedure, perhaps complicated to describe, was simple and straightforward to carry out.

We have, then, in Tables 44 and 45, a purely hypothetical expression of the behaviour of the various age-groups of the population over the thirty years. No allowance

Table 45.

Quinquennial Percentage Age-Distribution of the Population Based on "Smoothed" Age-Group Changes.

Years	-1	-2	-5	-10	-15	15-	All Ages
1916-20	2.2	2.1	6.0	10.0	9.4	70.3	100
1921-25	2.1	2.0	5.8	9.8	9.2	71.1	100
1926-30	2.0	1.9	5.6	9.6	9.0	71.9	100
1931-35	1.9	1.8	5.4	9.4	8.8	72.7	100
1936-40	1.8	1.7	5.2	9.2	8.6	73.5	100
1941-45	1.7	1.6	5.0	9.0	8.4	74.3	100

Table 46.

Relative Changes in Population between the 0 - 2 and 2 - 5 Age-Groups and between the 0 - 5 and 5 - 15 Age-Groups.

Years	0-2	2-5	$\frac{2-5}{0-2}$	0-5	5-15	$\frac{5-15}{0-5}$
1916-20	4.3	6.0	1.40	10.3	19.4	1.88
1921-25	4.1	5.8	1.41	9.9	19.0	1.92
1926-30	3.9	5.6	1.44	9.5	18.6	1.96
1931-35	3.7	5.4	1.46	9.1	18.2	2.00
1936-40	3.5	5.2	1.48	8.7	17.8	2.05
1941-45	3.3	5.0	1.52	8.3	17.4	2.10

has, however, been made for short-term fluctuations in birth rate with corresponding short-term variations in age-distribution. In spite, however, of this "smoothing out" of short term variations, it is probable that the two hypothetical tables give a much truer picture of the relative changes within the age-groups than does Table 43, derived directly from the census estimates.

From these "smoothed" population distributions it was a simple matter to construct Table 46 showing, 1) the percentages of the population in the 0-2 and 2-5 age-groups at each quinquennium, and the ratios of the 2-5 to the 0-2 age-groups, and 11) the corresponding figures for the 5-15 and 0-5 age-groups.

Before we proceed to correct the age-distributions of morbidity and mortality, given in Section 1 of this chapter, for the variations in the age-distribution of the population, let us consider for a moment what we may expect to happen to the age-incidence of a disease when there occurs a change in the age-distribution of the population at risk. This can be readily done by adopting a very simple algebraic treatment of the problem.

Let us consider 2 populations. Let the first consist of C "children" and A "adults"; the total population therefore consists of C+A persons. Let the second population consist of C-d "children" and A+d "adults". Again the total population numbers C+A persons, but has a greater proportion of adults than the first.

Let us assume that the attack-rate of a disease is the same for the children of the two populations, and the same for the adults of the two populations, but that the attack-rate for children is greater than for adults.

Let 'x' per person be the attack-rate on children.

Let 'x/k' per person be the attack-rate on adults. Since x is greater than x/k, k is greater than 1.

i) The incidence of the disease upon the first population will be $Cx+Ax/k$; and upon the second population $(C-d)x+(A-d)x/k$, i.e $(Cx+Ax/k)-dx(1-1/k)$. Now $dx(1-1/k)$ must be positive since k is greater than 1; therefore the incidence in the second population is less than in the first.

ii) In the first population the ratio of incidence among children to incidence among adults is $\frac{Cx}{Ax/k}$ which is equal to Ck/A.

In the second population the ratio of incidence among children to incidence among adults is $\frac{(C-d)x}{(A+d)x/k}$ which is equal to $(C-d)k/(A+d)$.

Obviously the ratio in the first population is greater than the ratio in the second since the numerator of the first is greater than the numerator of the second, and the denominator of the first is smaller than the denominator of the second.

Therefore, in the second population compared with the first, relatively more cases have occurred among the adult portion of the population.

In dealing with the 'infectious diseases of childhood', which Chalmers, (1913), describes, as a "convenient phrase whereby to express the increasing immunity to these diseases which individuals acquire on passing through childhood to maturity", the problem is not quite so simple that we can postulate two such populations in which the "children" and the "adults" attack rates remain constant in spite of change in the age-constitution of the population. For one thing we have ignored the basic fact that immunity is more a function of experience than age, though the two may run together. However, in our imaginary second population the same proportion of children out af a smaller total number of children are being rendered immune by attack, and the increased adult population is due not to an influx of possibly susceptible adults but to the longer living of the already existing adult population. Hence the above simple algebraic exposition probably does indicate what should actually be happening in the "infectious diseases of childhood", namely, a reduction in total incidence and a transfer of cases to a later age.

We already have seen that the total incidence of cases in each of the four diseases has not very greatly declined. Perhaps factors other than altered age-constitution of the population are operating in such a way as to maintain or to increase the attack rates.

That there has been a transfer of cases to a later age in each of the diseases except Scarlet Fever has been demonstrated. Obviously the age-shift in Scarlet Fever cannot readily be explained by the age-shift in the population at risk, since the two age-shifts are in opposite directions. It may be, however, that the age-shift to a later age in each of the other diseases may be explainable purely on the basis of population change. How far this may be the case we shall now proceed to investigate.

The direct method would be to calculate an attack rate within each age-group on the basis of the ratio of the number of cases to the number of persons within each age-group. In so doing, it would be necessary to compensate for changes in total incidence from quinquennium to quinquennium, and also for changes in the total population. Obviously, the same result is achieved if we calculate the ratio of the percentage of total cases occurring in an age-group to the percentage of the total population within that age-group. In doing this we are keeping the total incidence and the total population constant at 100.

Alternatively, and we come now to the method which has actually been adopted, we may consider the two tables, Tables 37 and 44, in which the percentage of cases and the percentages of population within each age-group in the 1916-20 quinquennium have been raised to 100, and the subsequent percentage distributions raised in proportion to this figure. If we now take each entry in Table 37 (Age-distribution of cases) and divide it by each corresponding entry in Table 44, (Age-distribution of population), multiplying each quotient by 100 to bring the 1916-20 figures once more up to 100, we achieve, in Table 47, the same result as in table 37, except that the effect of population changes has now been taken into consideration. In other words, we are now showing the trend of the attack-rates within each age-group, when that attack-rate in 1916-20 is represented by 100, and the total population and total cases are held constant at all ages.

By an exactly similar process, Table 38 (the proportionate age-distribution of deaths)becomes Table 48, in which again we have made allowance for the altered age-constitution of the population.

Let us examine Table 47. In Scarlet Fever the relative transfer of cases from the -1, the -15, and the 15- age-groups to the -2, -5, and -10 age-groups is still occurring. In Diphtheria a fall occurs in the two earliest age-groups; the -5 age-group shows little change; and the later age-groups each show a rise. In Measles, the -1 incidence falls slightly from 1921-25 onwards; the next two age-groups show slight falls, but the later age-groups except the age-group for adults show definite increase. In Whooping Cough, it is

Table 47.

Quinquennial Age-Distribution of Cases. Relative Changes within Age-Groups, Allowance having been made for Population Changes in Age-Groups. 1916-20 = 100.

Years	-1	-2	-5	-10	-15	15-
Scarlet Fever						
1916-20	100	100	100	100	100	100
1921-25	117	111	109	105	106	80
1926-30	87	112	112	108	94	94
1931-35	79	141	125	107	97	86
1936-40	70	184	151	108	87	73
1941-45	75	194	158	120	96	49
Diphtheria						
1916-20	100	100	100	100	100	100
1921-25	132	99	96	99	117	104
1926-30	99	87	93	116	117	101
1931-35	67	58	88	128	153	90
1936-40	45	51	95	121	154	107
1941-45	67	58	100	111	150	125
Measles						
1916-20	100	100	100	100	100	100
1921-25	117	114	100	104	85	53
1926-30	111	101	101	118	70	41
1931-35	115	102	100	128	83	30
1936-40	113	105	99	134	121	44
1941-45	109	88	89	153	210	51
Whooping Cough						
1916-20	100	100	100	100	100	100
1921-25	136	125	111	86	61	198
1926-30	133	135	112	92	47	147
1931-35	119	125	107	107	69	97
1936-40	113	120	108	117	76	48
1941-45	117	120	108	123	94	47

necessary once more to ignore the first quinquennium if we are to get progressive trends. Having done so, we find there is a fall in the -1 age-group, the -2 and -5 age-group remain steady, the -10 and -15 age-groups show a rise, and the adult group is falling.

It seems probable that in estimating our "smoothed" population distributions, in which, as was stated, no regard was paid to short-term fluctuations in the population, we have allowed the -1 population, and probably the -2 population in the 1916-20 quinquennium to be too high. During 1917, 1918, 1919, the city birth rate was much lower than in the several years preceding and following.

If the actual -1 age-group population in the 1916-20 quinquennium had been 25% less than what we have assumed it to be, the effect would be that instead of 100 cases, for the 1916-20 quinquennium in Table 46, the figure shown would be 133, i.e. (100/75) x 100. But the birth rate for the 1916-20 period was not in actual fact low enough to have produced so large a reduction in the -1 population. A reduction of about 10% would be much closer to reality, and this would give a 1916-20 case rate represented by 111 instead of 100, i.e. (100/90) x 100. But the substitution of 111 for 100 for 1916-20 in the -1 age-group column would still not fit well into the general trend of the age-group.

Be that as it may it is evident that in spite of a reasonable correction having been made for the population change, the general position still remains that there is evidence in Scarlet Fever (except in the first year of life) of a relative age-shift from higher to lower ages. In the other three diseases, there is still a transfer of cases from the lower to the higher age-groups.

Let us now consider Table 48, where we see that correction for the altered age-constitution of the population has not altered the general picture of age-shift of deaths that was presented in Table 38.

Except in Diphtheria, the proportion of deaths in the -1 age-groups shows a greater increase since we have considerably reduced the proportion of the population within the age-group. In Diphtheria, there has been, as before, a relative transfer of deaths from all the lower age-groups to the higher ones. In Scarlet Fever the transfer of deaths is still from the -5 and -10 age-groups to both the lower and higher age-groups In Measles and Whooping Cough, we see a rise in the -1 age-group, a rather doubtful fall in the -2 age-group, no real changes in the next two groups, and a suggestion of a rise in the later groups. As we have previously mentioned, the paucity of deaths in the higher age-groups for both Measles and Whooping Cough renders the interpretation of changes in these age-groups difficult.

It will be remembered that, in Tables 41 and 42, changes in the ratio of cases and deaths between the 2-5; 0-2, and

Table 48.

Quinquennial Age-Distribution of Deaths. Relative Changes within Age-Groups, Allowance having been made for Population Changes in Age-Groups. 1916-20 = 100.

Years	-1	-2	-5	-10	-15	15-
Scarlet Fever						
1916-20	100	100	100	100	100	100
1921-25	116	108	111	80	167	103
1926-30	172	134	101	75	122	143
1931-35	152	103	101	80	205	172
1936-40	211	138	101	67	116	199
1941-45	193	153	62	88	331	189
Diphtheria						
1916-20	100	100	100	100	100	100
1921-25	109	117	101	98	153	52
1926-30	121	122	100	95	151	100
1931-35	82	74	101	133	394	129
1936-40	31	45	132	160	315	82
1941-45	84	60	146	116	328	120
Measles						
1916-20	100	100	100	100	100	100
1921-25	117	114	87	61	204	50
1926-30	142	120	77	38	208	74
1931-35	154	117	80	86	-	97
1936-40	174	124	75	60	-	214
1941-45	267	80	86	64	778	165
Whooping Cough						
1916-20	100	100	100	100	100	100
1921-25	128	120	65	38	102	99
1926-30	147	108	74	47	104	98
1931-35	162	111	75	29	-	97
1936-40	178	109	73	64	-	-
1941-45	200	106	75	52	222	-

the 5-15: 0-5 age-groups were demonstrated. It is necessary now to correct these tables for the changes in the population at risk in the different age-groups. To do this we shall utilise Table 46 in which were shown the changing ratios of the population within these age-groups. The method of correction that has been employed is as follows:- We divide the population ratio in the 1916-20 quinquennium by the population ratio in each succeeding quinquennium. This gives a "correcting factor", by which we multiply the case (or death) ratio in each quinquennium. An actual example will make the working clearer; let us calculate the corrected ratios for Scarlet Fever cases in the e.g. 1941-45 quinquennium for the 2-5 and 0-2 age-groups. The population ratio 2-5: 0-2 in 1916-20 was 1.40. We divide this by the corresponding ratio for the 1941-45, namely 1.52, and arrive at a correcting factor of 0.9211. We then multiply the ratio of Scarlet Fever cases in 1941-45 for the 2-5: 0-2 age-groups which, from Table 41, we see is 542, by the correcting factor, 0.9211, and obtain the corrected ratio 499.

Obviously, the same series of correcting factors is used for each disease, both for cases and for deaths. When however, we correct the 5-15: 0-5 ratios, we must use a different series of correcting factors derived from the 5-15: 0-5 population ratios.

Considering first the 2-5 series (Table 49) we see that, as we saw before in Table 41, the only convincing evidence

Table 49.

Age-Shift in Morbidity and Mortality between the 0 - 2 and 2 - 5 Age-Groups, Allowance having been made for Changes in Population in the Age-Groups.

Years	Population Ratio	Correcting Factor
1916-20	1.40	1.0000
1921-25	1.41	0.9929
1926-30	1.44	0.9722
1931-35	1.46	0.9589
1936-40	1.49	0.9396
1941-45	1.52	0.9211

	Cases		Deaths	
	Actual Ratio	Corrected Ratio	Actual Ratio	Corrected Ratio
Scarlet Fever				
1916-20	532	532	180	180
1921-25	520	516	183	182
1926-30	573	557	130	126
1931-35	547	525	168	161
1936-40	538	506	125	117
1941-45	542	499	76	70
Diphtheria				
1916-20	264	264	116	116
1921-25	239	237	104	103
1926-30	277	269	97	94
1931-35	402	385	160	153
1936-40	540	507	395	371
1941-45	478	440	270	249
Measles				
1916-20	206	206	42	42
1921-25	183	182	32	32
1926-30	206	200	25	24
1931-35	202	194	27	26
1936-40	202	190	23	22
1941-45	211	194	27	25
Whooping Cough				
1916-20	175	175	37	37
1921-25	152	151	20	20
1926-30	151	147	23	22
1931-35	161	154	22	21
1936-40	173	163	20	19
1941-45	176	162	21	19

of age-shift of cases occurs in Diphtheria, the age-shift being to the later age-group. Scarlet Fever deaths show a shift to the younger age-group, Diphtheria deaths to the later age-group. The changes in Measles and Whooping Cough deaths after 1916-20 remain indefinite. The correction for population change has not materially altered the trends demonstrated in Table 41.

Similarly, in the 5-15: 0-5 age-group series, (Table 50) correction for population change does not produce any material difference in age-shift from what has already been indicated by Table 42. Scarlet Fever cases show an increased age-shift to the earlier age-group, while the other diseases show a lessened age-shift to the later age-group. Only Diphtheria shows a definite age-shift of deaths, to the later age-group. In the other diseases, the ratios of deaths fluctuate, but do not reveal any progressive trend.

It seems apparent, therefore, that those progressive variations in age-incidence that have been demonstrated cannot be adequately explained by an altered age-distribution of the population at risk. Population changes of the extent which we may presume to have occurred are insufficient by themselves to account for the age-shift of cases from the 0-5 to the 5-15 age-group in Diphtheria, Measles and Whooping Cough. In Scarlet Fever, the age-shift of cases has been in a direction contrary to the age-shift of the population.

Table 50.

Age-Shift in Morbidity and Mortality between the 0 - 5 and 5 - 15 Age-Groups, Allowance having been made for Changes in Population in the Age-Groups.

Years	Population Ratio	Correcting Factor
1916-20	1.88	1.0000
1921-25	1.92	0.9792
1926-30	1.96	0.9592
1931-35	2.00	0.9400
1936-40	2.05	0.9171
1941-45	2.10	0.8953.

	Cases		Deaths	
	Actual Ratio	Corrected Ratio	Actual Ratio	Corrected Ratio
Scarlet Fever				
1916-20	244	244	66	66
1921-25	238	233	54	53
1926-30	235	225	47	45
1931-35	210	197	61	57
1936-40	171	157	43	39
1941-45	183	164	86	77
Diphtheria				
1916-20	117	117	40	40
1921-25	124	121	39	38
1926-30	152	146	37	35
1931-35	202	190	71	67
1936-40	191	175	81	74
1941-45	170	152	52	47
Measles				
1916-20	67	67	5.1	5.1
1921-25	67	66	3.1	3.0
1926-30	79	76	2.0	1.9
1931-35	87	82	4.0	3.8
1936-40	95	87	2.7	2.5
1941-45	126	113	3.5	3.1
Whooping Cough				
1916-20	83	83	5.3	5.3
1921-25	61	60	1.9	1.9
1926-30	65	62	2.4	2.3
1931-35	83	78	1.3	1.2
1936-40	94	86	3.0	2.8
1941-45	99	89	2.6	2.3

Only in Diphtheria, where the fatality rate has fairly evenly declined in each age-group does the age-shift of deaths closely follow that of cases, but this age-shift is greater than can be explained by the population age-shift. In the other diseases, such smaller age-shifts of deaths as have occurred are maintained even when the influence of age-redistribution of the population has been taken into account.

Section 3

The Effect of the Diphtheria Immunisation Campaign upon Age-Incidence.

In Chapter 1, a brief reference was made to the effect of the Diphtheria Immunisation Campaign upon the general morbidity, mortality and fatality rates. We shall now look more particularly at the age-distribution of Diphtheria cases during the years 1941 to 1945.

During these war years, the position is seriously confused by doubts, not only about the size of the total population of the city, but also about the size of the child population. At July 1941, some 27,000 (35%) pre-school children and 50,000 (29%) school children were stated by the Medical Officer of Health to have been evacuated from the City. As very little information was published during the war years on population statistics, it is problematical how rapidly these children returned to the City.

The effect of evacuation upon age-incidence should have been shared by all four diseases, though not necessarily equally; the age-incidence of Measles and Whooping Cough differs from that of Diphtheria, and the age-incidence of Scarlet Fever may possibly behave in a different fashion. Let us, however, examine the age-distribution of cases of each of the diseases during the individual years just before, and during the war, (see Table 31).

In Scarlet Fever the age-distribution of cases in 1941 was closely similar to that of 1938. During the next two years, 1942 and 1943, there was a relative reduction in the pre-school and adult incidence with a corresponding rise in the school-age incidence.

1941, being a non-epidemic year for Measles, with the age-distribution possibly influenced by the low prevalence of that year (we shall refer to this effect in the next section) we shall omit it from the present discussion. There is certainly no marked change in the age-distribution of Measles between 1938 and 1940. In 1942, however, there is some transfer of cases from the -2 and -5 age-groups to the higher age-groups especially to the -10 age-group. In 1943, this age-shift is more marked.

In Whooping Cough, the 1941 age-distribution of cases is very similar to that of 1938, and while there is a slight transfer of cases from the pre-school to the school ages in subsequent years, this transfer does not seem to have taken any sudden jumps.

It seems, therefore, that the evacuation of children has produced only very slight changes in the age-distribution of Scarlet Fever, Measles, and Whooping Cough. Now let us look at the Diphtheria age-distribution over these years, to see whether the changes in age-distribution are greater than we might expect in comparison with the other three diseases. It will be remembered that approximately one-quarter of the pre-school and one half of the school popullation had been immunised during 1941. Between the 1940 and 1941 there is a very striking increase in the 15- proportion of cases, which rises from 20.2% to 25.6%. This higher relative incidence in the 15- age-group was maintained during 1942, declined in 1943, and 1944, and by 1945 had returned approximately to its pre-war level. In none of the other age-groups does any marked change in relative incidence occur; and such changes as do occur are no greater than those seen from year to year at any other period.

Within all the childhood age-groups, therefore, we may say that immunisation has had no obvious effect upon age-distribution. No comparable transfer of incidence to the 15- age-group is seen in the other diseases, and it is possible that this transfer in Diphtheria has been due to the Immunisation Campaign. It is however, impossible to be certain about this, since an age-shift to the 15- age-group might perhaps have been brought about by a war-time influx of young adults into the city to whom the prevailing strain of C.diphtheriae might be unfamilar and for whom therefore it might show an enhanced infectivity.

Section 4

Variations in Age-Incidence associated with Changes in Total Prevalence.

Turner, (1923) pointed out that both in London and Manchester, during years of high Scarlet Fever prevalence the children of school ages were affected in relatively greater numbers than were younger children. Similarly, Cheeseman, Martin, and Russell, (1939) and Martin (1942), investigating the age-incidence of Diphtheria in London, report a relative transfer of incidence from pre-school to school children during years of high Diphtheria prevalence.

Of the several tentative explanations that have been put forward to explain this occurrence in Diphtheria, one is that a change in the predominant type of the infecting organism finds the younger age-groups in their usual state of susceptibility; the older age-groups, who are expected, under normal circumstances, to be less susceptible by reason of past experience, do not enjoy this advantage when the new type of organism is one of which they have had no past experience. Hence, relatively more attacks occur in the later age-group, producing not only a period of increased prevalence but also a temporary relative age-shift to the later age-group.

Another explanation, which does not postulate any change in the type of infecting organism, is that during a period of increased prevalence (which might be due to various causes) when susceptibles within the normally most susceptible age-groups are exhausted, the organism, still infective, finds a number of persons susceptible within age-groups that are normally relatively insusceptible. Martin regards as improbable this latter explanation.

Whatever the explanation of this temporary age-shift, we can at any rate with our annual data of total prevalence and age-distributions, (Tables 1 and 31) examine the Glasgow experience over the 30 years to ascertain whether any of the diseases demonstrate the phenomenon. We shall look at peak years to see whether there is evidence of a temporary age-shift in such years compared with neighbouring years.

Taking Scarlet Fever first, and comparing the age-distribution of cases in the peak year 1926, with the previous and following year, there is certainly no convincing evidence of age-shift. Similarly the next peak year, 1932, fails to show any serious disturbances from the prevailing age-distribution.

In Diphtheria, a moderate peak occurred in 1927; in this year the percentage of cases in the 15- age-group was 21.8%, the highest percentage in that age-group from 1916 up to 1937. But in the next peak year, 1940, no similar rise in the 15- age-group occurred, and the age-distribution of cases in that year was much the same as in previous years. In the next two years, 1941 and 1942, however, there was a rise in the 15- age - group incidence, though this , as we suggested in the last section, may have been due to the Immunisation Campaign or to a war-time change in the age-constitution of the population. On the whole there is no real evidence to suggest that in Glasgow years of exceptionally high Diphtheria prevalence are associated with a change in the age-distribution of cases.

Measles, presents an interesting feature, namely a marked change in age-distribution associated with the violent inter-annual fluctuations in total prevalence. During the years of very low prevalence, i.e.1933, 1935, 1937, and 1939, there has occurred a very sharp transfer of cases from ages under 5 to ages over 5, more especially to the -10 and -15 age-groups, though the 15- age-group has also received a share of the transferred cases. The -1 age-group does not seem to take much part in the transfer, and on the whole, its percentage of cases remains fairly normal. In 1941, a year in which prevalence was very low, the temporary age-shift did not occur.

While it is not possible to offer a full explanation for this age-shift in Measles in non-epidemic years, it may perhaps be due to the exhaustion of the normally susceptible population during the preceding period of high epidemicity. It will of course be observed that in Measles in Glasgow we are seeing the opposite of what we were looking for in Scarlet Fever and Diphtheria. In Measles, the age-shift to higher ages occurs in association with low instead of high prevalence.

Since Whooping Cough similarly presents annual fluctuations in prevalence it might be expected that an age-shift similar to that of Measles would occur in non-epidemic years. The only years, however, during the whole series, in which prevalence was exceptionally low were 1940 and 1942, in both of which evacuation may have influenced the age-distribution. In 1940, for whatever reason, there is a relative age-shift from the -1, -2 and -5 age-groups to the -10 age-group.

It is possible that, using fuller data, such as the weekly case-rates and single years of age for age-distributions, (in the manner of Cheeseman, Martin, and Russell for Diphtheria in London), some evidence of age-shift in Scarlet Fever and Diphtheria to higher ages during periods of increased prevalence might have been found. But with the present data, no such age-shift can be demonstrated.

Section 5

The Influence of Age-Shift upon Fatality Rates.

That there has taken place a substantial decline in the general fatality rate in each of the diseases was demonstrated in Chapter 1. It was also shown that the fatality rates, at least during the years of childhood, are inversely proportional to the age of attack. It has been further shown, in this chapter, that the age of attack in each disease has been changing, in Scarlet Fever to an earlier age, and in the other diseases to a later age. In each disease there has been some reduction in cases in the first year of life, in which year the fatality rate is notably high.

In this section it is proposed to investigate how far these age-shifts have been effective in reducing the general fatality rate of each disease.

During the 1916-20 quinquennium there were 330 deaths from Scarlet Fever out of 13,697 cases. The fatality rate, therefore, was 330 x 100/13,697, i.e. 2.4%. This fatality rate is, however, the weighted average of the fatality rates of each age-group. If we express the general fatality rate for "all ages" as "F.R.", the fatality rate within the -1 age-group as "f_{-1}", within the -2 age-group as "f_{-2}", and so on, and express the total number of cases as "N", composed of $n_{-1} + n_{-2} + \ldots\ldots + n_{15-}$ cases, we may express the general fatality rate thus:-

$$F.R. = \frac{(f_{-1} \cdot n_{-1}) + (f_{-2} \cdot n_{-2}) + \ldots\ldots + (f_{15-} \cdot n_{15-})}{N}$$

It is, of course, unnecessary, in forming the weighted average, to employ the actual numbers of cases in each age-group. The same result will be achieved by employing the percentage age-distribution of total cases. Thus "N" = 100.

In 1916-20, the age-distribution of cases and of fatality rates for Scarlet Fever were as shown in Table 51. Adding each entry in the lowest row, we find that the sum is 241.40. Now since S(n x f) = 241.40, and N = 100,

F.R. = 2.4%.

Thus the two methods of calculating the fatality rate for Scarlet Fever in 1916-20 give the same result.

In the "direct method" for calculating Standardised Death Rates in Vital Statistics it was for many years the custom to use, as a standard population, a "standard million" based on the population of England and Wales in 1901. The local crude death rates were standardised by weighting the local death rates for separate age- and sex-groups by the number of persons within each corresponding group in the "standard million".

By an exactly similar process we may standardise the general fatality rate of a disease by weighting the fatality rate within each age-sex-group by the number of cases within each such group in a standard "population" of cases. For our present purpose we shall employ as the standard "population"

Table 51.

The Fatality Rate (All Ages) in Scarlet Fever, 1916-20,
Calculated from the Fatality Rates in Age-Groups.

Age-Group	-1	-2	-5	-10	-15	15-
% Cases (n)	0.9	2.9	20.2	40.0	18.4	17.6
Fatality Rate (f)	10.9	12.7	4.2	1.9	0.6	1.3
Product (n x f)	9.81	36.83	84.84	76.00	11.04	22.88

S (n x f) = 241.40

N = 100

Therefore Fatality Rate (All Ages) = 2.4

Table 52.

Calculation of the Standardised Fatality Rate.

The Fatality Rate in Scarlet Fever, 1921-25, Standardised
on the 1916-20 Age-Distribution of Cases.

Age-Groups	-1	-2	-5	-10	-15	15-
1916-20 % Cases (n)	0.9	2.9	20.2	40.0	18.4	17.6
1921-25 Fatality Rate (f)	9.0	10.4	3.5	1.2	0.7	1.4
Product (n x f)	8.10	30.16	70.70	48.00	12.88	24.64

S (n x f) = 194.48

N = 100

Therefore Standardised Fatality Rate = 1.9

of cases, the 1916-20 case incidence, or rather the percentage age-distribution of 100 cases in the 1916-20 period, no regard being paid to differences in sex.

In practice all we have to do is to repeat Table 51, substituting the age-fatality rates of successive quinquennia, but maintaining the 1916-20 case-distribution, and to recalculate each (n x f) product. In this way we obtain, for each quinquennium, a standardised fatality rate, which tells us what the fatality rate in that quinquennium would have been if the 1916-20 age-distribution of cases had been maintained. In Table 52, we carry out this process for Scarlet Fever in 1921-25.

Hence we find that S(n x f)/N = 194.48 / 100.

Therefore the standardised fatality rate is 1.9%. This we may compare with the actual fatality rate in that quinquennium, i.e. 2.0% (from Table 36).

Repeating the process for each quinquennium and for each disease, we arrive at a series of standardised fatality rates, all based on the 1916-20 age-distribution of cases for each disease.

These results are shown in Table 53, in which the actual and the standardised fatality rates are given side by side. It must be remembered, that the standardised fatality rate is merely a hypothetical expression of what the actual fatality rate would have been in any quinquennium if in that quinquennium the age-distribution of cases had been as in 1916-20.

Table 53.

Actual Fatality Rates (Quinquennial) and Fatality Rates Standardised on the 1916-20 Age-Distribution of Cases.

Years	Scarlet Fever Actual	Scarlet Fever Standardised	Diphtheria Actual	Diphtheria Standardised
1916-20	2.4	2.4	10.0	10.0
1921-25	2.0	1.9	7.4	7.5
1926-30	1.2	1.2	5.3	5.8
1931-35	1.1	1.0	5.2	6.2
1936-40	0.6	0.6	4.5	5.3
1941.45	0.2	0.2	2.9	3.6

Years	Measles Actual	Measles Standardised	Whooping Cough Actual	Whooping Cough Standardised
1916-20	4.1	4.1	8.4	8.4
1921-25	5.5	5.2	6.1	5.1
1926-30	2.7	2.8	4.3	3.7
1931-35	2.4	2.6	3.8	3.7
1936-40	1.4	1.5	2.7	2.9
1941-45	0.5	0.6	2.0	2.2

The striking feature about the table is the close similarity between the two series of fatality rates. In Scarlet Fever the two sets of values are practically identical. In Measles, the actual fatality rates are only very slightly lower than the standardised rates, and in Whooping Cough, too, there is little difference. In Diphtheria the differences are rather greater but here again it is obvious that the altered age-distributions have not played a major part in bringing about the fall in fatality rate.

We seem justified in concluding, therefore, that variations in the age of attack in each of the diseases during these thirty years have had almost negligible effect upon the trend of reduction in fatality rates.

When we seek to explain the marked reduction in fatality rates that has taken place during these years, we must look for causes other than variation in the age of attack.

CHAPTER 3

The Association between Social Environment and Morbidity, Mortality, and Fatality.

Section 1.

Morbidity, Mortality and Fatality Rates Correlated with Overcrowding and Birth Rates.

In Chapter 1, reference was made to the influence of social factors upon the incidence of cases and deaths. In this chapter we shall investigate further this aspect of infecticus disease. We shall not, for the present, concern ourselves further with age-distributions, but shall consider only the total morbidity, mortality and fatality rates of each of the four diseases within the different social environments that are found in the city. Our criterion of social conditions will be the degree of overcrowding existing in the various wards of the city at the 1931 Census.

In the first place, we shall investigate the extent of general correlation existing between case, death and fatality-rates and overcrowding over the middle portion of the thirty years 1916-1945. Since the experience of single wards cannot be presumed to be constant over short periods of only one or two years, we shall consider the aggregate of cases and deaths over a fifteen year period, centred, for greater accuracy of population and overcrowding data, upon the Census year, 1931. The fifteen year period therefore is from 1924 to 1938 inclusive.

To correlate the ward disease-experience with ward overcrowding we shall calculate coefficients of correlation, employing the product-moment method, the basis of calculation being the formula:-

$$r_{xy} = \frac{S\,(xy)}{n\,\sigma_x\,\sigma_y}$$

where r_{xy} is the coefficent of correlation between x and y, n is the number of variables (namely 37, the number of wards in 1931), x is the morbidity, mortality, or fatality rate within each ward measured from the mean of all the wards, y is the degree of overcrowding in each ward, measured from the mean of all wards, and σ_x and σ_y are the standard deviations of x and y.

Before we can calculate these coefficents of correlation, a considerable amount of preliminary work must be done.

The standard of overcrowding in each ward will be taken as the percentage of the population in the ward living more than 2 persons per room at the 1931 Census.

The total population of each ward will be taken as that of the 1931 Census. Scrutiny of the ward population estimates for each of the 15 years with which we are concerned shows that very little error will be introduced by taking the Census ward population as a measure of the average ward population over the 15 years. In some wards the population remained practically constant throughout the period, and in those others in which an increase or a decrease took place the 1931 figures usually occupy a central position.

A minor snag arose due to the introduction of a 38th Ward in 1933. This difficulty has been overcome by amalgamating the data for the new ward with that of Ward 25, from which the new ward had been split off. Accordingly we have treated Wards 25 and 38 as one ward.

The estimation of the child population in each ward for 1931 presented certain difficulties. Nevertheless, a reasonably accurate assessment of the number of children in each ward was necessary in order to calculate incidence rates based on that part of the population that was chiefly at risk. The published Census data do not include age-distributions for the population of individual wards. This information was formerly contained in special census reports by the Medical Officer of Health, but the last of these reports was published in 1911; this naturally is quite useless for the present purpose. The information is not available in the official records of the Public Health Department; some unoffical estimates that were examined proved to be too inaccurate for any use to be made of the.

Clearly if these ward child populations for 1931 were to be obtained, some indirect form of estimation would have to be devised.

A well established method of estimating child populations based on the numbers of births and deaths, is, very briefly, to go back a selected number of years, subtract from the annual births the number of deaths occurring in the -1 year age-group, carry the difference forward, and subtract the deaths at later ages in each succeeding year, always introducing the fresh annual births. This procedure, tedious even for the estimation of one population, would be a task of great magnitude when 37 populations are required. It is, moreover, impractical in the present instance due to the absence of available data concerning deaths in individual wards at ages after the first year of life.

Retaining the general principle of the method, I have simplified it very considerably, such loss in accuracy that has occurred being more than compensated for by the resulting straight-forwardness of calculation.

My procedure has been to sum the annual births for each individual ward for the 5 years 1927-31. From this sum I have subtracted one and a half times the sum of the infant deaths, (i.e. deaths under the age of 1 year). The net result is the estimated total child population under the age of 5 years for each ward for the year 1931. The subtraction of one and a half times the sum of the infant deaths requires a word of explanation. Obviously at least the actual number of infant deaths must be subtracted. Now child deaths at ages 2, 3, and 4 are very much fewer in number and the total of deaths at these ages is rather less than 50% of the deaths in the first year of life. For ease of calculation I have assumed it to be actually 50%.

The method makes allowance for a smaller mortality in good wards than in bad at each age of childhood by assuming that in each year of life after the first, the child deaths in the different wards are proportional to the infant mortality of the different wards.

Although by the method employed, a wider age-range of child population could have been estimated, the estimation has been restricted to that of the "under 5 years" population. For later ages the influence of migration and of other factors might be expected seriously to interfere with the validity of the estimations.

As an example of how the calculations of the "under 5 years" population were carried out, Table 54 illustrates the calculation for Ward 1 in 1931. From this we estimate the "under 5" child population of the ward to be 3,633.

The same process is repeated for each of the other wards. In Section 2 of this chapter the same method will be employed to estimate child population in the wards for the years 1925 and 1941.

While a very high degree of accuracy cannot be claimed for the results of what is admittedly an over-simplified procedure the gross error is not great. The 1931 Census estimate of the total "under 5" population for the whole city was 98,977. Summing the calculated estimates of the 37 individual wards the total is 97,768. The gross error is therefore only in the region of 1%. It is probable therefore that the method gives a reasonably accurate basis for

Table 54.

Calculation of the "Under 5 years" Child Population in Ward 1 for the year 1931.

Years	Number of Births	Number of Infant Deaths
1927	759	96
1928	869	86
1929	829	89
1930	859	75
1931	967	87
Total	4283	433

Total Births	4283
Less Total Infant Deaths	433
	3850
Less 50% of Total Infant Deaths	217
	3633

Therefore "Under 5 years" Child Population = 3633.

comparison of the child populations for the individual wards. In the complete absence of more reliable data it will have to serve. Moreover, as the ratio of "children under 5" to "children under 10" or "children under 15" does not presumably differ greatly in the different wards, the "under 5" population estimates give a comparative index of ward child populations within any of the childhood age-groups.

The total and "under 5 " populations for each ward will be found in Table 55.

An annual record is maintained in the Public Health Department of the number of cases and of deaths from each of the infectious diseases, in each of the wards of the city. This data was abstracted for the four diseases we are investigating, for each of the fifteen years, 1924-38, and the 15-year aggregates were obtained (see Table 56).

The ward aggregates were thereupon reduced to four average annual rates, viz.

a) Case rates, i. per thousand of total ward population (all ages).
ii. per thousand of ward child population under the age of 5 years.
b) Death rates i. per 100,000 of the total ward population (all ages).
ii. per 10,000 of ward child population under the age of 5 years.

Average fatality rates for each disease in each ward were obtained by expressing the 15-year aggregate of deaths as a percentage of the 15-year aggregate of cases.

Table 55.

Miscellaneous Ward Data, 1931.

Ward No.	Total Population	-5 Child Population	% Child Population	Birth Rate	% 2+ Overcrowding	Room Density
1	39869	3633	9.1	23	47	1.8
2	39418	4038	10.2	24	56	2.1
3	35824	4499	12.6	28	69	2.5
4	34389	3725	10.8	27	58	2.0
5	21430	2807	13.1	30	67	2.4
6	22439	2291	10.2	24	52	2.0
7	25560	1618	6.3	17	24	1.3
8	41788	4135	9.9	26	46	1.8
9	22512	2002	8.9	22	48	1.9
10	25547	2028	7.9	22	45	1.8
11	27376	2367	8.6	23	44	1.8
12	16523	1593	9.6	26	50	1.9
13	13705	978	7.1	19	37	1.4
14	26909	2678	10.0	25	52	1.9
15	20232	1739	8.6	21	37	1.4
16	20727	952	4.6	9	11	0.9
17	35723	4263	11.9	29	59	2.1
18	33072	3504	10.6	25	49	1.8
19	41243	3414	8.3	23	45	1.9
20	21029	1777	8.5	20	35	1.4
21	25524	2397	9.4	23	46	1.8
22	23348	818	3.5	7	2	0.7
23	28541	2297	8.0	19	39	1.4
24	23730	2174	9.2	20	37	1.4
25	56430	4071	7.2	18	23	1.2
26	38851	4483	11.5	28	64	2.3
27	46831	5039	10.8	26	53	1.9
28	30336	3422	11.3	27	53	1.9
29	35763	3756	10.5	25	51	1.8
30	35969	3909	10.9	26	59	2.0
31	32188	2773	8.6	20	44	1.8
32	28842	1472	5.1	10	7	0.8
33	19007	931	4.9	10	8	1.0
34	21171	1511	7.1	16	34	1.3
35	32514	2570	7.9	17	32	1.6
36	17980	862	4.8	9	7	1.0
37	26121	1242	4.8	12	9	0.9
Total	1088461	97768				

Table 56.

Aggregates of Cases and Deaths in Wards for the Fifteen-Year Period, 1924-38.

Ward	Scarlet Fever		Diphtheria		Measles		Whooping Cough	
	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
1	3021	30	1285	67	5823	131	3778	173
2	2877	36	1304	64	6064	144	4204	183
3	2518	48	1183	83	6424	223	4653	268
4	1823	17	1161	68	5624	216	3564	230
5	1567	26	817	59	4515	135	3187	196
6	1444	18	956	46	3308	93	2255	150
7	1637	22	757	30	2800	26	1951	52
8	2750	36	1345	53	5791	142	4421	207
9	1650	22	694	41	2823	37	2006	75
10	1522	19	681	41	3717	45	2297	65
11	1748	12	929	46	2615	104	2009	100
12	989	12	525	35	2352	70	1567	97
13	649	10	361	15	1503	42	1138	65
14	1782	24	943	58	5372	147	3907	144
15	1357	8	594	42	2328	88	1815	94
16	894	12	369	18	1275	19	853	16
17	2242	34	1083	67	6339	220	4533	226
18	2079	30	950	50	4858	127	3655	172
19	3381	37	1476	65	6792	110	4225	115
20	1477	14	541	34	2407	38	1626	63
21	2027	21	875	30	4052	51	2461	73
22	1034	9	356	13	1081	4	531	5
23	1573	21	901	43	3740	99	2781	112
24	1872	21	890	50	3070	57	2082	66
25	4036	46	1708	76	7171	61	4307	71
26	2875	32	1062	79	6835	248	4723	233
27	2903	35	1381	97	7686	353	5854	287
28	1741	24	1058	67	4413	189	3177	193
29	2536	30	1362	64	5253	158	3900	185
30	2435	29	1338	81	6108	222	4608	206
31	2403	22	1162	65	4558	66	2962	94
32	1935	18	589	21	2781	20	1711	27
33	1069	6	300	11	1686	5	1003	15
34	1569	10	670	28	2718	33	1740	40
35	2602	20	766	47	3787	38	2408	56
36	1096	6	278	13	1870	5	1074	5
37	1729	15	456	22	2583	9	1706	16

Table 57.

Annual Average Ward Case, Death, and Fatality Rates, 1924-38.
(Case Rates per 1,000 Total Population and per 1,000 Child Population. Death Rates per 100,000 Total Population and per 10,000 Child Population. Fatality Rates= All Ages).

Scarlet Fever.

Ward	Case Rates (Total Pop.)	Case Rates (Child Pop.)	Death Rates (Total Pop.)	Death Rates (Child Pop.)	Fatality Rates
1	5.1	56	5.0	5.4	1.0
2	4.9	48	6.1	6.0	1.3
3	4.7	37	8.9	7.1	1.9
4	3.5	32	3.3	3.1	0.9
5	4.9	37	8.1	6.0	1.7
6	4.3	42	5.3	5.2	1.2
7	4.3	68	5.7	9.0	1.3
8	4.4	44	5.7	6.0	1.3
9	4.9	55	6.5	7.3	1.3
10	4.0	51	5.0	6.3	1.2
11	4.3	50	2.9	3.4	0.7
12	4.0	42	4.8	5.0	1.2
13	3.2	45	4.9	6.9	1.5
14	4.4	44	5.9	5.9	1.3
15	4.5	52	2.6	3.0	0.6
16	2.9	63	3.9	8.5	1.3
17	4.2	35	6.3	5.3	1.5
18	4.2	40	6.0	5.7	1.4
19	5.5	66	6.0	7.2	1.1
20	4.7	55	4.4	5.2	1.0
21	5.3	56	5.5	5.9	1.0
22	3.0	86	2.6	7.4	0.9
23	3.7	46	4.9	6.1	1.3
24	5.3	58	5.9	6.4	1.1
25	4.8	67	5.4	7.5	1.1
26	4.9	43	5.5	4.8	1.1
27	4.1	38	5.0	4.6	1.2
28	3.8	34	5.3	4.7	1.4
29	4.7	45	5.6	5.3	1.2
30	4.5	41	5.4	5.0	1.2
31	5.0	58	4.6	5.3	0.9
32	4.5	88	4.2	8.2	0.9
33	3.7	76	2.1	4.3	0.6
34	4.9	69	3.1	4.4	0.6
35	5.3	67	4.1	5.2	0.8
36	4.1	85	2.2	4.6	0.5
37	4.4	92	3.8	7.9	0.9

Table 57 (continued).

Diphtheria

Ward	Case Rates (Total Pop.)	Case Rates (Child Pop.)	Death Rates (Total Pop.)	Death Rates (Child Pop.)	Fatality Rates
1	2.1	23	11	12	5.2
2	2.2	22	11	11	4.9
3	2.2	17	15	12	7.0
4	2.3	21	13	12	5.9
5	2.5	19	18	14	7.2
6	2.8	27	14	14	4.8
7	2.0	32	8	13	4.0
8	2.1	21	9	9	3.9
9	2.1	24	12	13	5.9
10	1.8	23	11	14	6.0
11	2.3	27	11	13	5.0
12	2.1	22	14	15	6.7
13	1.8	25	7	9	4.2
14	2.3	23	14	14	6.2
15	2.0	23	14	16	7.1
16	1.2	26	6	13	4.9
17	2.0	17	13	11	6.2
18	1.9	18	10	9	5.3
19	2.4	29	11	13	4.4
20	1.7	20	11	13	6.3
21	2.3	24	8	9	3.4
22	1.0	29	4	11	3.7
23	2.1	26	10	13	4.8
24	2.5	27	14	15	5.6
25	2.0	28	9	13	4.4
26	1.8	16	14	12	7.4
27	2.0	19	14	13	7.0
28	2.3	20	15	13	6.3
29	2.5	24	12	11	4.7
30	2.5	23	15	14	6.1
31	2.4	28	14	16	5.6
32	1.4	27	5	10	3.6
33	1.1	22	4	8	3.7
34	2.1	30	9	13	4.2
35	1.6	20	10	13	6.1
36	1.0	21	5	10	4.7
37	1.2	25	6	12	4.8

Table 57 (continued).

Measles

Ward	Case Rates (Total Pop.)	Case Rates (Child Pop.)	Death Rates (Total Pop.)	Death Rates (Child Pop.)	Fatality Rates
1	9.7	107	22	24	2.2
2	10.3	101	24	24	2.4
3	12.0	95	42	33	3.5
4	10.9	101	42	39	3.8
5	14.0	107	42	32	3.0
6	9.8	96	28	27	2.8
7	7.3	116	7	11	0.9
8	9.2	93	23	23	2.5
9	8.4	94	11	12	1.3
10	9.7	123	12	15	1.2
11	6.4	74	25	29	4.0
12	9.5	99	28	29	3.0
13	7.3	103	20	28	2.8
14	13.3	133	36	36	2.7
15	7.7	90	29	34	3.8
16	4.1	89	6	13	1.5
17	11.8	99	41	34	3.5
18	9.8	92	26	25	2.6
19	11.0	113	18	22	1.6
20	7.6	89	12	14	1.6
21	10.6	113	13	14	1.3
22	3.1	89	1	3	0.4
23	8.7	109	23	29	2.7
24	8.6	93	16	17	1.9
25	8.5	118	7	10	0.9
26	11.7	102	43	37	3.6
27	10.9	101	50	46	4.6
28	9.7	86	42	37	4.3
29	9.8	93	30	29	3.0
30	11.3	104	41	38	3.6
31	9.4	109	14	16	1.4
32	6.4	125	5	10	0.7
33	5.9	120	2	4	0.3
34	8.6	121	10	14	1.2
35	7.8	99	8	10	1.0
36	6.9	144	2	4	0.3
37	6.6	137	2	4	0.3

Table 57 (continued).

Whooping Cough

Ward	Case Rates (Total Pop.)	Case Rates (Child Pop.)	Death Rates (Total Pop.)	Death Rates (Child Pop.)	Fatality Rates
1	6.3	69	29	32	4.6
2	7.1	70	31	30	4.3
3	8.7	69	50	40	5.8
4	6.9	64	45	42	6.5
5	9.9	76	61	47	6.2
6	6.7	66	45	44	6.7
7	5.1	81	14	22	2.7
8	7.1	72	33	33	4.7
9	5.9	66	22	25	3.7
10	6.0	76	17	22	2.8
11	4.9	57	24	28	5.0
12	6.3	66	39	41	6.2
13	5.5	77	32	45	5.7
14	9.7	97	36	36	3.7
15	6.0	70	31	36	5.2
16	2.7	59	5	11	1.9
17	8.5	71	42	35	5.0
18	7.4	70	35	33	4.7
19	6.8	82	19	23	2.7
20	5.2	61	20	24	3.9
21	6.4	68	19	20	3.0
22	1.5	43	1	3	0.9
23	6.5	81	26	33	4.0
24	5.8	63	19	21	3.2
25	5.1	71	8	11	1.6
26	8.1	70	40	35	4.9
27	8.3	77	41	38	4.9
28	7.0	62	42	37	6.1
29	7.3	70	35	33	4.7
30	8.5	78	38	35	4.5
31	6.1	71	20	23	3.2
32	4.0	78	6	12	1.6
33	3.5	71	5	10	1.5
34	5.5	77	13	18	2.3
35	4.9	62	12	15	2.3
36	4.0	83	2	4	0.5
37	4.4	92	4	8	0.9

For each of the four diseases we now have, for each of the 37 wards, two case rates, two death rates, and one fatality rate. These rates are given in Table 57.

Each of these series of rates has now to be correlated with the overcrowding index for the wards (See Table 55); 20 coefficients of correlation have therefore now to be calculated.

In actual practice the general formula given above for the calculation of r, the coefficient of correlation, is not used since it would be inexpedient to have to calculate the deviation from the true mean of each of the 37 variables. The arithmetic is facilitated by the adoption of a "working mean" which can most conveniently be given the value of zero. x and y, the deviations from the means, now become the actual values of each variable. Hence the formula for r now becomes

$$r_{xy} = \frac{\frac{S(xy)}{n} - \bar{x}\,\bar{y}}{\sqrt{\frac{Sx^2}{n} - (\bar{x})^2}\sqrt{\frac{Sy^2}{n} - (\bar{y})^2}}$$

where x and y are the actual values, x indicating the ward rates and y the ward overcrowding index; $\bar{x}$ and $\bar{y}$ are the means of the 37 x's and y's respectively.

The working procedure will now be described. Each of the 20 columns of ward rates (x) and the one column of ward overcrowding indices (y) was summed. The sum in each case was divided by 37 to give the means of x and y, i.e. $\bar{x}$ and $\bar{y}$.

Each item in each of the 21 columns was now sqared (employing Barlow's Tables): The squares were summed and divided by 37 to give $\frac{Sx^2}{n}$ and $\frac{Sy^2}{n}$.

From the "mean of the squares" we subtract the "square of the mean" to get the variance, σ_x^2 and σ_y^2. The square root of the variance, i.e. σ, is the Standard Deviation.

i.e. $\sigma_x = \sqrt{\frac{Sx^2}{n} - (\bar{x})^2}$

and $\sigma_y = \sqrt{\frac{Sy^2}{n} - (\bar{y})^2}$

Each variable in the x-column was now multiplied by the corresponding variable in the y-column, and the sum of these 37 products was divided by 37 to get the "mean product". The "mean product" minus the "product of the means" is the same as the mean of the products of the deviations of x and y from their true means.

We now have all the values needed for substition in the working formula above to arrive at the 20 coefficients of correlation between the ward rates and overcrowding. While it would of course have been perfectly practicable to have worked out each coefficient independently from beginning to end, in actual practice the process was carried through concurrently for the 20 correlations. The full set of means of x, x^2, xy, y, and y^2 for the 20 correlations are set out in Table 58. By employing a tabular method for the substitution of the necessary values from this table in the formula for r and again carrying out the substitution concurrently

Table 58.

Coefficients of Correlation, 1924-38.

Means of Variables, Squares of Variables, and Products.

		Sx/n	Sx^2/n	Sxy/n
Scarlet Fever				
Cases	(Total Pop.)	4.4027	19.7786	182.1135
	(Child Pop.)	54.3514	3211.6760	1945.2164
Deaths	(Total Pop.)	4.9324	26.4673	217.5568
	(Child Pop.)	5.8135	35.8121	226.0836
Fatality Rates		1.1189	1.3443	48.4270
Diphtheria				
Cases	(Total Pop.)	1.9892	4.1562	86.9108
	(Child Pop.)	23.4595	565.4055	915.0812
Deaths	(Total Pop.)	10.8378	129.5405	493.0811
	(Child Pop.)	12.3243	155.7296	508.1617
Fatality Rates		5.3297	29.6616	228.4000
Measles				
Cases	(Total Pop.)	9.0351	86.9892	401.9865
	(Child Pop.)	105.3243	11339.0553	4170.6221
Deaths	(Total Pop.)	21.7027	672.4595	1096.5405
	(Child Pop.)	22.3243	631.2426	1072.2151
Fatality Rates		2.2216	6.4476	107.0054
Whooping Cough				
Cases	(Total Pop.)	6.2054	41.7400	280.3270
	(Child Pop.)	71.2433	5168.3789	2891.7030
Deaths	(Total Pop.)	25.9730	898.7838	1293.8919
	(Child Pop.)	27.1621	879.7559	1282.5933
Fatality Rates		3.8405	17.6354	180.8838

	Sy/n	Sy^2/n
Overcrowding (% 2+)	40.5135	1959.7027

for the twenty correlations, errors in substitution and in arithmetic were rendered less likely and the whole process rendered less taxing than if the 20 correlations had been calculated individually from beginning to end.

It is unnecessary to show the full working for all twenty correlations, but, as an example, Table 59 shows the calculation of the coefficient of correlation between ward overcrowding and ward cases of Scarlet Fever per thousand total ward population. The other 19 calculations were made in the same way.

The values of the full series of coefficients are set out in Table 60.

The significance of r may be most conveniently tested by Fisher's "t" method, by which we find that for 37 variables a significant value of r is 0.3250, (Chambers, 1946, page 51). When the calculated value of r is as big or bigger than this, then for P = 0.05, it indicates a real correlation between the two series of variables.

Considering the results presented in Table 60, between the Scarlet Fever case rates per thousand total population and ward overcrowding the correlation is just significant. In the other diseases the corresponding correlation is high. The correlation between death rates based on total population and overcrowding is high in each disease, though lower

Table 59.

Calculation of Coefficient of Correlation. Wofked Example.

Scarlet Fever Cases per 1,000 Total Population = x.

Percentage of Population living more than 2 persons per room = y.

$\bar{x}$	= 4.4027	$\bar{y}$	= 40.5135
Sx^2/n	= 19.7786	Sxy/n	= 182.1135
$\bar{x}^2$	= 19.3838	$\bar{x}\,\bar{y}$	= 178.3688
σ_x^2	= 0.3948	Numerator	= 3.7447
σ_x	= 0.6283	σ_y	= 17.8426

$$r_{xy} = \frac{\text{Numerator}}{\sigma_x \sigma_y}$$

$$= \frac{3.7447}{0.6283 \times 17.8426}$$

$$= +0.3341$$

Table 60.

Coefficients of Correlation. Ward Rates and Overcrowding.

	(Total Population) Cases	Deaths	(Child Population) Cases	Deaths	Fatality Rate
Scarlet Fever	+0.3341	+0.6794	-0.8966	-0.3728	+0.5709
Diphtheria	+0.7933	+0.8707	-0.5105	(+0.2534)	+0.6239
Measles	+0.8704	+0.8580	-0.3447	+0.8158	+0.7749
Whooping Cough	+0.9016	+0.9045	(+0.0313)	+0.8568	+0.8344

Criterion of Significance: For P = 0.05 a significant value of r is 0.3250.

"Not significant" values of r are enclosed in brackets.

in Scarlet Fever than in the other diseases. Similarly, the correlation between the Scarlet Fever fatality rate and overcrowding, though fairly high, is lower than in the other three diseases.

When we turn to the correlations between overcrowding and the case and death rates based on child population, the picture is considerably changed. The Scarlet Fever case rates now show a high degree of negative correlation with overcrowding. In Diphtheria the corresponding correlation is negative and moderately high; in Measles, it is negative and barely significant; and in Whooping Cough, it is weakly positive and quite insignificant. On the other hand, with death rates, the Scarlet Fever coefficient, while negative, is barely significant; the Diphtheria coefficient is positive and not significant; the Measles and Whooping Cough coefficients remain positive and very high.

To generalise, therefore, we may say that Scarlet Fever is exceptional in showing only a low positive correlation between overcrowding and case rates based on total population, and a very high negative correlation when the case rates are based on child population. For all four diseases the correlations between overcrowding and death rates based on total population and between overcrowding and fatality rates are invariably high. When the death rates are based on child population, the correlation remains high in Measles and Whooping Cough.

Evidently the introduction of the child population as a basis for the ward rates considerably alters the value and sometimes the sign of the coefficients. The reason for this becomes apparent if we consider the relationship between ward rates based on total and child population. If the proportion of children within a ward is high, the effect of basing the rate on the child population is to reduce very considerably the numerical value of the rate. Now, in 1931, the proportion of children was highest in those wards in which overcrowding was greatest, (the coefficient of correlation between ward overcrowding and percentage of children in ward populations will be seen later, in Table 64, to be practically +1). Therefore when we base the rates for cases and deaths on the child population,— which is equivalent to dividing the rates based on total population by 1/100 of the percentage of children in each ward— we are reducing the rates in the overcrowded wards very much more than in the less overcrowded wards, in which the divisor, 1/100 of the percentage of children, is very much smaller. Hence a correlation which is in the neighbourhood of zero when the rate is based on total population, e.g. the Scarlet Fever case-rate, will become strongly negative when the rate is based on child population. Similarly a high positive correlation, such as with the Whooping Cough case-rate, may be reduced to a near-zero correlation. If, however, as in the case of the Measles and Whooping Cough death rates, these rates are many times higher in the most over-crowded than in the least over-crowded wards, the effect of introducing the child population as a base is insufficient to reduce the high positive correlation to a level approaching zero such as has happened with Diphtheria.

It may be of interest, before proceeding further, to re-produce a table by Woods (1933) showing, for various periods of time, her coefficients of correlation for Scarlet Fever, i) between attack rates and overcrowding in London and Glasgow at ages 0-15 and at all ages, and ii) between fatality rates and overcrowding in Glasgow at all ages. These are shown in Table 61. To Woods'results has been added one extra line showing the relevant coefficients given in Table 60 for the period 1924-38.

These coefficients suggest an apparent difference in the behaviour of Scarlet Fever between the two cities. In London, the attack rate based on child population shows a near-zero correlation with overcrowding, while in Glasgow, the corresponding correlation is, as we have seen, strongly negative. In both cities, there is a high degree of association between fatality rate and overcrowding.

In the meantime, we shall be content merely to point this apparently anomalous behaviour of Scarlet Fever in Glasgow, leaving further discussion to a later stage. It will be remembered that in the last chapter, we saw that the age-shift of Scarlet Fever cases in Glasgow was different from that

Table 61.

Coefficients of Correlation, for London and Glasgow, between Scarlet Fever Attack Rate and Fatality Rate and Overcrowding.

(Coefficients in brackets are "not significant")

Years	Attack Rate (Age 0-15)	Attack Rate (All Ages)	Fatality Rate
London			
1901-10	(+0.135)	+0.453	
1911-14	-0.355	(+0.040)	
1919-23	(-0.064)	+0.450	
1923-26		+0.562	
Glasgow			
1899-1902	-0.860	-0.483	+0.586
1903-08	-0.861	(-0.172)	+0.789
1909-13	-0.647	(+0.251)	+0.727
1921-25	-0.721	(+0.168)	+0.619
1924-38	-0.897*	+0.334	+0.571

(* = Age 0-5)

Table 62.

Coefficients of Correlation between Mortality and Overcrowding, (London and Glasgow), Social Index (London), and Children per Family(London).

		Diphtheria	Measles	Whooping Cough
Overcrowding (Glasgow),	1924-38	+0.871	+0.858	+0.905
Overcrowding (London),	1929-33	+0.490	+0.865	+0.515
" "	1924-38	+0.503	+0.838	+0.729
Social Index (London)	1929-33	+0.487	+0.434	(+0.280)
Children per Family (London)	1929-33	+0.476	(+0.173)	(+0.126)

of the other diseases, and different apparently from the age-shift of Scarlet Fever cases in London, (Woods 1933).

Wright and Wright, (1942), calculated coefficients of correlation between "Substandard Housing" (assessed on the percentage of overcrowding) and the mortality of Diphtheria, Measles, and Whooping Cough at ages 0-4 for the London Boroughs, for the periods 1929-33 and 1924-38. In addition, they correlated the mortality rates with a "Social Index" for 1931 and with "Number of Children per Family".

In Table 62, are shown the Wrights' coefficients together with, for comparaison, the corresponding coefficients for Glasgow from Table 60. It should be noted that the Glasgow and London death rates are not strictly comparable; the London deaths are those at ages 0-4 years, while in Glasgow they are for all ages. In Measles and Whooping Cough, however, practically all the deaths occur in the 0-4 age-group, so that the difference in method is of negligible importance. In Diphtheria, where only some 60% of the deaths occur in the 0-4 age-group, the difference in method is obviously important, and the two series of coefficients cannot justifiably be compared. It is apparent, however, that the correlations of mortality with overcrowding in Glasgow are broadly similar to those of London for the three diseases.

With regard to morbidity, i.e. case-rates, Wright and Wright give a coefficient of correlation with overcrowding only for Diphtheria. The value of their coefficient was +0.893, which is similar to our Glasgow value of +0.793.

With Diphtheria fatality rates, however, they found a negative correlation, the value of the coefficient being -0.467. This they suggested, was due to a higher immunity among the badly housed due to more frequent exposure. The corresponding Glasgow coefficient, as we saw, has a value of +0.624.

Correlations with Family Size.

In forming an index of family size, Wright and Wright went to the 1931 Census and enumerated, for each Borough, the children in families of more than four members. Cheeseman, Martin & Russell took birth rates in the Boroughs as an index of family size. While neither method can do more than give approximate values, the latter is simpler and more straightforward. Another approximate method would be to consider the percentage of the total population that the child population constitutes within each area.

In calculating the correlations between the ward case and death rates and family size, any of the above methods for obtaining an index of family size might have been employed. I have used the ward birth rates. Though the birth rates in individual wards remain fairly steady from year to year, it was considered advisable in preference to using the birth rates of only 1931 to take the average of the birth rates of the three years, 1930, 1931, and 1932, (see Table

55).

The method of working was the same as for the correlations with overcrowding; correlations with case and death rates based on child populations were however not considered likely to yield profitable results and these correlations were not therefore repeated; ward case and death rates based only on total populations were employed.

The resulting coefficients are set out in Table 63.

When we compare these coefficients with the corresponding ones for correlation with overcrowding (Table 60), we find that a very high degree of similarity exists between the two series.

There are several additional coefficients that have been calculated and it will be convenient at this stage to give the results in tabular form, Table 64.

By "Room Density" in Table 64, is meant the average number of persons per room in each ward at the 1931 Census. As would be expected there is a very high degree of correlation between the percentage child population and the birth rate (the latter having been used to calculate the former), and similarly a very high degree of correlation between overcrowding and room demsity. It is interesting to find, however, an equally high degree of correlation between birth rate and overcrowding. Naturally some evidence of an association between the two might be expected since the overcrowding is at least partly due to large families, but the actual

Table 63.

Coefficients of Correlation between Ward Rates (Based on Total Population) and Birth Rate.

	Cases	Deaths	Fatality Rate
Scarlet Fever	+0.3258	+0.6685	+0.5647
Diphtheria	+0.7871	+0.8570	+0.6053
Measles	+0.8639	+0.8645	+0.7925
Whooping Cough	+0.9038	+0.9058	+0.8446

(Significant Value of r = 0.3250)

Table 64.

Miscellaneous Coefficients of Correlation.

Ward Variables (1)	(2)	Coefficients of Correlation r_{12}
% Child Population	Overcrowding (2+)	+0.9656
Birth Rate	Overcrowding (2+)	+0.9714
% Child Population	Birth Rate	+0.9683
Overcrowding (2+)	Room Density	+0.9740

(Significant Value of r = 0.3250.)

size of the coefficient of correlation is surprisingly great.

Coefficients of Partial Correlation.

It had been hoped that, by calculating coefficients of partial correlation between ward case and death rates, ward overcrowding, and ward birth rates it might be possible to determine which of these two latter variables was more strongly correlated with ward rates.

The calculation of the coefficients of partial correlation was carried out in a straightforward manner by means of the formula,

$$r_{xy.z} = \frac{r_{xy} - r_{xz}r_{yz}}{\sqrt{(1-r^2_{xz})\,(1-r^2_{yz})}}$$

where x represents the ward case or death rates, y represents ward overcrowding, and z represents ward birth rates.

The results of the two series of calculations for $r_{xy.z}$ and for $r_{xz.y}$ are shown in Table 65.

It will be at once seen that none of these coefficients is significant and that all of them have values very close to zero. Results such as this are not unexpected in view of the very high degree of correlation that we have seen to exist between y and z, i.e. between ward overcrowding and ward birth rates.

It may be of interest to examine for a moment the correlation that exists between three variables when the coefficient

Table 65.

Coefficients of Partial Correlation.

Correlation between Ward Rates and Overcrowding, Excluding Birth Rate.

	Cases	Deaths	Fatality Rate
Scarlet Fever	(+0.0784)	(+0.1699)	(+0.1143)
Diphtheria	(+0.1960)	(+0.3123)	(+0.1899)
Measles	(+0.2609)	(+0.1526)	(+0.0352)
Whooping Cough	(+0.0354)	(+0.2445)	(+0.1101)

Correlation between Ward Rates and Birth Rate, Excluding Overcrowding.

	Cases	Deaths	Fatality Rate
Scarlet Fever	(+0.0058)	(+0.0488)	(+0.0518)
Diphtheria	(+0.1141)	(+0.0959)	(-0.0043)
Measles	(+0.1574)	(+0.2541)	(+0.2653)
Whooping Cough	(+0.2726)	(+0.2685)	(+0.2605)

Significant value of r = 0.3250.

None of the above coefficients is "significant".

of correlation between two of the variables has a value of 1.

Let us consider three variables, X, Y, and Z, and let the simultaneous regression of X on Y and Z be represented by the equation

$$x = ay + bz$$

where x, y and z are the measures from the means of X, Y and Z; and where a and b are the coefficients of partial correlation; i.e.

$$a = r_{xy.z} \qquad \text{and } b = r_{xz.y}$$

Also let $r_{yz} = 1$.

The coefficients a and b are determinable by the method of least squares from the equations

$$S(xy) = a\,S(y^2) + b\,S(yz) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$S(xz) = a\,S(yz) + b\,S(z^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

These two equations may be alternatively expressed

$$r_{xy}\sigma_x\sigma_y = a\,\sigma^2_y + b\,r_{yz}\sigma_y\sigma_z \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$r_{xz}\sigma_x\sigma_z = a\,\sigma_y\sigma_z r_{yz} + b\,\sigma^2_z \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

On dividing though, in equation (3) by σ_y, and in equation (4) by σ_z, we get

$$r_{xy}\,\sigma_x = a\,\sigma_y + b\,\sigma_z r_{yz} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

$$r_{xz}\,\sigma_x = a\,\sigma_y\,r_{yz} + b\sigma_z \quad \ldots\ldots\ldots\ldots\ldots (6)$$

But $r_{yz} = 1$

Therefore the right hand side of equation (5) is the same as the right hand of equation (6).

Therefore $r_{xy} = r_{xz}$ and the two coefficients a and b cannot be separately determined.

If we now attempt to evaluate $r_{xy.z}$ from the formula

$$r_{xy.z} = \frac{r_{xy} - r_{xz}\, r_{yz}}{\sqrt{(1-r^2_{xz})(1-r^2_{yz})}}$$

when $r_{yz} = 1$, and therefore $r_{xy} = r_{xz}$,
the right hand side of the formula reduces to $\frac{0}{\sqrt{0}}$

which cannot be evaluated.

Returning now to the coefficients of correlation and of partial correlation between case and death rates, overcrowding, and birth rates, it is clear that the very high degree of correlation between the second and third explains the close similarity in the coefficients of correlation between the first and second and between the first and third. Moreover while it has been possible arithmetically, since the correlation between the second and third is not quite +1, to calculate coefficients of partial correlation, these coefficients do not merely approach zero and fail to satisfy the test for statistical significance but are probably entirely meaningless.

In Glasgow, therefore since ward overcrowding and family size as measured by ward birth rates run so closely in parallel, it is impossible here to determine statistically whether one of these two factors exerts a greater influence upon case and death rates than does the other.

Moreover, since the coefficient of correlation between birth rates and percentage child populations is also practically

+1 the use of the latter as a measure of family size could not be expected to yield results in any way different or more profitable than those that have been obtained.

Section 2

Changes in Correlation between Morbidity, Mortality and Fatality Rates and Room Density.

It has been seen that in proportion to the number of children in the wards of the city, the Scarlet Fever attack rate is apparently highest in those wards in which there is least overcrowding. Further, this high negative correlation, as we see from Table 61, has been maintained at a fairly constant level during several periods of time from 1899-1902 to 1924-38.

Brownlee, naturally, has observed this feature of Scarlet Fever and has given two interesting tables relating to Scarlet Fever in Glasgow, 1898-1902. He divided the city into five groups with respect to room density, i.e. the average number of persons per room. Room density is, as we have seen from Table 64, very closely correlated with the percentage of the population living more than 2 persons per room, and for practical purposes may be regarded as an equally reliable index of overcrowding. Brownlee's two tables, the one relating to attack rates and the other to fatality rates, have been condensed into one table and reproduced as Table 66. Brownlee's figures have been quoted by Woods (1933), and it is from her work instead of the original that I have taken them.

It is obvious that, from Table 66, the attack rate of Scarlet Fever is strongly correlated in a negative direction

Table 66.

Scarlet Fever in Glasgow, 1898-1902. The Attack Rate per 10,000 Children Living under the Age of 10 Years, and the Fatality Rate, Compared with the Number of Persons per Occupied Room.

(Brownlee, quoted by Woods)

District	Persons per Room	Attack Rate	Fatality Rate
1	0.5-1.0	388.2	2.3
2	1.0-1.5	315.6	3.5
3	1.5-2.0	251.8	4.1
4	2.0-2.5	100.3	5.05
5	2.5-2.75	138.4	5.6

with room density, and that the fatality rate is strongly correlated in a positive direction. In other words, the correlations are the same as those that were demonstrated by coefficients of correlation in the previous section.

It is intended now to employ Brownlee's method of tabular correlation, as in Table 66, to explore the correlation of Scarlet Fever with room density at several later periods of time to see whether any trend of correlation in either direction can be found. At the same time the other three diseases will be studied in a similar manner.

It was intended at first to study these correlations during three quinquennia centred on the census years 1921 and 1931 and the 'missed' census year 1941. It will be remembered, however, that the present arrangement of the wards of the city only goes back to 1921. Thus it is impossible to go further back than that year for ward data that can be compared with later data. Accordingly, the three quinquennia that have been selected for study are 1921-25, 1929-33, 1939-43.

The determination of room density and the formation of groups of wards of similar room density are based on the census returns of 1931. The actual wards constituting each group therefore remain the same, though their populations, and presumably also their room densities, have been altering.

To Group 1 have been allocated those wards with a room density of less than 1 person per room; Group 2 comprises wards with 1 to 1.5 persons per room; Group 3, 1.5 to 2 persons per room; and Group 4, more than 2 persons per room. The highest room density is found in Ward 3, 2.47 persons per room. Brownlee's fifth group, more than 2.5 persons per room, has ceased to exist.

The total populations for the wards have been taken from the Annual Reports of the Medical Officer of Health for 1925, 1931, and 1941. The populations for 1931 are the same as those of the Census of that year.

Child populations for the wards have been calculated from births and infant deaths by the method described in the previous section. For the 1921-25 quinquennium, the rearrangement of the wards in 1921 has made it impossible, by the method used, to determine "under 5 years" child populations until 1925. Accordingly, both for total and child populations, in the 1921-25 quinquennium , figures for 1925 have been used instead of 1923. This substitution cannot be regarded as a source of any serious error.

The formation of the four groups of wards is shown in Table 67, giving the number and name of each ward and the number of persons per room. It will be noted that Ward 38 has been placed in Group 1. As this ward was not in existence at the time of the 1931 Census, there is no record of its room density. In 1935, however, a housing survey of the city was carried out. Ward 38 was found to have 9% of its houses overcrowded and came sixth in the ward order of least

Table 67.

Grouping of the Wards of the City according to the Average Number of Persons per Room at the Census of 1931.

Group	Ward Number	Ward Name	Persons per Room
	16	Park	0.91
	22	Kelvinside	0.65
1	32	Pollokshields	0.80
	33	Camphill	0.98
	36	Langside	0.96
	37	Cathcart	0.87
	38	Yoker & Knightswood	-
	7	Dennistoun	1.33
	13	Blythswood	1.43
	15	Sandyford	1.43
2	20	North Kelvin	1.35
	23	Partick (East)	1.41
	24	Partick (West)	1.41
	25	Whiteinch	1.23
	34	Pollokshaws	1.25
	1	Shettleston & Toll-cross	1.78
	6	Whitevale	1.95
	8	Provan	1.78
	9	Cowlairs	1.90
	10	Springburn	1.76
	11	Townhead	1.76
3	12	Exchange	1.88
	14	Anderston	1.87
	18	Woodside	1.76
	19	Ruchill	1.85
	21	Maryhill	1.75
	27	Gorbals	1.94
	28	Kingston	1.92
	29	Kinning Park	1.84
	31	Fairfield	1.76
	35	Govanhill	1.55
	2	Parkhead	2.07
	3	Dalmarnock	2.47
	4	Calton	2.04
4	5	Mile-End	2.38
	17	Cowcaddens	2.09
	26	Hutchesontown	2.29
	30	Govan	2.02

overcrowding with a position intermediate between ward 33 and Ward 16, both of which are in Group 1.

To each of the wards in each group are now allocated the total and child populations for 1925, 1971 and 1941. Hence, by addition, we find total and child populations for each of the four groups for each of the three periods. These group population figures are given in Table 68. Also shown in the table are the percentages of the total populations that the child populations constitute within each group.

It will be seen that a reduction in percentage child population occurred in all groups from 1925 to 1931, that in Group 4, the most overcrowded, this reduction continued up to 1941; but that in Group 1, the original percentage child population of 1925 was practically restored by 1941.

The next Table, Table 69, also deals with group populations. Expressing the total population of the city, and the "under 5" population of the city each as 100, the table shows the distribution of the populations among the four groups at each period.

The proportions of population in Groups 2 and 3 remain fairly constant throughout. In Group 1, they have been rising, and in Group4, falling. Moreover, the reduction in the child population proportion in Group 4 is, as we have seen from Table 68, a reduction in relation to the total population of the group as well as in relation to the child population of the whole city.

Table 68.

Total and "under 5" Child Populations of Ward Groups in 1925, 1931, and 1941, with Percentage Child Populations.

Group	1925 Population		1931 Population		1941 Population	
	Total	Child	Total	Child	Total	Child
1	127483	7162	136025	6277	185833	10163
	100%	5.6%	100%	4.6%	100%	5.5%
2	196195	17802	210398	16165	175138	13453
	100%	9.1%	100%	7.7%	100%	7.7%
3	507268	55085	500434	47602	478435	45545
	100%	10.9%	100%	9.5%	100%	9.5%
4	266895	33788	241604	27724	205927	22361
	100%	12.6%	100%	11.5%	100%	10.8%
City	1097841	113837	1088461	97768	1045333	91522

Table 69.

Percentage Distribution of the Total Population and of the Child Population among the Four Groups.

Group	Total Population			Child Population		
	1925	1931	1941	1925	1931	1941
1	11.6	12.5	17.8	6.3	6.4	11.1
2	17.8	19.4	16.7	15.6	16.5	14.7
3	46.3	46.0	45.8	48.5	48.7	49.8
4	24.3	22.1	19.7	29.6	28.4	24.4
City	100	100	100	100	100	100

If the child population s had been obtained by enumeration, we might have been inclined to assume that these group population changes were the result of a transfer, after 1931, of famlies that included large numbers of children from Group 4 to Group 1. This cannot be the full explanation, however. The child populations were estimated from birth rates, so that we must conclude that the birth rates of Group 4 have been falling, and those of Group 1 rising between 1931 and 1941.

These population changes between Group 4 and Group 1 have presumably been brought about by the "slum clearance" and the suburban rehousing programmes of the thirties. Accordingly, the very high correlation between overcrowding and birth rates that was found in 1931 may in the ensuing years have been considerably reduced. Until the next census or housing survey, however, it will be impossible satisfactorily to estimate the degree of overcrowding in the city in more recent years. We can, nevertheless, fairly safely assume that the large families who formerly lived in the slums in conditions of gross overcrowding and who now live in rehousing areas in houses of many more apartments are no longer living in such grossly overcrowded conditions.

While the details of this internal migration of population are incomplete and confusing, enough has been said to indicate that its main features are a falling child population in the most overcrowded districts and an increasing child population in districts where overcrowding is least.

Having now formed the four groups and having obtained, for each of the three quinquennia, total and child populations for each group, we come now to the collection of the group morbidity, mortality, and fatality rates.

The actual numbers of cases and deaths for each disease in each single ward for each year of the fifteen years comprising the three quinquennia were abstracted from the Public Health Department records; aggregated for each quinquennium; and, allocating the aggregate for each ward to the group containing the ward, distributed among the four groups. Thus were found total numbers of cases and deaths for each group for each quinquennium. These figures are included in Table 70. From these totals we shall later calculate group fatality rates.

With the total cases and deaths in Table 70, and the group populations in Table 68, it is now possible to calculate group rates. In the four parts of Table 70, are given, for each of the four diseases, case and death rates, i) per 100,000 group population, and ii) per 100,000 ("under 5 years") group child population. As has been mentioned before, the under five years child populations may be regarded as indices of the total child populations.

The case and death rates in Table 70 are complicated by the varying trend of total morbidity and mortality of the diseases for the whole city. This renders a comparative interpretation

Table 70.

5-Year Totals of Cases and Deaths in Ward Groups, with 5-Year Case and Death Rates per 100,000 Total and 100,000 Child Populations.

Scarlet Fever		Cases			Deaths		
Group		1921-25	1929-33	1939-43	1921-25	1929-33	1939-43
1	Total	1626	3320	1544	22	31	4
	Rate (Total)	1275	2441	831	17	23	2.2
	Rate (Child)	22699	52888	15196	307	494	39
2	Total	3620	5920	1769	54	61	4
	Rate (Total)	1845	2814	1010	28	29	2.3
	Rate (Child)	20337	36609	13153	303	377	30
3	Total	7550	15292	6210	147	147	21
	Rate (Total)	1488	3055	1298	29	29	4.4
	Rate (Child)	13703	32128	13631	267	309	46
4	Total	4021	7135	2839	112	86	13
	Rate (Total)	1507	2953	1379	42	36	6.3
	Rate (Child)	11898	25736	12696	331	310	58
City	Total	16817	31667	12362	335	325	42
	Rate (Total)	1532	2911	1183	31	30	4.0
	Rate (Child)	14777	32395	13512	294	332	46

Table 70 (continued).

Diphtheria		Cases			Deaths		
Group		1921-25	1929-33	1939-43	1921-25	1929-33	1939-43
1	Total	686	792	1418	35	32	48
	Rate (Total)	538	582	763	27	24	26
	Rate (Child)	9577	12617	13956	489	510	472
2	Total	1684	2092	2662	92	100	89
	Rate (Total)	858	994	1520	47	48	51
	Rate (Child)	9461	12937	19792	517	618	662
3	Total	4090	5252	9346	339	281	378
	Rate (Total)	806	1049	1953	67	56	79
	Rate (Child)	7423	11034	20514	615	590	830
4	Total	2032	2561	4244	183	186	191
	Rate (Total)	761	1060	2061	69	77	93
	Rate (Child)	6013	9238	18979	541	671	854
City	Total	8492	10697	17670	649	599	706
	Rate (Total)	773	983	1691	59	55	68
	Rate (Child)	7462	10943	19313	570	613	772

Table 70 (continued).

Measles		Cases			Deaths		
Group		1921-25	1929-33	1939-43	1921-25	1929-33	1939-43
1	Total	2911	2823	3441	27	13	8
	Rate (Total)	2283	2076	1852	21	10	4
	Rate (Child)	40638	44970	33866	377	207	79
2	Total	7916	6849	3650	292	98	24
	Rate (Total)	4035	3255	2085	149	47	14
	Rate (Child)	44472	42354	27138	1640	606	178
3	Total	21431	18995	14630	1219	468	103
	Rate (Total)	4224	3795	3058	240	94	22
	Rate (Child)	38897	39908	32113	2212	983	226
4	Total	14028	11197	7695	1022	362	69
	Rate (Total)	5256	4634	3737	383	150	34
	Rate (Child)	41509	40388	34412	3024	1306	309
City	Total	46286	39864	29416	2560	941	204
	Rate (Total)	4215	3664	2815	233	86	20
	Rate (Child)	40672	40781	32152	2249	963	223

Table 70 (continued).

Whooping Cough		Cases			Deaths		
Group		1921-25	1929-33	1939-43	1921-25	1929-33	1939-43
1	Total	2255	2096	2654	47	27	24
	Rate (Total)	1769	1541	1428	37	20	13
	Rate (Child)	31480	33389	26121	656	430	236
2	Total	6577	5403	3100	302	184	75
	Rate (Total)	3352	2568	1770	154	87	43
	Rate (Child)	36950	33412	23049	1697	1138	558
3	Total	18917	14892	12347	1193	629	295
	Rate (Total)	3729	2975	2581	235	126	62
	Rate (Child)	34334	31288	27102	2165	1322	648
4	Total	12442	8274	6513	910	453	179
	Rate (Total)	4662	3425	3163	341	187	87
	Rate (Child)	36816	29844	29126	2693	1634	800
City	Total	40191	30665	24614	2452	1293	573
	Rate (Total)	3660	2818	2355	223	119	55
	Rate (Child)	35316	31370	26903	2155	1323	626

somewhat difficult. Some adjustment is therefore desirable to eliminate the effect of the total trend.

Accordingly, we shall represent the rates for the whole city for each disease in each quinquennium as 100, and express the group rates as proportions of the city rates. Thus the city rates remain at a constant level.

Table 71 shows the results of this manoeuvre. The Table consists of two parts: a) Proportionate group case and death rates based on total group populations, and b) Proportionate group case and death rates based on group child populations.

Let us in the first place look at the general picture presented in the table without particular regard to differences between the three time-periods.

Considering, first, the case rates based on total population, in Scarlet Fever, we find some evidence of a weak positive correlation with room density, i.e. the proportionate rates in Groups 3 and 4 are higher than those in Groups 1 and 2. In Diphtheria the correlation is [illegible], on the whole, stronger; in Measles, and in Whooping Cough it is very strong.

With death rates based on total population there is, in each disease, a strong positive correlation.

Now turning to case rates based on child population, in Scarlet Fever, the correlation is negative. In Diphtheria a negative correlation in the first two periods becomes perhaps a weak positive in the third. In Measles and Whooping Cough, there is no evidence of positive or negative correlation.

With death rates based on child population the correlation

Table 71.

Proportionate Group Case and Death Rates in each Quinquennium, the City Rate taken as 100 in each Quinquennium.

A. Rates based on Total Population.

		Case Rates			Death Rates	
	1921-25	1929-33	1939-43	1921-25	1929-33	1939-43
City	100	100	100	100	100	100
Group	Scarlet Fever					
1	83	84	70	55	77	55
2	120	97	85	90	97	58
3	97	105	110	94	97	110
4	98	101	117	135	120	158
	Diphtheria					
1	70	59	45	46	44	38
2	111	101	90	80	87	75
3	104	107	115	114	102	116
4	98	108	122	117	140	137
	Measles					
1	54	57	66	9	12	20
2	96	89	74	64	55	70
3	100	104	109	103	109	110
4	125	126	133	164	174	170
	Whooping Cough					
1	48	55	61	17	17	24
2	92	91	75	69	73	78
3	102	106	110	105	106	113
4	127	122	134	153	157	158

Table 71 (continued)

B. Rates based on Child Population.

	Case Rates			Death Rates		
	1921-25	1929-33	1939-43	1921-25	1929-33	1939-43
City	100	100	100	100	100	100
Group	**Scarlet Fever**					
1	154	163	112	104	149	85
2	138	113	97	103	114	65
3	93	99	101	91	93	100
4	81	79	94	113	93	126
	Diphtheria					
1	128	115	72	86	83	61
2	127	118	102	91	101	86
3	99	101	106	108	96	108
4	81	84	98	95	109	111
	Measles					
1	100	110	105	17	21	35
2	109	104	84	73	63	80
3	96	98	100	98	102	101
4	102	99	107	134	136	139
	Whooping Cough					
1	89	106	97	30	33	38
2	105	107	86	79	86	89
3	97	100	101	100	100	104
4	104	95	108	125	124	128

in Scarlet Fever is variable — indefinite in the first period, negative in the second, and positive in the third. In Diphtheria there is a moderate positive correlation. In Measles and Whooping Cough there is a strong positive correlation.

These results are closely consistent with those revealed by the coefficients of correlation presented in the previous section, (Table 60). Indeed they could not very well be expected to be otherwise, since we have applied what is fundamentally the same process of analysis to similar data over practically the same period of time.

These correlations in Table 71, remain, on the whole, constant in direction during the three quinquennia, The only exceptions are, 1) the Diphtheria case rates based on child population which changed their direction of correlation from a definite negative in 1929-33 to a less definite positive in 1939-43; and, ii) the Scarlet Fever death rates based on child population which, while showing a tendency towards positive correlation in the first and third periods, show a quite definite negative correlation in the middle period.

So far we have added little to what has already been learned in the previous section from the calculation of coefficients of correlation. It is proposed now to examine the trend of incidence in each group over the three quinquennia with the object of ascertaining whether changes in the total numbers of cases and deaths have been evenly distributed among the groups or whether a relative rise or fall in incidence has been occuring in any of the four groups.

In Table 71 the rates for the whole city were held constant at 100 in each period, the purpose being to eliminate the obsuring influence of changes in the total rates for the city, and so make easier the recognition of the general state of correlation between the rates and the room densities of the groups. Our object now is no longer to examine the general state of correlation but to study the trend of the case and death rates within each of the groups. We shall, therefore, dispense with the assumption of a constant total rate for the city, an assumption which might now cause a degree of confusion since death rates which we know to be falling might appear to be rising. Returning to Table 70, we shall assume the case and death rates for each disease, in each group and for the city, to be 100 in the 1921-25 quinquennium, and we shall express each of the 1929-33 and 1939-43 rates as a proportion of the corresponding rate for 1921-25. Carrying out this procedure yields Table 72.

It will be noted from this Table that the figures for the city do not invariably lie within the range of the group figures, as we might have expected them to do. Why this can be so will be realised when it is remembered that the figures represent not true rates but proportionate rates, i.e. ratios of the 1929-33 and 1939-43 rates to the 1921-25 rates, the

Table 72.

Proportionate Group Case and Death Rates in Quinquennia, the Rates in 1921-25 being taken as 100.

A. Rates based on Total Population.

Group	Case Rates 1921-25	Case Rates 1929-33	Case Rates 1939-43	Death Rates 1921-25	Death Rates 1929-33	Death Rates 1939-43
Scarlet Fever						
1	100	192	65	100	136	13
2	100	153	55	100	104	8.2
3	100	206	87	100	100	15
4	100	196	92	100	86	15
City	100	190	78	100	97	13
Diphtheria						
1	100	108	142	100	89	96
2	100	116	178	100	102	109
3	100	130	243	100	84	118
4	100	140	271	100	112	135
City	100	127	219	100	93	115
Measles						
1	100	91	81	100	48	19
2	100	81	52	100	32	9.4
3	100	90	73	100	39	9.2
4	100	88	71	100	53	8.9
City	100	87	67	100	37	8.6
Whooping Cough						
1	100	87	81	100	54	35
2	100	77	53	100	57	28
3	100	80	69	100	54	26
4	100	74	68	100	55	25
City	100	77	64	100	53	25

Table 72 (continued).

B. Rates based on Child Population.

Group	Case Rates 1921-25	Case Rates 1929-33	Case Rates 1939-43	Death Rates 1921-25	Death Rates 1929-33	Death Rates 1939-43
Scarlet Fever						
1	100	233	67	100	161	13
2	100	181	65	100	125	9.9
3	100	235	99	100	116	17
4	100	216	107	100	94	18
City	100	189	92	100	113	16
Diphtheria						
1	100	132	146	100	104	97
2	100	137	209	100	119	128
3	100	149	277	100	96	135
4	100	154	315	100	124	158
City	100	147	259	100	108	136
Measles						
1	100	111	83	100	55	21
2	100	95	61	100	37	11
3	100	102	83	100	45	10
4	100	98	83	100	43	10
City	100	100	79	100	43	10
Whooping Cough						
1	100	106	83	100	66	35
2	100	90	63	100	67	33
3	100	91	79	100	61	30
4	100	81	79	100	61	30
City	100	89	76	100	61	29

latter being represented as 100; and the city figures are equivalent to the ratios of the weighted averages of the original groups rates, weighted averages in which the relative size of the weights, (the group populations), are subject to considerable variation. Perhaps a completely imaginary fully-worked arithmetic example will clarify the meaning of the last sentence. This is done in Table 73, in which we see that the final figure for the city lies well outside the range of the figures for the groups.

Looking now at Table 72, let us examine the trends within the groups remembering that the rates for each group are presumed to start at 100. Obviously, the trends in the two parts of the table — rates based on total population, and rates based on child population — are closely similar and it is unnecessary to consider them separately.

We shall commence with case-rates. In Scarlet Fever a rise in prevalence in the middle period has been shared fairly equally by all groups. The subsequent fall in prevalence has taken place to a greater extent in Groups 1 and 2 than in Group 3 and 4. In Diphtheria, the increased prevalence has involved the worse groups, 3 and 4, much more than the better groups, Groups 1 and 2. Measles and Whooping Cough case rates both show a fall in all groups, which is greatest in Group 2 and least in Group 1. Scarlet Fever and Diphtheria behave in one way and show a relative increase in prevalence in the two most overcrowded groups. On the other hand,

Table 73.

Imaginary Example of the Calculation of Proportionate Group Rates, the Rates in 1921-25 being taken as 100.

Case Rates for 1921-25

Group	Population	Number of Cases	Case Rate per 1,000
1	1000	2	2
2	2000	2	1
3	4000	4	1
4	3000	12	4
City	10000	20	2

Case Rates for 1929-33

Group	Population	Number of Cases	Case Rate per 1,000
1	2000	3	1.5
2	3500	2	0.57
3	3500	2	0.57
4	1000	3	3
City	10000	10	1

Proportionate Rates for 1929-33, the Rates for 1921-25 being taken as 100.

Group	1921-25	1929-33
1	100	75
2	100	57
3	100	57
4	100	75
City	100	50

Measles and Whooping Cough show a relative increase in prevalence in the least overcrowded group (not shared by the next least overcrowded group).

With death rates, again Scarlet Fever and Diphtheria behave in one way, and Measles and Whooping Cough in another. The greatest relative falls in death rate for Scarlet Fever are in the two best groups.

In Diphtheria, the death rate has risen less in Group 2 than in Groups 3 and 4, and it has fallen in Group 1. On the other hand, in Measles and Whooping Cough the falls in death rates are least in the better groups, and certainly least of all in Group 1.

Before introducing Table 72, the table we have just been examining, it was pointed out that in it the case and death rates for the city as a whole had been allowed freedom to vary in proportion to their actual behaviour during the three quinquennia. As a matter of interest, and not really in the hope of eliciting further information, an additional table, Table 74, has been prepared, in which the two assumptions made in Table 71 and Table 72 have been combined. Thus, the rates for the whole city have been held constant at 100, and similarly the rates for 1921-25 have also been held constant at 100. This of course gives a false picture; periods of increased prevalence in Scarlet Fever and Diphtheria disappear, and we no longer see the fall in death rates that occurred in each disease except in Diphtheria. This table tells us no more than we already know from the

Table 74.

Proportionate Group Case and Death Rates, the Rates for the Whole City being held Constant, and the 1921-25 Rates being taken as 100.

A. Based on Total Population.

Group		Case Rates			Death Rates		
		1921-25	1929-33	1939-43	1921-25	1929-33	1939-43
	Scarlet Fever						
1		100	101	84	100	140	100
2		100	81	71	100	108	64
3		100	108	113	100	103	117
4		100	103	119	100	89	117
	Diphtheria						
1		100	84	64	100	96	83
2		100	91	81	100	109	94
3		100	103	111	100	89	102
4		100	110	124	100	120	117
	Measles						
1		100	106	122	100	133	222
2		100	93	77	100	86	109
3		100	104	109	100	106	107
4		100	101	106	100	106	104
	Whooping Cough						
1		100	115	127	100	100	141
2		100	99	82	100	106	113
3		100	104	108	100	101	108
4		100	96	106	100	103	103

Table 74 (continued).

B. Rates Based on Child Population.

Group	Case Rates 1921-25	Case Rates 1929-33	Case Rates 1939-43	Death Rates 1921-25	Death Rates 1929-33	Death Rates 1939-43
Scarlet Fever						
1	100	106	73	100	143	82
2	100	82	70	100	111	63
3	100	106	109	100	102	110
4	100	98	116	100	82	112
Diphtheria						
1	100	90	56	100	97	71
2	100	93	80	100	111	95
3	100	102	107	100	89	100
4	100	104	121	100	115	117
Measles						
1	100	110	105	100	124	206
2	100	95	77	100	86	110
3	100	102	104	100	104	103
4	100	97	105	100	101	104
Whooping Cough						
1	100	119	109	100	110	127
2	100	102	82	100	109	113
3	100	103	104	100	100	104
4	100	91	104	100	99	102

two earlier ones, though it does bring out in perhaps a more striking fashion the relative differences in the behaviour of the four diseases among the four groups of the population.

Group Fatality Rates.

From the figures for the actual numbers of cases and deaths given in Table 70, we can calculate fatality rates for each group at each period of time. These fatality rates are given in Table 75.

As the rates stand, we see an obvious positive correlation in every instance between fatality rates and group room densities, confirming the findings in the previous section by the calculation of coefficients of correlation.

Following the same procedures that were adopted in the study of the group case and death rates above, we may first hold the city fatality rates constant at 100 for each quinquennium, (Table 76), and second, we may give the city rates freedom to change in their natural manner but express all the rates for the 1921-25 period as 100, (Table 77). The third procedure, the combination of the first two, has not been repeated.

Table 76, illustrates again, in a clear fashion, the high degree of positive correlation that we have just seen in Table 75. This high degree of correlation does not seem to be markedly diminishing, though there are indications of a

Table 75.

Group Fatality Rates for each Quinquennium.

Group	1921-25	1929-33	1939-43
Scarlet Fever			
1	1.35	0.93	0.26
2	1.49	1.03	0.23
3	1.95	0.96	0.34
4	2.79	1.21	0.46
City	1.99	1.03	0.34
Diphtheria			
1	5.10	4.04	3.38
2	5.46	4.78	3.34
3	8.29	5.35	4.04
4	9.01	7.26	4.50
City	7.64	5.60	4.00
Measles			
1	0.93	0.46	0.23
2	3.69	1.43	0.66
3	5.69	2.46	0.70
4	7.28	3.23	0.85
City	5.53	2.36	0.69
Whooping Cough			
1	2.08	1.29	0.90
2	4.59	3.41	2.42
3	6.31	4.22	2.39
4	7.32	5.48	2.75
City	6.10	4.22	2.33

Table 76.

Proportionate Group Fatality Rates. City Fatality Rate = 100.

Group	1921-25	1929-33	1939-43
Scarlet Fever			
1	68	90	76
2	75	100	68
3	98	93	100
4	140	117	135
City	100	100	100
Diphtheria			
1	67	72	85
2	71	85	84
3	109	96	101
4	118	130	113
City	100	100	100
Measles			
1	17	19	33
2	67	61	96
3	103	104	101
4	132	137	123
City	100	100	100
Whooping Cough			
1	34	31	39
2	75	81	104
3	103	100	103
4	120	130	118
City	100	100	100

Table 77.

Proportionate Group Fatality Rates. 1921-25 Rates = 100.

Group	1921-25	1929-33	1939-43
Scarlet Fever			
1	100	69	19
2	100	69	15
3	100	49	17
4	100	43	16
City	100	52	17
Diphtheria			
1	100	79	66
2	100	88	61
3	100	65	49
4	100	81	50
City	100	73	52
Measles			
1	100	49	25
2	100	39	18
3	100	43	12
4	100	44	12
City	100	43	12
Whooping Cough			
1	100	62	43
2	100	74	53
3	100	67	38
4	100	75	38
City	100	69	38

lessening difference between the best groups and the worst.

In Table 77, the indications of correlation are removed by giving each group the same initial proportionate rate, i.e.100. The table shows the direction (invariably downwards), and the degree of change in the fatality rates of each group. The behaviour of each of the diseases in relation to the four groups is fairly uniform. We find a rather greater reduction in fatality rates in the worst than in the best groups, though the differences in the reduction between the four groups are not, on the whole, very marked. There is however a definite tendency for the difference in rates between the best and worst groups to become less, thus bringing about a diminishing degree of correlation between fatality rates and room density.

Before concluding this section, let us review some of the more salient features of the group behaviour of the four diseases that have emerged from these tables of group case, death, and fatality rates.

Both Scarlet Fever and Diphtheria case rates are becoming relatively less in the best (the least overcrowded) groups and relatively greater in the worst groups; if coefficients of correlation had been calculated for each of the three quinquennia between case rates and room density we should have found that the coefficients were increasing in positive value. What was a strong negative correlation between Scarlet Fever case rates based on child population and room density has become a weak negative correlation, and the corresponding moderate negative correlation in Diphtheria has become a weak positive correlation.

In Measles and Whooping Cough, relatively increased case rates have occurred in Group 1, but, on the other hand, the rates for Group 2 have been quite rapidly falling. Just what this means, so far as changes in the state of correlation between case rates and overcrowding is concerned, is rather difficult to decide. Probably there is a slight change in the negative direction.

In Group 1 in which, as we saw earlier, the proportion of children in the population has not fallen, but has, in the last period, shown a rise, an associated happening has been, therefore, a relative reduction in case rates in Scarlet Fever and Diphtheria and a relative increase in Measles and Whooping Cough. The apparent effect of the increasing child population seems to be to have increased the incidence of Measles and Whooping Cough, and to have decreased the incidence of Scarlet Fever and Diphtheria.

With death rates, the high state of positive correlation between overcrowding and rates based on total population has increased in Scarlet Fever and Diphtheria and has diminished in Measles and Whooping Cough. As with case rates the change in correlation is in a positive direction in the first two diseases, and negative in the second two. Similarly, when death rates are based on child population, a weak negative correlation in Scarlet Fever becomes positive, a weak positive correlation in Diphtheria becomes more strongly positive but, in Measles and Whooping Cough, the strong positive correlation is reduced. Whereas in Scarlet Fever and Diphtheria the fall in death rate in Groups 1 and 2 has been greater than in the other groups, in Measles and Whooping Cough the fall in death rate, at least in Group 1, has been less.

We saw that the reduction in fatality rates has been fairly equal among the four groups, though rather less in Groups 1 and 2 than in Group 3 and 4, and that in this respect each of the diseases has behaved in similar fashion. The differences in behaviour of death rates between Scarlet Fever and Diphtheria on the one hand and Measles and Whooping Cough on the other has been, therefore, due to a similar difference in the behaviour of case rates rather than to a difference in the behaviour of fatality rates.

CHAPTER 4

Age of Attack in relation to Social Environment.

Section 1

Age of Attack in relation to Room Density in a Group of Wards.

In Chapter 2 we dealt with variations in the age of attack and of death over a period of thirty years for the city as a whole, no regard being paid to different social classes within the city. In Chapter 3, we studied the correlations between social environment and case, death, and fatality rates no regard being paid to the age of attack or of death. In this chapter we shall cease to consider these correlations with social environment but shall look now into the age of attack of each disease in a number of wards of the city in which there are differences in the degree of overcrowding.

Records are available, and were used in previous chapters, of the age-distribution and the ward-distribution of cases in the city as a whole. No record is prepared or kept in the Public Health Department of the age-distribution of cases in individual wards, information which is now required for the present investigation. It was necessary, therefore, for the purpose of ascertaining the age of cases in the individual wards to go back to the original Annual Registers in which each case is entered when its existence is known, amendments being later made for altered diagnoses. These registers, compiled in sections for each disease and for each of the five divisions of the city, give the date of reporting, number of the ward in which the case occurred, age of the patient, address, date of sickening, school attended, and other similar information. These registers are available from 1933 to 1945 inclusive.

To have gone through the registers for these 13 years, and to have classified all the cases into wards and ages, would have been a task of forbidding magnitude and one which could not readily be rendered simpler by mechanical methods of classification.

It was decided therefore, to concentrate upon only two years, 1933 and 1945, and to include only the seven wards comprising the Eastern Division of Glasgow, namely the wards numbered 1 to 7. Neither the selection of the yearsnof of the wards was random in the true sense. The years 1933 and 1945 were selected because they were first and last years for which the required data was obtainable. The seven wards of the Eastern Division were selected in preference to a purely random sample from the 38 wards of the city because, in the first place, the registers are complied in Divisions and extraction was thus simplified, and in the second place, it was felt that these seven closely adjacent wards were more likely in a period of time as short as a single year to share the same epidemiological experience. Random-selected and possibly widely scattered wards might not have had similar-epidemiological experience, a factor which might yield biased age-distributions among the different wards.

Fortunately the seven wards of the Eastern Division offer a fairly good representative sample of all the wards comprising the city, so far as overcrowding is concerned. Ward 7 came eighth in the order of least overcrowding of wards in the city in 1935, and with a room density of 1.34 in 1931 occupied a middle position in Group 2 in the ward groups of the previous chapter. Wards 1 and 6 lie respectively near the beginning and end of Group 3. The remaining four wards, Wards, 2, 3, 4, and 5, constitute more than half of Group 4 in the previous chapter, and have therefore a very high degree of overcrowding. The Eastern Division includes , therefore, one ward with little overcrowding, two wards with moderate overcrowding, and four wards with gross overcrowding. Geographically, the seven wards are closely adjacent to one another.

In 1933, the Measles incidence for the city was very low, and, as we mentioned in Chapter 2 (Section 4), in such years the age-distribution of Measles cases is abnormal. For this reason it was decided to omit Measles from the present investigation, and to consider only Scarlet Fever, Diphtheria, and Whooping Cough. There is indeed little that we could hope to add by the present investigation to what Halliday has already told us about age and social environment in Measles in Glasgow.

The procedure followed in the present examination of age of attack in the seven wards was to go through the registers case by case, and to note down the age in years of each patient, and the ward in which he lived. Thereafter a grouped frequency distribution table was prepared for each ward, showing the number of cases occuring in the ward at each year of age. A combined table, showing these frequency distributions for each ward for 1933 and 1945 and for each of the three diseases, is provided in Table 78.

Cases aged 15 years and over have been gathered into one age-group and are shown in the table for completeness only. They will not be further discussed in this section. In calculating a mean age of attack, which we are now about to do, these few adult cases carry a disproportionately heavy weight, and it has seemed advisable and more likely to give a truer indication of the differences in age of attack in the different wards to consider only those cases occurring at ages under 15 years. Many of theses adult cases, moreover, cannot be regarded as having occurred in persons exposed to the normal risk of the ward in which they lived; a large proportion of cases occurring in adult females have, no doubt, been brought about by attendance upon sick children. In this respect such adults are in the same position as nurses in infectious disease hospitals who are exposed to a risk presumably greater than that of the general population of the district in which they live.

The method employed to calculate the mean age of attack

Table 78.

Age-Distribution of Ward Cases, 1933 and 1945.

Scarlet Fever

1933

Age	Ward No. 1	2	3	4	5	6	7
0	5	2	2	3	2	1	1
1	17	15	16	7	10	7	10
2	26	20	19	14	19	15	10
3	39	37	20	19	15	28	12
4	34	28	17	17	19	21	15
5	64	39	25	17	21	16	27
6	43	34	15	17	16	16	23
7	26	38	17	18	14	14	22
8	21	16	16	12	6	9	13
9	25	17	10	9	11	9	10
10	25	16	7	10	11	9	14
11	12	11	12	4	3	7	5
12	13	10	5	7	3	4	9
13	13	5	9	6	3	5	3
14	7	4	1	1	-	2	3
0 - 15	370	292	191	161	153	163	177
15+	37	33	18	17	13	12	33
All Ages	407	325	209	178	166	175	210

1945

Age	1	2	3	4	5	6	7
0	1	-	-	-	-	-	-
1	12	10	8	2	6	7	4
2	22	9	10	6	10	16	4
3	24	15	14	5	17	4	3
4	26	15	13	14	4	9	5
5	27	26	19	5	8	6	8
6	24	16	7	2	5	7	8
7	18	10	7	3	5	5	5
8	21	8	8	3	6	12	9
9	8	5	6	3	3	6	2
10	15	2	-	1	1	3	4
11	15	3	1	1	3	-	-
12	8	10	3	4	1	1	-
13	8	2	4	-	3	1	3
14	3	1	-	1	1	-	1
0 - 15	232	132	100	50	73	77	56
15+	15	12	1	2	2	7	5
All Ages	247	144	101	52	75	84	61

Table 78 (continued).

Diphtheria **1933**

Age	Ward No. 1	2	3	4	5	6	7
0	1	1	-	2	-	1	2
1	4	2	3	1	1	2	-
2	4	4	3	4	3	4	-
3	4	11	6	2	4	3	9
4	6	8	11	3	4	5	3
5	8	5	6	6	6	5	5
6	6	5	7	3	6	4	4
7	8	4	4	7	3	5	2
8	10	2	4	7	12	5	3
9	5	4	5	2	3	3	7
10	2	3	2	4	-	2	3
11	2	6	7	3	2	3	4
12	5	5	2	3	3	3	4
13	1	2	2	2	1	3	1
14	3	3	1	-	1	3	1
0 - 15	69	65	63	49	49	51	48
15+	9	13	12	5	6	13	13
All Ages	78	78	75	54	55	64	61

1945

Age	1	2	3	4	5	6	7
00	-	-	2	1	-	-	1
1	5	7	2	1	-	2	2
2	5	3	8	11	1	5	2
3	16	10	7	6	4	4	3
4	15	12	10	9	6	4	4
5	8	11	8	4	3	7	5
6	20	10	8	6	2	4	7
7	8	6	6	8	4	5	5
8	9	5	1	5	-	4	5
9	2	5	8	3	2	-	2
10	5	4	3	2	2	2	-
11	3	4	1	3	-	2	3
12	4	7	1	6	1	1	-
13	5	3	-	-	1	1	2
14	1	1	1	2	-	3	1
0-15	106	88	66	67	26	44	42
15+	26	5	7	14	6	2	7
All Ages	132	93	73	81	32	46	49

Table 78 (continued).

Whooping Cough **1933**

Age	Ward No. 1	2	3	4	5	6	7
0	31	28	24	29	42	13	6
1	27	33	35	28	29	21	16
2	32	28	16	21	31	19	12
3	25	40	26	23	45	16	10
4	20	28	18	21	29	18	11
5	67	54	44	27	31	27	31
6	17	23	10	19	19	7	7
7	10	7	6	11	8	4	5
8	4	4	3	2	3	-	-
9	2	2	1	3	4	-	-
10	1	1	-	-	-	-	-
11	2	-	1	2	-	-	-
12	-	-	-	-	3	-	-
13	-	-	-	1	-	-	-
14	-	-	-	-	-	-	-
0 - 15	238	248	184	187	244	125	98
15+	-	1	-	-	-	-	-
All Ages	238	249	184	187	244	125	98

1945

Age	Ward No. 1	2	3	4	5	6	7
0	4	14	5	6	6	8	7
1	8	10	4	9	9	8	3
2	4	13	5	10	7	9	4
3	8	9	12	8	7	7	-
4	4	3	7	6	2	7	8
5	12	23	16	25	9	18	21
6	5	15	6	7	4	8	12
7	3	5	4	4	3	9	4
8	1	2	3	-	1	1	1
9	-	1	2	1	-	-	1
10	-	-	-	1	-	-	1
11	2	-	-	-	-	1	-
12	1	-	-	-	-	-	-
13	-	-	-	-	-	-	-
14	1	-	-	-	-	-	-
0 - 15	53	95	64	77	48	76	62
15+	-	-	-	-	-	-	-
All Ages	53	95	64	77	48	76	62

with its standard error, is illustrated by a fully worked example in Table 79 dealing with Scarlet Fever in 1933 in Ward 1. The age of each case is assumed to be at the middle of each year of age, e.g. all cases aged 1 year and under 2 years are assumed to be aged 1.5 years; cases aged 2 years and under 3 years are assumed to be aged 2.5 years; and so on. Objection might be taken to the placing of all the "under 1 year " cases at 0.5 years, since the majority of these cases actually occur in the second six months of the first year. The approximation is justified, however, by the considerable facilitation of calculation that results and by the negligible error that is introduced. For instance, by the method illustrated, the mean age of attack for Scarlet Fever in Ward 1 in 1933 is 6.662 years. If, alternatively, we allocate the five "under 1 year" cases to their true ages in months, the new mean age of attack becomes 6.665. The difference between the two results is negligible.

The calculation of the mean age of attack is facilitated by the adoption of 'new class marks' (X), based on a working mean arbitrarily placed at 5.5 years, which, in the new working scale, becomes zero. When f is the number of cases at each year of age, and n = Sf, the true mean age of attack is 5.5 + SfX/n. This is greater or less than 5.5 depending on the sign we have to prefix to SfX/n.

The Standard Error of the true mean is $\sigma/\sqrt{n}$ where σ is the standard deviation of the actual ages of attack; i.e.

Table 79.

Calculation of Mean Age of Attack (Cases under 15 years).

Scarlet Fever, 1933, Wardl 1.

Age (Years)	Class Marks	New Class Marks (X)	X^2	Frequency f	fX	$f(X^2)$
0	0.5	-5	25	5	-25	125
1	1.5	-4	16	17	-68	272
2	2.5	-3	9	26	-78	234
3	3.5	-2	4	39	-78	156
4	4.5	-1	1	34	-34	34
5	5.5	0	0	64	0	0
6	6.5	+1	1	43	+43	43
7	7.5	2	4	26	52	104
8	8.5	3	9	21	63	189
9	9.5	4	16	25	100	400
10	10.5	5	25	25	125	625
11	11.5	6	36	12	72	432
12	12.5	7	49	13	91	637
13	13.5	8	64	13	104	832
14	14.5	9	81	7	63	567
		Total		370	+430	4650
		Total / 370			+1.162	12.57
		Square of 1.162				1.35
		Difference = σ^2				11.22
		Standard Deviation, σ				3.3496
		Standard Error, $\sigma/\sqrt{370}$				0.174

Mean Age of Attack (Years) = $(5.5 + 1.162) \pm 0.174$

$= 6.662 \pm 0.174$

Table 80.

Working Totals in Calculation of Mean Age of Attack.

	Ward No.	1	2	3	4	5	6	7
Scarlet Fever								
1933	Sf	370	292	191	161	153	163	177
	SfX	430	286	172	165	68	125	246
	SfX^2	4650	3178	2470	1949	1484	1857	2132
1945	Sf	232	132	100	50	73	77	56
	SfX	274	91	25	27	16	14	67
	SfX^2	3012	1381	929	547	840	700	631
Diphtheria								
1933	Sf	69	65	63	49	49	51	48
	SfX	117	109	94	88	85	105	98
	SfX^2	1029	1155	858	722	601	967	800
1945	Sf	106	88	66	67	26	44	42
	SfX	109	114	26	74	26	55	54
	SfX^2	1199	1210	602	918	244	635	512
Whooping Cough								
1933	Sf	238	248	184	187	244	125	98
	SfX	-355	-402	-337	-308	-457	-241	-144
	SfX^2	1837	1812	1539	1740	2291	937	592
1945	Sf	53	95	64	77	48	76	62
	SfX	-42	-135	-56	-94	-90	-85	-35
	SfX^2	528	735	370	486	412	533	345

Table 81.

Mean Age of Attack, and Standard Error, for Cases under 15 Years of Age. Wards 1 to 7, 1933 and 1945.

Ward No.	1	2	3	4	5	6	7
Scarlet Fever							
1933	6.662 0.174	6.479 0.184	6.401 0.252	6.525 0.262	5.944 0.249	6.267 0.257	6.890 0.239
1945	6.681 0.224	6.189 0.275	5.750 0.304	6.040 0.462	5.719 0.396	5.682 0.343	6.696 0.419
Diphtheria							
1933	7.196 0.418	7.177 0.480	6.992 0.425	7.296 0.484	7.235 0.435	7.559 0.537	7.542 0.510
1945	6.528 0.311	6.795 0.370	5.894 0.368	6.604 0.432	6.500 0.568	6.750 0.541	6.786 0.501
Whooping Cough							
1933	4.008 0.152	3.879 0.137	3.668 0.165	3.853 0.188	3.627 0.155	3.572 0.174	4.031 0.199
1945	4.708 0.420	4.079 0.245	4.625 0.280	4.279 0.250	3.625 0.325	4.382 0.275	4.935 0.291
Persons per Room (1931)	1.8	2.1	2.5	2.0	2.4	2.0	1.3

$\sigma = \sqrt{Sf(X^2)/n - (SfX/n)^2}$. In the worked example, therefore, the true mean age of attack, 5.5 + SfX/n, = 5.5 +(+1.162) = 6.662 years. $\sigma = \sqrt{12.57 - (1.162)^2} = \sqrt{11.22} = 3.3496$. Therefore the standard error, $\sigma/\sqrt{n}$, is ± 0.174.

In exactly similar fashion the mean age of attack and standard error for each of the other wards for 1933 and 1945, for Scarlet Fever, Diphtheria, and Whooping Cough has been calculated. Working totals are given in Table 80, and the full set of results are given in Table 81. The latter table includes the "number of persons per room" for each of the seven wards at the Census of 1931.

It seems obvious, even without subjecting the results to close examination, that at both years the mean age of attack both of Scarlet Fever and Whooping Cough is higher in the two less overcrowded wards, Wards 7 and 1, than in the other five wards. With Diphtheria, on the other hand, no such obvious conclusion can be drawn.

The further investigation of these results will be done in two stages, In the first stage, we shall investigate more closely, without particular regard to changes in the results between 1933 and 1945, the correlation between the age of attack and room density of the wards. In the second stage we shall examine the differences, in the seven wards, between the age of attack in 1933 and 1945.

Stage 1.

As a preliminary measure, let us examine, for each disease and in each year, the mean age of attack in the seven wards, to ascertain whether the differences in the mean age of attack among the wards are statistically significant, or whether, having regard to the varying number of cases occurring in the wards, these differences between one ward and another could have arisen by chance. To do this, we shall employ the statistical procedure known as "Analysis of Variance" a procedure which, so far as I am aware, has not yet been much used in the statistical study of medical data.

The "variance" of a series of variables is the sum of the squares of deviations from the mean of the variables divided by the number of variables, i.e. variance is the square of the standard deviation, and may be represented as σ^2. If we have a series of variables in which x represents the deviation of each from the mean of the series, the variance is Sx^2/n. In a grouped frequency series this would be expressed Sfx^2/Sf, where f is the number of items in each group.

In our present problem, we have seven wards, for each of which we have a grouped frequency series of cases and for each of which we have calculated a mean age of attack. For the whole seven wards taken together, i.e. for the Eastern Division, there is also a mean age of attack which we could have calculated, had we wished, from the ages of all the cases in the seven wards; this we shall call the "general mean". Now the sum of the squares of all the deviations from the general mean may be regarded as consisting of two components,

a) the sum of squares of deviations of the ward means from the general mean, and, b) the sum of squares of deviations of the variables within each ward from the ward mean. By analysis of variance we estimate the relative weight of each of these two components, and thus test whether there is or is not a significant difference between the means of the various wards. We calculate the variance of component 'a' and of component 'b', and find the ratio of the larger to the smaller. If variance 'a' is smaller than variance 'b', there is obviously no significant difference between the ward means. On the other hand, if variance 'a' is greater than variance 'b', we must test the significance of the ratio by reference to a table of variance ratios, (F), such as that of Snedecor, (1946), where values of F are tabulated for varying numbers of variables and degrees of freedom. In each of our present series of analyses, the significant value of F is 2.1 for each disease and at each of the two years.

The arithmetic of the calculations is facilitated by retaining the 'new class marks' introduced for the earlier calculations of the mean age of attack in each ward. A fully worked example will be more useful to describe the method than a long verbal description. Accordingly, in Table 82 will be found the calculation of the analysis of variance for Scarlet Fever in 1933. In Table 83 are given the full series of results for all three diseases in 1933 and in 1945.

In Diphtheria, where the variance is greater within than

Table 82.

Calculation of Analysis of Variance.

Mean Age of Attack, Scarlet Fever, Wards 1 to 7, 1933.

	Total				Wards	Residual
	(1)	(2)	(3)	(4)	(5)	
Ward	Sf	SfX	$Sf(X^2)$	$(SfX)^2$	$\frac{(SfX)^2}{Sf}$	
1	370	430	4650	184900	499.7	
2	292	286	3178	81796	280.1	
3	191	172	2470	29584	154.9	
4	161	165	1949	27225	169.1	
5	153	68	1484	4624	30.2	
6	163	125	1857	15625	95.9	
7	177	246	2132	60516	341.9	
Total	1507	1492	17720		1571.8	
Square		2226064				(3)= 17720
Square/1507		1477.1 - - - - - - - - - - - - -			1477.1	(5)= 1571.8
Differences = Sums of Squares					94.7	16148.2
Degrees of Freedom	1506				6	1500
Variance					15.78	10.77
Variance Ratio						1.5
Significant Ratio						2.1

Result: Not Significant.

Table 83.

Analysis of Variance.

Mean Age of Attack, Wards 1 to 7.

Year	Wards Variance (a)	Residual Variance (b)	Ratio a/b	Result (Sig. Ratio = 2.1)
Scarlet Fever				
1933	15.78	10.77	1.5	Not Significant
1945	21.08	10.58	2.0	" "
Diphtheria				
1933	2.28	12.63	-1	" "
1945	6.35	11.12	-1	" "
Whooping Cough				
1933	5.73	5.25	1.1	" "
1945	10.92	5.99	1.8	" "

between the wards, i.e. variance 'b' is greater than variance 'a', it is unnecessary to calculate the ratio since the result is obviously "not significant". For Scarlet Fever the ratio for 1945 approaches closely to a significant level.

What do we learn from this?. We learn that in the group of wards, Wards 1 to 7, for each disease and at each of thetwo years, having regard to the number of cases occurring in each ward, and the age at which the cases occurred, and having no regard to any other circumstances about the wards, the mean age of attack, taking each disease and each year separately, does not differ significantly between one ward and another, all the seven wards being examined at the same time.

There is however, onecircumstance about the wards in which we are interested and which we must now consider in connection with mean age of attack. This is the room density of the seven wards. We have already observed, in Table 81, an indication of correlation between mean age of attack and room density. This correlation we shall now proceed to measure by means of coefficients of correlation.

The calculation of these coefficients is simple since there are only seven variables, namely the seven wards. It has been further simplified by adopting new class marks both for mean age of attack and for room density. As usual a fully worked example will be given to demonstrate the method. Table 84, therefore, shows the calculation of the coefficient for Scarlet Fever in 1933. Next, Table 85 gives the full set of

Table 84.

Calculation of Coefficient of Correlation between Mean Age of Attack (Scarlet Fever, 1933),(x), and Room Density (y).

Ward No.	Mean Age of Attack (x)	X	X^2	Room Density (y)	Y	Y^2	XY
1	6.7	+7	49	1.8	-2	4	-14
2	6.5	+5	25	2.1	+1	1	+ 5
3	6.4	+4	16	2.5	+5	25	+20
4	6.5	+5	25	2.0	0	0	0
5	5.9	-1	1	2.4	+4	16	- 4
6	6.3	+3	9	2.0	0	0	0
7	6.9	+9	81	1.3	-7	49	-63
Totals		+ 32	206		+ 1	95	- 56

$$\sigma_x = \sqrt{206/7 - (32/7)^2}$$
$$= \sqrt{418}/7$$
$$\sigma_y = \sqrt{95/7 - (1/7)^2}$$
$$= \sqrt{664}/7$$

Numerator $= -56/7 - 1/7.32/7$
$= -424/49$

$$\text{Therefore } r_{xy} = -\frac{424}{\sqrt{418}\cdot\sqrt{664}}$$
$$= -0.8050.$$

Table 85.

Coefficients of Correlation between Mean Age of Attack and Room Density, 1933 and 1945.

	1933	1945
Scarlet Fever	- 0.8050	- 0.8061
Diphtheria	(- 0.6561)	(- 0.6348)
Whooping Cough	(- 0.7127)	(- 0.6392)

Significant Value of r = 0.755

Coefficients in brackets are "not significant".

results for the three diseases at each of the two years.

As is to be expected when only seven variables are being considered, the level of significance for r is very high; by Fisher's 't' method it is ± 0.755. Using this criterion we find that only in Scarlet Fever are the results significant.

We may perhaps at this point compare these results in Table 85 with those of Wright and Wright (1942), who, correlating mean age of attack with substandard housing in the London Boroughs for the period 1924-38, found significant values of r as follows:-

Diphtheria	r	=	-0.704
Whooping Cough	r	=	-0.790

These very high coefficients in Table 85, calculated on only seven variables, are inclined to be misleading and to give the impression of unduly high degrees of correlation. In the seven wards the mean age of attack in any one ward is only very slightly different form that in any other ward. A much truer picture of the degree of correlation that exists would be obtained by calculating the coefficient of correlation between the age and housing conditions of each individual case in the combined seven wards. For Scarlet Fever in 1933, for instance, we should then have a series of 1507 variables, the total number of cases under the age of 15 years that occurred in the seven wards in that year.

With the data at our disposal we know only the age of each case; we do not know the number of persons per room in the house from which each case has come. We know, however, the average number of persons per room in the ward in which that house is situated. Each of the 1507 Scarlet Fever cases in 1933 therefore, can be allocated to one out of 15 age-groups (each age-group being a single year), and at the same time can be allocated to one out of seven degrees of room density, (the room densities of each of the seven wards). With this information we can proceed to calculate coefficients of correlation between room density and age of attack (N.B. Not now <u>mean</u> age of attack).

These calculations are rendered very simple since a great part of the work has already been done in finding the mean age of attack in the wards. Assuming x to represent age of attack and X to be the new class marks, we have already found values for SfX and SfX^2 for each disease and in each ward (Table 80). We have also, in correlating mean age of attack with room density, represented room density by new class marks, Y, each value of Y being a small whole number, (Table 84). It is now a simple matter to find values for SfY, SfY^2, and SfXY, and hence to calculate r_{xy}, the coefficient of correlation between x, the age of attack, and y, the room density. This calculation has been set out in full in Table 86 for Scarlet Fever in 1933. As usual we follow with the full series of results, and these will be found in Table 87. The test for significance has been taken as twice

Table 86.

Calculation of Coefficient of Correlation.

Age of Attack (Scarlet Fever, 1933),(x), and Room Density (y).

Ward No:	1	2	3	4	5	6	7	Total	Total/1507
Sf	370	292	191	161	153	163	177	1507	-
SfX	430	286	172	165	68	125	246	1492	0.9900
SfX^2	4650	3178	2470	1949	1484	1857	2132	17720	11.7585
Y	-2	+1	+5	0	+4	0	-7	-	-
SfY	-740	+292	+955	0	+612	0	-1239	- 120	- 0.0796
SfY^2	1480	292	4775	0	2448	0	8673	17668	11.7240
SfXY	-860	+286	+860	0	+272	0	-1722	-1164	- 0.7724

$$\sigma_x = \sqrt{11.7585 - (0.9900)^2} = 3.2831 \qquad \sigma_y = \sqrt{11.7240 - (-0.0796)^2} = 3.4231$$

$$r_{xy} = \frac{-0.7724 - (0.9900)(-0.0796)}{3.2831 \times 3.4231} = -0.0617$$

Significant Value of r = 2 x Standard Error = $2/\sqrt{Sf}$ = $2/\sqrt{1507}$
= 0.0516

Table 87.

Coefficients of Correlation between Age of Attack and Room Density.

		r	2 x S.E.	Result
Scarlet Fever	1933	-0.0617	0.0516	Significant
	1945	-0.1038	0.0746	Significant
Diphtheria	1933	-0.0365	0.1008	Not Significant
	1945	-0.0559	0.0954	Not Significant
Whooping Cough	1933	-0.0544	0.0550	Not Significant
	1945	-0.0926	0.0918	Significant

the standard error of each coefficient, the standard error being assumed to be $1 / \sqrt{n}$.

Though the values of r are found to be very small, nevertheless some of them do indicate a real association between age of attack and room density. There is a tendency, over a large number of cases, for the age of attack to be higher in the less overcrowded wards, a tendency which, though slight, is of statistical significance for Scarlet Fever in both 1933 and 1945, and for WhoopingCough in1945.

It should be noted that these results can be regarded as true only for the seven wards with which we have been dealing. These seven wards, however, are representative, so far as overcrowding is concerned, of by far the greater part of the whole city; only a small proportion of the total city population live in conditions materially better than those of the best of the seven wards, while the worst of the seven wards are the worst of the city.

Stage 2.

We come now to the second stage of the examination ofmean age of attack in the seven wards, and we shall now studythe difference in mean age of attack in the different wards between 1933 and 1945.

Table 81 gave the mean age of attack in each ward for each disease in 1933 and 1945. From these figures we can now prepare a further table, Table 88, in which are shown i) the differences in mean age of attack between the two years, and ii) these differences expressed as a percentage of the corres-

Table 88.

Differences in Mean Age of Attack between 1933 and 1945.
Actual Differences and Differences as Percentages
of Mean Age of Attack in 1933.

Ward No:	1	2	3	4	5	6	7
<u>Scarlet Fever</u>							
Actual	+0.019	-0.290	-0.651	-0.485	-0.225	-0.585	-0.194
Percent.	+0.29	-4.48	-10.17	-7.43	-3.79	-9.33	-2.82
<u>Diphtheria</u>							
Actual	-0.668	-0.382	-1.098	-0.692	-0.735	-0.809	-0.756
Percent.	-9.29	-5.32	-15.70	-9.49	-10.16	-10.70	-10.02
<u>Whooping Cough</u>							
Actual	+0.700	+0.200	+0.957	+0.426	-0.002	+0.810	+0.904
Percent.	+17.47	+5.16	+26.08	+11.06	-0.06	+22.68	+22.43
Persons per Room (1931)	1.8	2.1	2.5	2.0	2.4	2.0	1.3

ponding 1933 mean age of attack.

In six out of the seven wards, the mean age of attack for Scarlet Fever was lower in 1945 than in 1933. For W hooping Cough the mean age of attack has become higher in each ward. Such changes are in accord with the age-shift of these diseases that was demonstrated for the whole city in Chapter 2. For Diphtheria, however, each mean of attack is lower in 1945 than in 1933; the differences between these two years is not characteristic of the general age-shift of Diphtheria during the wider period of time that we have studied earlier. If we look back to Tables 31 and 33 we see that for the city the age of attack in Diphtheria in 1933 tended to be higher than the average for the quinquennium 1931-35, while in 1945 the age of attack was definitely lower than the average for the quinquennium 1941-45.

In Scarlet Fever the mean age of attack changed least in the two least overcrowded wards, Wards 1 and 7; Ward 1 shows a slight rise, and Ward 7 a slight fall. In the other wards the fall was much greater.

In Diphtheria, the fall in the mean age of attack is certainly no less in the better wards than in the worse.

In Whooping Cough the rise in the mean age of attack occurred especially in the better wards, but was greatest of all in the most overcrowded ward, Ward 3.

Obviously the three diseases have behaved in different ways. The mean age of attack in Scarlet Fever has changed most in the worst wards, in Whooping Cough in the best wards but also in the very worst, and in Diphtheria the changes have been similar in good and bad wards.

It would be most unwise, with such small samples of cases as those with which we are dealing, and with only two years under observation, to attempt to pursue this investigation any further. It is doubtful, indeed, if we are justified in drawing any but the most limited conclusions from the data so far presented in this chapter,

We are fairly safe in concluding that both in Scarlet Fever and in Whooping Cough the mean age of attack is usually lower in the more overcrowded districts; in Diphtheria we cannot be so certain, though there is a tendency (not statistically significant) in this direction.

So far as changes in the mean age of attack in the different wards are concerned, it is of interest to have observed that especially in Scarlet Fever the degree of change may be different in the better wards from the worse. It is unsafe, however, to assume that the changes seen between 1933 and 1945 are necessarily characteristic of these diseases over a wider period of time.

Section 2

The Effect of Differences in Age of Attack upon Ward Fatality Rates

From the previous section we were able to conclude that on the whole the age of attack tends to be lower in the more overcrowded wards than in the less overcrowded wards. But these differences between the bad and the good wards are only of small degree. It will be remembered that Ward 7, the best of the seven wards, comes high in the city's order of least overcrowding, so that it is probable that these seven wards are representative of the living conditions of between 80% and 90% of the child population of the city. Over by far the greater part of the city, therefore, we should not expect the age-distribtion of cases to differ markedly from the range of age-distributions covered by the seven-ward sample. Accordingly over the greater part of the city, the differences in age-distribution of cases between one ward and another will be comparatively small.

In Chapter 2 we saw that there is a strong negative correlation between fatality rates and overcrowding. In Chapter 1 it was seen that fatality rates, high in the first year of life, fall markedly during the succeeding childhood years. We may therefore regard fatality rate as an inverse function of age of attack and a direct function of overcrowding. Hence, since age of attack is lower in the more overcrowded districts, we might be tempted to ascribe the higher fatality rates of such districts purely to the lower age of attack. In the poorer and more overcrowded districts, children are attacked at an earlier age and are therefore more liable to die.

We have, however, just seen that the differences in age of attack between very overcrowded and not very overcrowded wards are comparatively small. Are these differences nevertheless large enough to account for the considerable differences in fatality rates between the good and the bad wards?

It will be remembered that in Chapter 2, Section 5, we examined the effect of age-shift upon city fatality rates by means of standardised fatality rates, the fatality rate for each quinquennium being calculated upon a standard age-distribution of cases, that of the 1916-20 quinquennium. In seeking an answer to the question that has been raised in the previous paragraph, we may adopt the same standardising principle, though the actual method of application must be different. The method employed in Chapter 2 was akin to the "Direct Method" of standardisation in vital statistics. In the present problem the limitations of available data make it necessary to employ the "Indirect Method". Information is not available concerning ward fatality rates for different age-groups, therefore such rates cannot be directly standardised against a standard age-distribution of cases. We do know, however, the fatality rates within different age-groups for the city as a whole both in single years and in quinquennia, (Tables 35 and 36), and these city age-fatality rates may be applied to the age-distributions of cases in individual wards. This maneouvre will yield an "Index Fatality Rate" for each ward, telling us what would have been the city fatality rate if the city had had the same age-distribution of cases as had each ward. The ratio of the standard fatality rate of the city to the "Index Fatality Rate" of each ward gives us a "Standardising Factor" for each ward. The actual fatality rate in each ward multiplied by the standardising factor for that ward yields the "Standardised Fatality Rate" of the ward.

We may in this way obtain a standardised fatality rate for each of the seven wards with with we dealt in the last section, i.e. Wards 1 to 7. These standardised fatality rates are of course fictitious rates. Their purpose is to allow us to compare the actual fatality rates of different wards after allowance has been made for the differing age-distributions of cases among these wards.

It is not a matter of critical importance which standard we choose to employ as the standard age-distribution of fatality rates, provided it is one which is not too dissimilar from that of the wards we wish to examine. The standard that has been here adopted is the city age-fatality rate distribution for 1931-35, (Table 36.)

The first step is to calculate the index fatality rate and hence the standardising factor for each of the seven wards. Knowing the age-distribution of cases in each ward in 1933 and the age-distribution of fatality rates for the city in 1931-35, we calculate from these the index fatality rate for each ward. An example of the calculation is given in Table 89, dealing with Scarlet Fever in Ward 1. The index fatality rate is found to be 1.1 The fatality rate for the city in 1931-35, also 1.1, is now divided by the ward index fatality rate, and we get a standardising factor for Ward 1 of 1.00. Similarly index fatality rates and standardising factors are calculated for the other wards and for the other two diseases, Diphtheria and Whooping Cough. The full series of results are given in Table 90.

If we now multiply the actual fatality rates of the individual wards by the appropriate standardising factors, we get standardised ward fatality rates. Although the standardising factors have been calculated from the 1933 age-distributions of ward cases, the factors can be employed to standardise the fatality rates not only of 1933 but of any other period of time in which the age-distribution of cases has not departed grossly from that of 1933. In the next two tables, Tables 91 and 92, are shown the standardised fatality rates for Wards 1 to 7 for the single year, 1933, and also for the 15-year period, 1924-38, the standardisations in both instances being based on our 1933 age-distribution of ward cases. While we cannot be sure that the age-distribution of cases in the 1924-38 period can be safely represented by that of 1933, this standardisation has been done because the character-

Table 89.

Calculation of Index Fatality Rate and Standardising Factor.

Scarlet Fever, Ward 1, 1933.

Age-Group	City Fatality Rates (1931-35)	Cases (1933)	100 x Expected Deaths
-1	9.3	5	46.5
-2	4.3	17	73.1
-5	1.5	99	148.5
-10	0.6	179	107.4
-15	0.5	70	35.0
15+	1.1	37	40.7
All Ages	1.1	407	451.2

Index Fatality Rate = 451.2/407 = 1.1

$$\text{Standardising Factor} = \frac{\text{City Fatality Rate}}{\text{Index Fatality Rate}} = \frac{1.1}{1.1} = 1.00$$

Table 90.

Index Fatality Rates and Standardising Factors, Wards 1 to 7, 1933.

Ward No:	1	2	3	4	5	6	7
Scarlet Fever							
Index Fatality Rate	1.1	1.1	1.2	1.2	1.2	1.1	1.0
Standardising Factor	1.00	1.00	0.92	0.92	0.92	1.00	1.10
Diphtheria							
Index Fatality Rate	5.3	5.1	5.1	5.2	4.7	4.8	4.7
Standardising Factor	0.98	1.02	1.02	1.00	1.11	1.08	1.11
Whooping Cough							
Index Fatality Rate	4.4	4.4	5.3	5.3	5.4	4.7	3.7
Standardising Factor	0.86	0.86	0.72	0.72	0.70	0.81	1.03

Table 91.

Actual and Standardised Ward Fatality Rates, 1933.

Ward No:	1	2	3	4	5	6	7
Scarlet Fever							
Actual Fatality Rate	0.5	1.5	2.4	0.6	2.4	1.7	1.9
Standardised " "	0.5	1.5	2.2	0.55	2.2	1.7	2.1
Diphtheria							
Actual Fatality Rate	6.4	5.1	1.3	5.6	5.5	0.0	3.3
Standardised " "	6.3	5.2	1.3	5.6	6.1	-	3.7
Whooping Cough							
Actual Fatality Rate	5.1	5.6	4.3	7.5	5.3	4.8	3.1
Standardised " "	4.4	4.8	3.1	5.4	3.7	3.9	3.2
Room Density (1931)	1.8	2.1	2.5	2.0	2.4	2.0	1.3

Table 92.

Actual and Standardised Ward Fatality Rates, 1924-38.

Ward No:	1	2	3	4	5	6	7
Scarlet Fever							
Actual Fatality Rate	1.0	1.3	1.9	0.9	1.7	1.2	1.3
Standardised " "	1.0	1.3	1.8	0.8	1.6	1.2	1.4
Diphtheria							
Actual Fatality Rate	5.2	4.9	7.0	5.9	7.2	4.8	4.0
Standardised " "	5.1	5.0	7.1	5.9	8.0	5.2	4.4
Whooping Cough							
Actual Fatality Rate	4.6	4.3	5.8	6.5	6.2	6.7	2.7
Standardised " "	4.0	3.7	4.2	4.7	4.3	5.4	2.8
Room Density (1931)	1.8	2.1	2.5	2.0	2.4	2.0	1.3

istically higher fatality rates in the more overcrowded wards are much more apparent over the longer period of years than in the single year 1933.

In Scarlet Fever and Diphtheria, the standardising factors are all very close to 1,00, so that standardisation does not markedly alter the actual fatality rates. In Whooping Cough, however, there is, in most of the wards, quite a marked difference between the actual and the standardised rates.

If differences in the age-distribution of cases in the different wards had been the sole reason for the differences in ward fatality rates, the standardised fatality rates, in which allowance is made for these differences in age-distribution of cases, should for each disease, be the same in each ward. We see, however, that in Scarlet Fever and in Diphtheria the standardised rates for the seven wards remain almost the same as the actual rates. In Whooping Cough, where the effect of standardisation is more apparent, the fatality rates in the good wards and in the bad wards are brought more closely together. Nevertheless, the differences are not smoothed out and the fatality rates of the worse wards still tend to be higher than those of the better wards.

We must conclude, therefore, that a lower age of attack in the more overcrowded wards is not the only factor that causes the fatality rate in these wards to be higher than that of the less overcrowded wards.

CHAPTER 5

Discussion.

Section 1

The Declining Fatality Rates.

In our review in Chapter 1 of the trend of morbidity, mortality and fatality rates for the city from 1916 to 1945, we saw that the outstanding feature in the behaviour of the four diseases was a marked and progressive reduction in fatality rates.

What reasons can we offer to account for this reduction in fatality rates?

We must first consider whether the apparent decline is real; do the fatality rates presented in the tables, calculated on the basis of so many reported deaths per 100 reported cases, truly indicate the actual fatality rates of the four diseases? So far as reported deaths are concerned, it is a reasonable assumption that when one of the diseases is stated to have been the cause of a death, the diagnosis was probably accurate. On the other hand it is generally recognised that there exists a wide margin of error between reported and actual cases, an error which operates in both directions - failure to recognise and report actual cases, and the reporting of cases which, had a correct diagnosis been made, would not have qualified for notification.

Differences in standards of notification render it a precarious matter to compare incidence between two different localities. Similarly in one locality the standards of notification may have changed in the course of a score or more of years. Parents might become more ready to call in a doctor, and the doctor might become more ready to notify mild, early, atypical, and doubtful cases.

A failure of the morbidity rate to decline when the rate is based on total population, indicates an increasing morbidity rate when the rate is based on child population, since the proportion of children in the total population has been fairly rapidly diminishing. It may be that this apparent failure of the morbidity rates to fall is due to improved standards of ascertainment of cases, e.g. by better notification. On the other hand, it may be that as the proportion of children declines the morbidity rates may actually be rising.

But however much we may agree that notifications, as a measure of actual morbidity, are inaccurate and liable to give a false impression that fatality rates have altered when actually it is the notifications that have altered, it is certain that a very considerable decline in fatality rates has taken place. Accepting it as a fact, therefore, that the apparent decline is substantially real, let us now consider the factors that may have brought it about.

1. Variations in the Lethality of the Infecting Organism.

Scarlet Fever has, as we know, over the course of the last few centuries, fluctuated in prevalence and severity. It seems impossible to ascribe these fluctuations solely to variations in the influence of such factors as climate, hygiene, treatment, or living conditions. It is more probable that the virulence of the causative organism has varied. Not merely have there been variations in the Scarlet Fever death rate, but the clinical character of the disease has from time to time undergone striking changes, at one period manifesting itself with all the symptoms and signs of a severe toxaemia and invasion, and at another period, such as in recent years, being a relatively mild, uncomplicated, and often trivial infection. Something will be said later concerning the part played by the many types of haemolytic Streptococcus in producing the syndrome we designate as "Scarlet Fever", and we shall meantime pass on to the other diseases.

Prior to 1931 it had, of course, been realised that Diphtheria varied in severity from time to time and from place to place. In 1931 the publication of the work of Anderson, Happold, McLeod, and Thomson, in which the three main types of C.diphtheriae were described, initiated a new phase in the study of Diphtheria. The bacteriological typing of C. diphtheriae has become a routine procedure in many laboratories and in recent years much information has been obtained about the relative predominance of the three types and about their associated clinical features. In subsequent work the three main types have been subdivided, and it is now known, for example, that different subtypes of gravis may be responsible for either mild or severe infections. In Glasgow, where Carter has done much of this work, we mentioned in Chapter 1 that the gravis type which became predominant in 1938 was not a particularly lethal variety though productive of a sharp rise in prevalence. In other cities, the temporary introduction of a highly virulent strain has resulted in a greatly increased fatality rate. In Leeds, for instance, a virulent gravis strain caused a high fatality rate during 1931 and 1932. By 1935, however, this strain had been largely replaced by mitis and the resulting clinical type of Diphtheria was much less fatal (Cooper, Happold, McLeod and Woodcock, 1936). Similarly, in Hull, the predominance of the atypical gravis strain, E.C.4., was attended in 1941 by a high fatality rate (Leete, 1944).

Unfortunately we have no accurate knowledge of the bacteriological types of C.diphtheriae that were predominant prior to 1931. It is probable, however, that some of the temporary rises in fatality-rates that have occurred have been due to the temporary appearance of a more lethal strain.

We have seen that, in Glasgow, the trend of fatality in Diphtheria has been progressively downwards for at least the past 30 years. It is hardly feasible that from year to year, with minor variations, ever milder and less lethal types of C.diphtheriae have found their way into Glasgow to produce a progressively declining fatality rate. There is no evidence to support the suggestion that the sustained diminution in fatality has been due to the progressive predominance of strains of diminishing lethality.

Concerning variations in the virulence of the virus of Measles, there is nothing that can profitably be said at present. The study of viruses is a rapidly developing branch of bacteriology, and it is probable that, in the near future, much more will be known about their nature and habits. We do know that the apparently same virus can exist in several forms, possessing differing degrees of virulence. For instance, there are grounds for the belief that the virus of Variola Major, of Variola Minor, and of Vaccinia, are all essentially the same virus exhibiting constant differences in virulence (Harries and Mitman, 1947, p.305). Although there is at present no evidence, it is possible that variants of the Measles virus may also exist. It was Brownlee's view that the decline of a Measles epidemic was due to a loss of virulence by the virus rather than to an increased resistance in the exposed population.

Clinically there is nothing to suggest that Measles is a milder infection now than heretofore. Most children are still attacked during the course of their childhood years, some early, some late, some mildly, and some with severe and complicated illness. There is no evidence that Measles is now less fatal due to some change in the character of the Measles virus.

We are still very much in the dark about possible variations in type of H.pertussis. In culture, rough and smooth phases of the organism can be recovered. The existence of a "Para-pertussis" variant has recently been suggested. But on the whole the position is much the same as with Measles. We do not know what part is played by variants of the organism, if such variants exist, and there is no reason to believe that Whooping Cough has become less lethal due to diminished virulence of the causative organism.

2. Increased Resistance of the Host.

Are the children of Glasgow, while still as liable as ever to be attacked, more able, by reason of an enhanced resistance, to overcome the effects of attack?

We have seen that the age of attack is an important factor with regard to fatality. But we have also seen, in Chapter 2, that though there has been, in three out of the four diseases, an age-shift of attack to a more favourable age, this age-shift cannot by any means fully explain the reduction in fatality rates that have occurred. Only in Diphtheria was there more than a minimal difference between the actual and the standardised rates, and even in Diphtheria it was evident that the fall in fatality attributable to age-shift was much less than that due to other causes, whatever those other causes may have been. The later age of attack cannot therefore be regarded as a factor contributing to a material extent to the reduction in the fatality rates.

Apart from age there are numerous other factors influencing individual resistance; these, however, we shall discuss under the next heading.

3. Social and Environmental Factors

The importance of a good nutritional state was referred to early in this work, when it was stated that it was a factor of importance in preventing death, rather than in preventing attack. We are not, however, in a position accurately to determine the part that improvements in standards of nutrition have played during the course of these 30 years that have been under review. Nevertheless the part played has no doubt been one of importance especially in reducing fatality among the poorest and formerly most undernourished section of the population.

Overcrowding in those districts that were formerly grossly overcrowded has been reduced, due partly to the falling birth rate and partly to the provision of new houses. It has been shown how close is the correlation between overcrowding and fatality rates and it must be assumed that a part of the decline in these fatality rates has been brought about by imrpovements in housing conditions. It was observed that the decline in fatality was rather greater in the worst than in the best districts.

There has taken place what may most conveniently be described as an improvement in standards of living. Children of all social classes, but probably more especially in the worst, have become better fed, better housed, better clothed. and receive more fresh air and sunshine. Health education, a growing part of the work of the Public Health Department, has made parents more aware of their responsibilities and more willing and able to carry them out. As a result the child of today is less likely to die as a result of the infectious diseases of childhood.

A part, and perhaps a major part, of the credit for the decline in fatality rates must be given to the preventive and curative services. While we saw no definite evidence as yet of a dramatic reduction in the fatality rates of Diphtheria as a result of the Immunisation Campaign, the evidence that immunised children are less likely to die is convincing. It is safe to say that but for the campaign the reduction in the last quinquennium would have been less.

Sulphonamides and Penicillin have found an effective place in the treatment of what were formerly often fatal complications of the four diseases, and as a result have contributed to the decline in fatality. But these new chemotherapeutic and antibiotic agents are only of limited usefulness — in Diphtheria, Penicillin as an adjunct to anti-serum has so far been used only experimentally, (e.g. Long, 1947), and it would be wrong to claim that they alone have completely changed the trend of fatality rates. The decline in fatality rates was a process that was taking place at a rapid pace long before the new drugs were introduced.

In a more general way the Public Health services, the general practitioners, and the public are all taking a more active part in their efforts to minimise the severity of these diseases of childhood. The lives of children have become more important than once they were. It is recognised that while every life cannot be saved it is inexcusable that a child should die from one of these common infectious diseases until every effort of modern medicine has been made to save it. The earlier calling in of the doctor, a more acute perception by the doctor that a life may be saved by prompt and effective treatment, the availability of a hospital bed for every serious case, a well-trained and enthusiastic hospital staff, all these have contributed towards the reduction in fatality.

It will be realised, therefore, that there is no one factor which has been responsible for all or even most of the reduction in fatality. The several factors that have been mentioned have each contributed to a greater or a lesser extent. Each factor alone is only of limited importance, but each has played its part.

There is no reason to believe that further improvements will not take place. It is to be hoped that the reduction in fatality that has so far occurred is but the commencement of an accelerating process leading to the total elimination of death as an outcome of these infectious diseases.

Section 2

Age-Shift in Morbidity.

The infectious diseases of childhood are so called because children are chiefly attacked. Children are attacked not because of their younger age, their smaller size, their less robust constitution, but because of their lack of previous contact with the infection. Adults, most of whom have experienced such previous contact, enjoy a relative immunity. The causative organisms, so far as we know, have no special affinity for a young host; the susceptibility of children is the result not of weakness but of inexperience.

The history of Small-pox in this country gives us an enlightening example of the behaviour of a highly infectious disease introduced de novo into a susceptible population. In India, Small-pox has been known since the beginning of history. During the Dark Ages the disease occurred frequently in the Near East, and it was presumably Small-pox that caused the abandonment of the Seige of Mecca in 570 A.D. (Stallybrass, 131, p.475). Until the epidemics of 1628 and 1634, there does not appear to have been much Small-pox in England. In these first epidemics, and throughout the rest of the 17th century, the disease especially attacked young adults and among them produced its highest fatality. By the middle of the 18th century Small-pox was firmly established, and every person living in England or at any rate in the

the cities, was being frequently exposed to infection; and by now Small-pox had become a disease predominantly of childhood. "No mother could call her child her own till it had had Small-pox". During the next, i.e. the 19th century, the pendulum began to swing in the other direction. The disease became less prevalent, and finally died out. But as it did so once more the weight of the attack was concentrated not on children but on young adults, "and this change was by no means wholly due to vaccination in infancy protecting the younger children" (Burnet, 1940, from whom this account of Small-pox has largely been taken).

Thus we have seen the full cycle from the first appearance to the practical disappearance of an infectious disease. When the disease has become fully endemic, only the youngest members of the community are susceptible to its attack. But as prevalence diminishes the young adult population no longer enjoys the same degree of relative immunity, until finally it is they, and not the children, who are chiefly attacked.

This is an example of long-term age-shift, a process connected with the epidemic-endemic relationship between the population and the disease.

Can we on the same basis explain the age-shifts that were demonstrated in Chapter 2? Is the endemicity of Scarlet Fever increasing, and of Diphtheria, Measles and Whooping

Cough decreasing? Surely one of the features of the trend of these four diseases during the 30-year period has been the maintenance of morbidity at a fairly constant level. Apart from periodic fluctuations, and a wartime decline in Measles, each of the diseases is occurring as frequently as it did 30 years ago. There is nothing to suggest that any of them is becoming more, or less, endemic.

The next possibility that may be discussed is that there has been some change in the pathogenic organism so that it tends to attack a different age-group. We assume that children are attacked more often than adults because of the immunity that adults have acquired from past exposure. If, however, there occurs a change in the strain of prevailing organism, it might be that the new strain was one of which the older children and adults in the community had no previous experience. Their advantageous position and relative resistance would cease to exist. While the younger children would be in the same immunological state towards the new as towards the former strain and would not necessairly be attacked any more frequently than before, there would be an absolute increase in the number of cases among the older children and the adult population. As a result there would be a relative age-shift of incidence towards the adult side.

In view of our knowledge of different strains of C.diphtheriae, the above suggestion seems at first worthy of some consideration. But if our present knowledge of these strains is accurate, the suggestion becomes untenable. In Glasgow, as we know, the change-over in predominance from intermedius to gravis took place in 1938. There has been no sudden change in age-distribution of Diphtheria cases at or about the same time. Age-shift in Diphtheria has been a process that has been more or less continous from at least 1903. It is difficult to conceive that this long-continued process could have been due to a continuing change in the predominant strain of causative organism.

A further objection is that there are at present no gounds for believing that differing antibody reactions are produced in response to infection by different strains of C.diphtheriae. While some recent doubts have been cast on this view, by reason of the less effective protection given by the standard prophylactic toxin (Park-William) against gravis infections than against infections by other types (e.g.Russell, 1943), these doubts seem adequately met by attributing to gravis a higher degree of invasiveness with more rapid toxin-production and tissue-fixation than that of other types. Thus prophylaxis will be less effective against the more agressive type. There is no reason, therefore, to suppose that adults protected by previous contact with one strain should be at a relative disadvantage or, rather, cease to have an advantage, when the prevalent strain undergoes a change. Their immunity is to all strains, and a strain sufficiently virulent to overcome their immunity will attack much more readily young children who have no immunity of any sort. Accordingly, we have no reason to expect any change in the age-distribution of attacks. This view is supported by Burnet, who, without offering grounds for his opinion, expresses himself thus (1940, p.195):- "When a new, more virulent strain appears in a community, the increase in the number of cases is chiefly due to an increase in the ratio of clinical to sub-clinical cases. In all such outbreaks due to a more virulent type of a micro-organism already endemic the age-distribution of disease remains much the same as previously. Even the sudden widespread appearance of Diphtheria in many parts of the world around 1858 affected almost entirely young children. So did the more severe epidemics of Scarlet Fever which occurred ten or twenty years later".

It was the view of Sir Shirley Murphy, (1907), that the age-shift in mortality in Diphtheria which he showed to have occurred in London at the end of the last century was due to the increasing aggregation of children in elementary schools. Applying the same hypothesis to morbidity, it breaks down completely in view of the continuation of age-shift though so many years.

A fourth possible explanation for age-shift, and one which too we are unable to support, is that while the age of attack has remained constant within the different social groups, there has been a transfer of cases from one social group to another. If, in a social group in which the age of attack is always high, an increasing number of cases tend to occur, then for the city as a whole the net result would be an age-shift from a lower to a higher age. In Chapter 3, Section 2, we saw that in Scarlet Fever and Diphtheria the attack rate was falling in the better groups of wards, and rising in the worst. In Measles and Whooping Cough the movement was in the opposite direction. Now in each disease the mean age of attack is slightly higher in the better than in the worse wards. Thus, a relative fall in incidence in the good wards, as in Scarlet Fever and Diphtheria, would have the effect of lowering the age-distribution of cases for the city; and similarly a relative rise in incidence in the good wards, as in Measles and Whooping Cough, would raise the age-distribution for the city.

But here we are faced with the difficulty that this suggestion postulates for Diphtheria an age-shift which is actually in the opposite direction to that which has occurred. Further, as we saw in Chapter 4, when we examined the age of attack in seven wards in 1933 and 1945, the age of attack in each ward, at least in Diphtheria and Whooping Cough, did not remain steady but moved up or down with changes in the age-distribution of cases for the whole city. It does not seem that age-shift for the city as a whole can, therefore, be explained by the relative transfer of cases from an environment where age of attack remains low to one where the age of attack remains high.. In the absence of very much more complete data concerning changes in incidence and age of attack in the different social environments, with which a much fuller examination of the problem might have been made possible, we shall have to regard this fourth possibility as highly doubtful.

The fifth and final suggestion that will be put forward to account for age-shift in morbidity concerns the different speeds at which the birth rates have diminished and living conditions have improved in the different social groups of the community. We are not concerned, however, with the effect of the diminishing birth rate upon the age-constitution of the population. We have already seen that age-shift cannot adequately be explained by this altered age-constitution of the population. What we are now interested in is the smaller family size and the reduction in overcrowding that have been the results of the diminished birth rate.

Gegenbauer (1937, quoted by Wright, 1939) thought that age-shift in Diphtheria might be associated with, i) a lack of Diphtheria in post-war years, and a consequent increase in the number of unimmunised children in the later age-groups, and ii) the larger number of small families, which results in a larger number of children having their first encounter with infection in their school years.

In support of the second of these two factors, evidence of a most convincing character has been produced by Cheeseman, Martin and Russell, (1939), in their very thorough investigation into variations in age-incidence of Diphtheria in London. Russell,(1943), has summarised some of the results of this investigation in a later table, which is worthy of reproduction, (Table 93), though dealing not with case rates, but with death rates. It is obvious that in the best social group there has been a very constant ratio of death rates between the 0-5 and 5-15 age-groups. In the worst social group, however, this ratio has rapidly diminished, indicating a relative transfer of deaths from the lower to the higher age-group.

In addition to demonstrating an age-shift of deaths and showing that it has occurred chiefly in the worst social group, Cheesman,Martin and Russellwere able to demonstrate that an age-shift of morbidity had also occurred, again chiefly in the worst social group.

It seemed to them desirable to attempt to demonstrate which of two possible factors operating in the worst social group was the major cause of the age-shift, i) reduction in family size, or ii) environmental inprovement. With both of these factors changes had been much greater in the worst than in the best social groups. By means of coefficients of partial correlation they showed that reduction in family size was the more important factor.

Table 93.

Death Rates from Diphtheria per 10,000 of the Population, and the Ratio of the Death Rates at Ages 0 - 5 years to those at Ages 5 - 15 years in Two Groups of London Boroughs representing Social Class I (best social conditions) and Social Class IV (worst social conditions). (Russell).

Years	Social Class	0 - 5	5 - 15	Ratio
1911-13	I	5.51	2.61	2.11
	IV	9.36	1.47	6.37
1919-23	I	11.09	4.98	2.23
	IV	19.05	4.37	4.36
1929-33	I	5.23	2.42	2.16
	IV	7.23	1.93	3.75
1937-38	I	3.63	1.75	2.05
	IV	3.74	1.62	2.31

It is an attractive hypothesis that in the poorest districts where, during the last half-century or so, environmental improvement and decline in birth rate have been considerably greater than in the best districts and where, as a result, standards of living have been rising and approaching towards those of the best districts, the age of attack and of death in Diphtheria has also been approaching towards that of the best districts. The result, for the area as a whole, is an age-shift of cases and of deaths to a later age. It is difficult to find fault with this explanation of age-shift in Diphtheria in London. The investigation was carefully and thoroughly carried out, and the statistical evidence is convincing.

Can we explain in similar fashion the age-shift of Diphtheria in Glasgow, and is the same explanation applicable also to Measles and Whooping Cough? We have seen that it is in the worst districts of Glasgow that the birth rate has most rapidly declined. In the best districts the birth rates seems actually to have risen. Presumably, therefore, the size of the families in the worst districts is falling and approaching that of the best districts. Hence the age of attack may be fising in these worst districts and producing an age-shift for the city as a whole, in the same way as happened in London. In our investigation of age of attack in seven wards in 1933 and 1945, (Chapter 4, section 2) we were unable to show that in Diphtheria and Whooping

Cough changes in the mean age of attack were any greater in the worst than in the better wards. But perhaps a more extensive survey, with more wards and over a wider period of time, might have brought to light evidence of such changes.

It has not been possible to show that the same explanation that best accounts for age-shift in Diphtheria in London also accounts for age-shift in Glasgow. Nevertheless, it seems that in Glasgow the age-shift in Morbidity in Diphtheria, Measles, and Whooping Cough can best be explained by a more rapid reduction in birth rate and in family size with a consequent raising of the age of attack in those parts of the city where poverty and overcrowding have been greatest.

The age shift in morbidity in Scarlet Fever, opposite in direction to that of the others, will require special discussion. This we shall leave over to Section 4, and we shall meantime pass on, in the next section, to the discussion of age-shift in mortality.

Section 3

Age-Shift in Mortality.

In 1937 Picken pointed out that the age-shift in Diphtheria that had been described by several writers had, in almost all instances, been an age-shift in mortality. Only Chalmers (1913) had produced evidence of an age-shift in morbidity. Mortality being the resultant of morbidity and fatality, Picken proceeded to explore these two factors to determine whether one or other was the more concerned in producing age-shift in mortality. His conclusion was that age-shift in mortality was due in London to a change in age-fatality. In Manchester and to some extent in Glasgow he was able to demonstrate a similar change in age-fatality. "In all three cities the most prominent factor in the recent increase, or arrest in the decline, of fatality at all ages under 15 years has been a rise in fatality at ages 5-10, although the small changes in Glasgow are equivocal".

We may in this connection refer to Table 36, where we see that from 1926-30 to 1931-35 the fatality rate of Diphtheria in Glasgow rose from 3.3% to 4.2% in the -10 age-group. But the rise in the -15 age-group from 1.2% to 2.4% was relatively greater. In all of the other age-groups, as we previously observed, a uniform decline in fatality has taken place.

In Glasgow the ageshift in mortality in Diphtheria from the earlier to the later age-groups has been the result of age-shift in morbidity rather than to change in age-fatality. Only in the -15 age-group has the fatality rate failed to decline or at least to decline as rapidly as in the other age-groups.

In the other three diseases we do not find this close parallelism between age-shift in mortality and in morbidity that we find in Diphtheria. This, we saw, was due to different rates of decline of fatality in the different age-groups, the rate of decline being much slower under one year and over ten years of age than in the intermediate age-groups.

What reasons can we offer for these different rates of decline in fatality at different ages?.

In the first place, the fatality rates in the higher age-groups are always very much less than in the lower age-groups. Speaking of the relative failure of fatality rates in the higher age-groups to decline, Hedley Wright (1939) said,"This may simply mean that it is easier to affect a rate which stands at 20% than one which stands at 10% or less". In other words, in the lower age-groups there has been more room for improvement than in the higher age-groups and consequently a relatively more rapid improvement has taken place.

A second possibility is that the different rates of decline in fatality reflect some special age-affinity between organism and host. Either the organism has retained an enhanced lethality for certain age-groups, or these age-groups have remained unduly vulnerable. But at present such a possibility must remain no more than pure speculation.

A third and again very doubtful possibility is that relatively more cases at later ages are occurring in the worst social environments where, at all ages, the fatality rate is higher than in the better districts. This would tend to increase the fatality rate at higher ages for the city as a whole. It is most unlikely, however, that the marked differences in the rates of decline of fatality at different ages could be explained in this way.

If the first of these three suggestions were the true explanation, then in the first year of life, in which the fatality rate is highest, the relative decline in this rate should have been greatest. But we have seen that this has not happened. In Scarlet Fever, Measles and Whooping Cough, the -1 year fatality rate has failed to fall as rapidly as in the -2, -5 and -10 age-groups. Why should the fatality rate within the first year of life have failed to come down as rapidly as at pre-school and early school ages?.

Perhaps the apparent trend of fatality in the -1 age-group is false. Practitioners may perhaps nowadays be more hesitant to notify as suffering from these infectious diseases infants in their first year of life; fewer notifications, the real number of cases and deaths remaining constant, will produce an apparent rise in fatality rate. It is not evident why Diphtheria should have been excluded from such a possible reluctance to notify; and while there is, in Scarlet Fever, some justification for caution in notifying cases occurring in the first year of life, it is difficult to see why a similar attitude should have been adopted with regard to Measles and Whooping Cough.

Perhaps on the other hand the trend of fatality at pre-school and early school ages is false, due to improved measures of ascertainment of cases at these ages. If cases previously missed at these ages are now being reported, an artificially accelerated decline in fatality rate would result. Hence the fatality rate in the -1 year age-group would appear to be falling less rapidly.

If, however, we accept it as a fact that in the first year of life the fatality rate has fallen less rapidly than at later ages it is difficult to offer any satisfactory explanation of why this should be so. It cannot be due to a less effective response in infancy to Sulphonamide therapy since the slower decline in fatality in the first year was clearly visible long before the introduction of Sulphonamides. It would be unreasonable to suppose that the organism that attacks infants is different in its lethality from that which attacks older children; infants have failed to develop resistance to the effects of attack to the same extent as older children. Whatever factors have been instrumental in increasing the resistance of older children have been less effective in infancy.

The relatively high fatality rate within the first year of life, and the failure of this rate to decline to the same extent as at later ages constitutes one of the remaining serious problems in the elimination of these diseases as a cause of death among children.

Section 4

The Anomalous Behaviour of Scarlet Fever.

In Chapter 2 it was seen that in Diphtheria, Measles, and Whooping Cough there had been an age-shift in morbidity towards a later age. In Scarlet Fever there had been an age-shift in morbidity towards an earlier age (excluding the first year of life). In Chapter 4 it was seen that this age-shift in Scarlet Fever seemed to have been occurring especially in the more overcrowded wards of the city.

Here then we have a disease behaving in a manner different from that which we might expect. Falling birth rate, changes in the age-constitution of the population, diminishing family size, improvements in social environment, all these might lead to a later age of attack. But in Scarlet Fever the age of attack has moved to an earlier, not a later, age.

Moreover, the incidence of Scarlet Fever is apparently no greater in districts that are grossly overcrowded than in districts that have little or no overcrowding. In fact, in proportion to the number of children living in the various grades of social enviroment, Scarlet Fever seems to be conspicuously more prevalent in the better enviroments than in the worse. In the other disease any tendency in this direction is very slight, though rather more in Diphtheria than in Measles and Whooping Cough.

It has been seen, too, that while this negative correlation between Scarlet Fever case rates and overcrowding has been maintained at least since the beginning of this century, there are now some indications that the degree of negative correlation is becoming less, the relative excess of prevalence in the best wards having been reduced.

On the other hand, the fatality rate of Scarlet Fever follows the general rule, and is invariably higher in the poorer districts.

The mean age of attack in Scarlet Fever was found to be higher in the better than in the worse wards. This finding is of some importance. In view of the other "abnormalities" of the disease that have been demonstrated it would have been no more remarkable if the mean age of attack in the better wards had been found to be lower than in the worse. We might then have attempted to explain the "downward" age-shift in Scarlet Fever, by suggesting that, as social improvement took place in the worse wards, the age of attack in these wards had dropped towards that of the better wards. We might then, however, have some difficulty in accounting for the lower age of attack in the better wards. This difficulty does not, of course, arise, since there is no reason to doubt that the age of attack is definitely higher in the better than in the worse wards. But a problem of at least equal difficulty arises; if the age of attack in the worse wards is already lower than in the better wards, and in the worse wards the age of attack is becoming still lower, while it remains stationary in the better wards, the age of attack in the worse wards, in which social conditions are improving, and therefore approaching towards those of the better wards, is lowering away from, instead of rising towards, the age of attack in the better wards.

Our object now is to try and offer a solution to this apparent problem, and at the same time explain the downward age-shift in morbidity for the city and the relatively higher, but diminishing, prevalence in the better districts.

Discussing his findings in Glasgow that as overcrowding increased, the incidence in Scarlet Fever decreased, Brownlee commented "No matter how much stress may be laid on the lack of notification in the lower (i.e. more overcrowded) parts of the city as explaining the discrepancy, such a difference cannot be explained away". (Woods, 1933).

On the other hand, discussing the same discrepancy in Liverpool, Stallybrass (1931, p.459) says, "This observation is, in my opinion, entirely fallacious and the true incidence, as shown by the results of Schick and Dick tests, is probably heavier in the more crowded zones, but owing to more frequent failure on the part of parents to consult a doctor in the poorer parts, a large number of cases escape notification". In support of this view, Stocks (1933) states that there are good reasons for believing that while notifications in general are deficient they are especially so in the lower social districts.

The acceptance of this hypothesis that notifications in the worst districts have been defective provides us with a full explanation for all the apparent abnormalities that we have seen. The missed cases in the poorer districts would on the whole have a lower age of attack than would the cases actually notified for the whole city. Improvements in the standards of notification would have the effect, therefore, of increasing relatively the number of cases in the lower age-groups, and there would occur, for the city as a whole, an apparent age-shift towards an earlier age. Moreover, the uncovering of these missed cases in the worst districts would have the effect of reducing the relative excess of prevalence in the better wards, and so diminish the degree of negative correlation that has existed between case-rates and overcrowding. In would, too, probably have the effect of bringing down the mean age of attack in the worst wards.

The completeness with which this hypothesis of defective but improving notifications accounts for the facts renders it an attractive one. But it is not necessarily the true explanation. Admittedly the signs of the presence of Scarlet Fever often are slight and fleeting, and might be more often missed in the slums than in the better districts. The parents might have been less ready to call in a doctor. But is that enough to account for the missing of perhaps a thousand or more cases of Scarlet Fever in the poorer districts in a year? As parents have become more vigilant and more ready to call in a doctor, the disease has been becoming milder and perhaps less easy to recognise; thus, even with improved standards of notification, more cases are not necessarily being reported.

It is, moreover, an undoubted fact that the general public in Glasgow regard Scarlet Fever, while not necessarily as a dangerous disease, at least as a serious one. The reputation for deadliness which Scarlet Fever acquired in the latter half of the last century has been slow to die. While Measles and Whooping Cough are regarded as trivial afflictions from which most children will soon recover at home, notification, the "fever" ambulance, hospitalisation, and household disinfection all testify to the public the seriousness of Scarlet Fever. It is doubtful, therefore, in these circumstances, that the number of cases that have escaped notification is sufficient to justify the view expressed by Stallybrass.

An alternative explanation comes from Hilda Woods (1933, page 25): "There is of course the possibility that children in crowded dwellings build up a greater immunity to infection — one case, by sub-clinical doses of infection, may produce immunity in other members of the family. The result would be a lower attack rate among children in poor houses than among those living under better conditions. But one would expect such a condition to hold for London as well as for

Glasgow". Let us see now how far the suggestion of immunity by sub-clinical infection can explain the facts.

In 1899, Adami described a condition in which bacteria, such as B.coli, from the intestinal tract were carried by the lymph and the blood to other tissues and organs where they were speedily destroyed. Normally no "illness" was produced. Since then it has been recognised that in many diseases a not dissimilar condition can arise. Pathogens gain entry into the body, but are destroyed before their arises any gross evidence of their invasion. Nevertheslcss this imperceptible encounter between organism and host may endow the latter with a much increased immunity towards subsequent attack by the same organism. Various terms have been employed to describe this invisible process. The infection has been described as sub-clinical, inapparent, silent or latent; and the immunity as sub-clinical, latent, or sub-infective.

Stallybrass states that the condition has been recognised to occur in Tuberculosis, Leprosy, Enteric Fever, Typhus, Cholera, Undulant Fever, Poliomyelitis, Cerebro-spinal Fever, Yellow Fever, Dengue, Measles, Small-pox, Whooping Cough, Diphtheria, and Scarlet Fever.

Perhaps the most interesting and convincing account of latent immunisation has been given by Dudley in his studies of infectious disease, especially Diphtheria, at the Greenwich Hospital School (1923, 1926, and 1934). He demonstrated that boys entering the school with a positive Schick reaction gave a negative reation some years later, that to change over from positive to negative a boy did not require to have had a frank attack of Diphtheria, that the rate of change from positive to negative was a function not of age but of duration of residence at the school, and that the change-over from positive to negative occurred mainly at definite periods of time coinciding with epidemics of clinical Diphtheria in the school. "Thus during an epidemic of Diphtheria there is a coincident epidemic of immunisation to Diphtheria" (Dudley 1923). Every visible epidemic — an epidemic of cases of clinically recognisable disease, — is accompanied by an invisible epidemic — an epidemic of concealed but immunising infection.

Though his studies in Scarlet Fever were much less detailed than those in Diphtheria, it was Dudley's opinion that this same latent immunity occurred also in that disease. In Measles, the work of Stocks and Karn (1928) in the St.Pancras Borough of London produced evidence that latent immunisation of limited duration occurred in a certain number of children who were in contact with clinical cases of the disease. Similarly in Whooping Cough, Stocks (1933) was of the opinion that the same process was at work.

As a preliminary to further discussion of latent immunisation as a possible explanation for the anomalies in the behaviour of Scarlet Fever in Glasgow, let us look for a moment at some of Dudley's conclusions concerning the ecological relationship between organism and host, and the mechanism of infection. We quote from his second Medical Research Council Report,(1926, page 56.):-

i) A certain minimum mass of infective agent is required before the dependent organism can establish itself in its host.

ii) Less than this amount will be destroyed by the host, and cause some alteration in the degree of resistance.

iii) Time spent in an infective environment therefore becomes of importance, not only as regards the number of opportunities of receiving an infective dose as a whole, but because sub-infective doses can be summed to an infective one, or destroyed, thereby altering the resistance of the host.

iv) The quantitative factors of time, mass of infective agent, and degree of host resistance, make it essential to introduce three 'velocities' into the study of infection.

a) The velocity at which the infective material is received by the host.

b) The velocity at which it is destroyed by the host.

c) The velocity at which the host resistance alters in a positive or negative direction.

The resultant of these three is the 'velocity of infection' on whose magnitude depends the final result of the reaction between the host and the dependent organisms. This result may be an illness, mild or severe, the establishment of tolerance (i.e. commensalism or the carrier state), or the destruction of the parasite: and in all cases there will be a change in the host's defensive mechanisms for better or worse.

Keeping these conclusions of Dudley in mind, let us consider the special features of Scarlet Fever which may perhaps distinguish it ecologically from the other diseases. In the first place, what do we mean by 'Scarlet Fever'? Scarlet Fever is a disease-syndrome caused by beta-haemolytic streptococci of Group A, i.e. Str. pyogenes. The syndrome is characterised by:-

i) an inflammatory reaction at the site of invasion.

ii) a generalised rash caused by the erythrogenic exotoxin of the streptococcus.

Allison (1942) reports that in a series of 800 consecutive cases of Scarlet Fever, there were isolated 21 different serological types of Str. pyogenes, types 1, 2, 3, and 4 accounting for just over half the cases. Furthermore, the same serological type that in one individual produces Scarlet Fever may in others cause tonsillitis, otitis, puerperal sepsis, erysipelas, or other manifestation of streptococcal infection.

The occurrence of Scarlet Fever in an individual infected by Str. pyogenes depends on the organism's ability to produce erythrogenic toxin, and on the host's susceptibility or immunity to the toxin. Scarlet Fever is therefore merely the occasional manifestation of infection by an organism capable of revealing its presence by protean manifestations.

The carrier rate of beta-haemolytic streptococci in the general population is variously reported at from 5% to 30%. The carrier rate of C.diphtheriae is normally much lower. It is doubtful whether true carriers of the Measles virus and of the Haemophilus pertussis exist.

Returning to Dudley's 'velocity of infection', we remember that small doses of the organism may, if rapidly received, have the cumulative effect of producing clinical illness. Similar doses received more slowly may each be overcome by the natural resistance of the host without visible evidence of the attack. Nevertheless some specific resistance in the host towards that organism may be established, i.e. some degree of latent immunity. The latent immunity so produced may be of short duration. If, however, further minor stimuli are received before the immunity has completely disappeared the immunity will be reinforced. It will rapidly soar to a higher level and will be of longer duration. Repetition of such stimuli at occasional intervals may have the cumulative effect of producing a degree of immunity as high and as permanent as that produced by a frank clinical illness.

The response of the host to the stimulus of infecting doses will not necessarily be the same for each variety of pathogenic organism . In Measles and Whooping Cough, the high degree of infectiousness of the causative organism renders it probable that even a small dose will produce clinical illness. In a minority of instances, however, the host may receive a succession of doses small enough to permit of the building up of some degree of latent immunity. As epidemics are of fairly short duration, and recur only at intervals of about two years, this latent immunity may have disappeared entirely by the time the next epidemic occurs, and the risk of patent illness is now no less that it was in the first instance. Thus the majority of children sooner or later suffer a visible attack from these diseases, and usually, it is probable, at the first exposure.

In Diphtheria, the organism is less infectious; epidemics are less intense but more prolonged. The epidemiological behaviour of the disease is one of periodic intensification of an endemic state. The chances of receiving a succession of small doses are therefore greater and a better opportunity occurs for the building up of a permanent latent immunity.

Scarlet Fever exhibits a rather similar epidemiological pattern of behaviour; but the multiplicity of types of causative organism, the high carrier rate in the general population, and the numerous non-Scarlatinal infections due to types capable in suitable subjects of producing Scarlet Fever render the chances of repeated contact with the organism very much greater.

Returning now to the consideration of Scarlet Fever in

Glasgow, in the poorer districts of the city, where the families are large, and overcrowding is intense, the child has its first encounter with the streptococcus perhaps within the first few hours or days of its life. Even if none of the family circle is at that moment a disseminator of streptococci, within the matter of weeks one at least of the older children will come in contact with the infection at school, and will bring it back into the home. Crowding being extreme, the young infant will hardly escape a dose or repeated doses of streptococci. But at this early age the infant is immune, due to the antibodies it has acquired from its mother. It does not develop Scarlet Fever. Its inherited immunity, by now perhaps beginning to decline receives a re-inforcing stimulus; or more properly, while the inherited passive immunity is still present, the infant receives its first stimulus towards the development of active immunity . A few days or weeks later a further dose of streptococci is received and this active immunity is still further re-inforced. So the process is repeated until the succession of stimuli culminate in the establishment of a high degree of lasting active immunity. At no time during infancy, pre-school, school or later life is the subject free for long from bombardment with streptococci. His immunity is strong, and durable, and at no time in his life does he develop 'Scarlet Fever'.

Every infant, however, born into such an enviroment will not necessarily undergo exactly the same experience. At any time during infancy or childhood he may receive a massive dose or a very rapid succession of doses sufficient to overcome such immunity as he has succeeded in establishing. He may then develop clinical, notifiable Scarlet Fever. As his inherited immunity is strong, however, this is not likely to happen within the first six months or even perhaps twelve months of life.

In this grossly overcrowded environment, therefore, the probability is that the child will either develop an early and permanent immunity, or failing to develop an immunity powerful enough to resist the high infectivity of his environment, he will, at an early age, suffer a frank attack of Scarlet Fever, thereafter becoming immune.

At the other end of the social scale, where the family is small, and overcrowding is absent, the child is sheltered in his early years both from small and larges doses of streptococci. He sleeps by himself and plays with few other children. He comes into close contact with few adults. Occasional doses of streptococci may come his way, but these are too small to produce clinical illness, and too infrequent to build up more than a transient immunity. When he goes to school it is not long before he receives a massive infection resulting in frank Scarlet Fever.

Between these two extremes of social environment the frequency and strength of dosage with streptococci and the child's response to these will run an intermediate course. On the lower half of the social scale, early immunity or early clinical illness are to be expected; on the upper half of the scale, no early immunity and late clinical illness are more probable.

As a result we may expect to find relatively fewer cases of Scarlet Fever in the worst districts than in the best, but the age of attack of the cases that do occur in the worst districts will tend to be lower than the age of attack in the best districts.

If, now, in the very worst districts, where an early and lasting latent immunity is perhaps the most usual result, we begin to reduce the family size and the degree of over-crowding, the chance of the infant receiving small frequent immunising doses from birth, i.e. during the period of inherited immunity, is reduced, and the child is more liable at an early age to respond to a massive infection by developing a clinical illness. Thus more clinical cases will occur in this environment and many of these cases will occur at a very early age. As a result the mean age of attack in this social group will tend to fall.

With still further improvement in social conditions the chances of an early latent immunity being established are still further reduced, but so too are the chances of receiving at a very early age a massive 'pathogenic' dose of streptococci. Thus the mean age of attack will begin to rise again. A continuation of the process of improvement in social conditions in the worst districts will ultimately bring the age of attack in these districts up to the level of what are now the better districts.

If the number of children in the better districts increases instead of decreases, young children in this environment are likely to receive doses of streptococci from their elder brothers and sisters. Overcrowding not being marked, however, these doses are likely to be small, and more liable to produce latent immunity rather than clinical disease. Hence in this environment the number of cases will be reduced without an accompanying lowering of the age of attack.

While this account of the possible ecological relationships between streptococcus and host is necessarily speculative, and at present incapable of corroboration by definite and reliable evidence, it has been demonstrated by Herrman (1923), (quoted by Stallybrass, p.278) that the familial exposure of very young infants to Measles can produce an apparently permanent latent immunity, (See Table 94). If this can happen with the highly 'pathogenic' virus of Measles, it is by no means unreasonable to postulate its occurence still more frequently with the Streptococcus pyogenes.

It seems possible to explain the various apparent anomalies of Scarlet Fever in Glasgow by this hypothesis of the existence of widespread latent but diminishing immunisation in

Table 94.

Four Outbreaks of Measles in a Family of 7 Children, Showing Subsequent Immunity of Exposed Infants (0) although the Other Children are Infected (●).

Children in Family:	1	2	3	4	5	6	7
Year of Birth:	1901	1903	1905	1907	1909	1911	1914
Years of Occurrence of Measles.							
1903	●	0 $\left(\frac{3}{12}\right)$					
1909		0	●	●	0 $\left(\frac{3}{12}\right)$		
1913		0			0	●	
1915		0			0		●

($\frac{3}{12}$ indicates exposure at the age of 3 months).

the poorer districts. The hypothesis explains the relative infrequency of cases in these districts, explains the lower age of attack of the cases that do occur, and suggests why the age of attack might be falling instead of rising in the worst wards of the city. Earlier in this section we pointed out the difficulty of reconciling with improving environmental conditions a falling age of attack in these wards. By our hypothesis, however, when the social environment has improved to a certain extent the age of attack will commence to rise again, and will move towards that of the best districts.

In Glasgow, therefore, the age-shift in morbidity in Scarlet Fever towards a younger instead of an older age can be attributed to the same factors that are producing an age-shift to an older age in the other diseases, i.e. improvement in social conditions and reduction in family size in the worst districts of the city. When the social conditions of these districts have improved to such an extent that latent immunisation is much less frequent that it has been, the age-shift in Scarlet Fever will change direction, and will begin to move towards a later age as in other diseases.

It is significant that the degree of overcrowding in London in 1911 (16.8% of the population living more than 2 persons per room) was very much less than that of Glasgow in 1931 (42.3% of the population living more than 2 persons per room). On the basis of our hypothesis of latent immunisation, we can explain the absence of negative correlation in London between Scarlet Fever morbidity and overcrowding, and the age-shift in morbidity to a later age instead of to an earlier age, by postulating that in London the improvement in social conditions has long since passed the stage at which it produces more cases at an early age in the worst districts, and is now at the stage at which it is bringing about a later age of attack and a decrease in the number cases in these districts. Thus in London both incidence and age of attack in the worst districts should be approaching towards those of the better districts. The degree of overcrowding in London is so small, and in Glasgow, so large, that the epidemiological behaviour of Scarlet Fever in London is already at a stage which in Glasgow it may not reach for many years.

Two suggestions have now been made to account for the apparently anomalous behaviour of Scarlet Fever in Glasgow. The first is that actual clinical cases in the poorer districts are frequently missed and fail to be notified. The second is that a large number of cases in the poorer districts do not assume a visible form; they remain subclinical infections, and hence cannot be notified as Scarlet Fever.

It might perhaps be thought, as apparently Stallybrass did, that the presence of large numbers of Dick-negative children in the poorer districts should suggest that the real Scarlet Fever incidence in these districts is much higher than the notifications seem to indicate. As Friedemann,

(1928) has also observed, "the Dick test becomes negative earlier in the city than in the country, and among the poor than among the well-to-do".

But this observation is only of limited value. It does no mare than tell us that immunity to the toxin of Scarlet Fever is developed earlier in the poorer districts than in the better ones. It does not tell us whether this immunity is the result of clinical or subclinical infection. Accordingly, it does not help us to decide which of our two hypotheses is more likely to be the correct one; it merely suggests that exposure to the streptococcus occurs at an earlier age among the children of the poor.

Against both of these two possible explanations that have been put forward objections can readily be made, not the least being that both are conjectural and not based to an adequate extent upon solid evidence. It may be, as is most probable, that there is truth in both of them. Until we know more about the ecological and immunological relationships between organism and host and, more particularly, about the special and complex part played by the haemolytic streptococcus as a parasite of man, we cannot hope fully to understand the epidemiological behaviour of Scarlet Fever.

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