INFECTIOUS DISEASES IN A SEMI-CLOSED COMMUNITY

By SCOTT THOMSON, M.D., M.R.C.P.E., D.P.H.
AND A. J. GLAZEBROOK, M.R.C.S., L.R.C.P.

From the Departments of Bacteriology and Clinical Medicine, University of Edinburgh

(With 12 Figures in the text)

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PART I. THE EPIDEMICS OF TONSILLITIS AND ACUTE RHEUMATISM

Introduction

In a large institution whose population can be considered as forming a semi-closed community there frequently exist conditions favourable to the spread of infectious diseases. The organization of such an institution to avoid epidemics

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is an accepted difficulty of administration. The occurrence of an epidemic in a semi-closed community offers opportunity for thorough investigation, and is, therefore, of more than usual interest.

There are many circumstances which govern the spread of infection in a semi-closed community, and it does not follow that an epidemic will occur if certain conditions are fulfilled. Conditions in one institution may lead an observer to conclude that the risk of an epidemic is greater than that which obtains in another. Such a conclusion as to possible future events could only be an assumption.

The epidemics recorded here occurred in a training centre for adolescents who were admitted at ages 15–16. The outbreak of tonsillitis was of peculiar interest, not only because of the enormous proportions to which it attained but also because it was associated with an epidemic of acute rheumatic fever. Of great interest too was the fact that the epidemic started as soon as the training centre was opened and it persisted for over a year. None of the youths, therefore, had lived in the institution in a 'pre-epidemic' period.

Epidemics of tonsillitis have frequently occurred in public schools and other institutions (Haig Brown, 1886; Bradley, 1931–2; Collis, 1931–2; Glover & Griffith, 1930).

On occasions cases of acute rheumatism usually associated with an epidemic of tonsillitis have occurred in sufficient numbers to constitute a definite outbreak (Haig Brown, 1886; Schlesinger, 1930; Glover, 1930; Bradley, 1932; Glover & Griffith, 1931; Sheldon, 1931). A study of these epidemics has yielded much that is of interest to the student of epidemiology.

GENERAL DESCRIPTION OF THE INSTITUTION

The training centre was a converted liner capable of housing some 1800 youths and administrative staff. It was situated two miles from the nearest small town and four miles from a town of any size.

All training took place within the institution which had dormitories, class rooms, recreation rooms, hospital accommodation, etc. All youths were medically examined and passed as fit before entry.

The population was divided into divisions in much the same way as a school is divided into houses. There was a division designated 'preliminary' to which all entrants were admitted for a period of six to eight weeks before being assigned to one or other permanent division. When the population had grown to some 1500 there were five permanent divisions. The divisions were built up concurrently, each receiving a quota from every batch of entrants.

There was no real separation of the various divisions. Each had special tables in the dining hall, and in the main a division occupied certain dormitories. Apart from this the isolation of the divisions was not well defined.

The admission of all recruits to a preliminary group from which drafts were made to the divisions would tend to break down any isolation of the divisions from each other even although they had been more strictly separated. It will be noted later that the heaviest incidence of disease occurred amongst the recruits who would thus tend to carry infection to the permanent divisions.

The sleeping quarters were between decks with hammocks slung 2 ft. 6 in. apart. On the average there were 250 cu. ft. per youth in the dormitories, but the space varied from 150 to 450 cu. ft. in different dormitories. The dormitories were ventilated by a plenum system with punkah louvres in addition to the portholes. The ventilating inlets were often closed by the boys who had free access to them.

Method of recruitment

The training centre opened in May 1937, when fifty-six youths were admitted. Thereafter at fortnightly intervals further batches were admitted until the population reached 1800 (summer 1938). By this time some of the original entrants had completed their training and had left. The institution was open for a total of seven terms, viz. the summer of 1937 and the two sessions of 1937–8, 1938–9, each with three terms. There were holiday periods of one month in the summer and two weeks at Christmas and Easter. The epidemic proper started in the summer of 1937 and ended at the end of the summer term 1938 and accordingly lasted for four terms. The survey, however, was carried into the session 1938–9 (terms 5–7) to show how certain phenomena appeared also in this session.

The whole of the period of observation was subdivided into fortnightly periods which are accepted as convenient units of time for the purposes of description.

Although recruits joined in batches each fortnight none were admitted during the last two or three fortnightly periods of each term. At the opening of a new term a large batch of recruits was usually admitted, e.g. 358 at the opening of the second term and 188 at the opening of the third. The recruits admitted during any one term were not, therefore, admitted uniformly throughout that term. Generally, they were admitted in the first half of the term. This point is of interest because, for some of the analyses the batches of recruits were pooled into groups, each group consisting of those youths who had joined in one particular term.

This method of recruitment in fortnightly batches continued during the first four terms, i.e. during the period of the epidemic proper, but in the terms 5, 6 and 7 (session 1938–9) recruits were admitted as one large batch at the opening of the term. At the beginning of term 5 only 88 youths were admitted. The incidence of disease during terms 5–7 did not reach epidemic proportions, and the epidemic proper persisted during terms 1–4.

The holiday periods interfered with the continuity of events and for the purposes of description were neglected. It is not assumed, however, that the periodic dispersal of the population was without influence on the epidemic.

METHODS OF RECORDING THE EPIDEMICS

Since batches of recruits were admitted at fortnightly intervals it was decided to analyse the experience of each batch during the whole of the epidemic period. The four terms were subdivided into thirty periods of two weeks which were accepted as the units of time. The experiences of each batch and of the whole population at each of these fortnightly periods were recorded. In studying the records retrospectively, it was decided to accept all cases of 'tonsillitis', 'pharyngitis', 'scarlet fever', and 'otitis media' as 'tonsillitis'. If a youth showed two such attacks occurring within 10 days of each other, the second was regarded as a relapse and not as a separate illness. Similarly, if an attack of otitis media occurred in a youth who had had a previous attack, it was regarded as a recrudescence of a chronic suppurative otitis media.

It was suspected that the heaviest incidence of disease would be amongst those who had recently joined the institution. Accordingly, a record was made of the length of time a youth had been in the institution before he developed an attack of tonsillitis. The term 'institution age' is used to indicate the number of fortnights a youth had been in the institution. The term 'curtate age' states the number of complete fortnights that a youth had been in the institution but neglects the additional fraction of a fortnight. For example, if a youth was in the training centre for 17 weeks, his institution age was $8\frac{1}{2}$ but his curtate age was 8. If this youth took tonsillitis during his $(n+1)$th institution age the attack was considered to occur at institution age $n+\frac{1}{2}$ (i.e. midway through the age period) or at curtate age n. The object was to relate the number of cases occurring during curtate age n, i.e. between n and $n+1$, to the number of units of exposure during curtate age n. All events related to curtate age n refer to the events at institution age $n+\frac{1}{2}$. The unit of exposure was one youth per fortnightly period. A record was made for each youth of his curtate age at the end of the epidemic period or alternatively when he left the institution if this event preceded the former. If a youth left the institution with a curtate age n, he had completed n periods of 2 weeks' training and left in the interval between n and $n+1$. Holiday periods were neglected.

A table was compiled to show the experience of every youth with his curtate age on leaving (or at the end of the period), his curtate age when he took his attack or attacks of tonsillitis, his curtate age when he took acute rheumatism and his home county. All these points were considered to be of interest in order to calculate incidence of disease at the various institution ages, to correlate the acute rheumatism with the tonsillitis, and to determine whether the experience in the institution differed in youths who were recruited from urban or rural areas, etc.

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Out of the total of 2095 boys who lived in the institution during the epidemic for periods varying from 4 to 60 weeks, 1263 had one or more attacks of tonsillitis. Multiple attacks were common amongst those who reached a high institution age, i.e. amongst those who were in the institution during the greater part of the epidemic period. There were in all 1903 attacks of tonsillitis, and the number of latent infections must have been of a very high order.

The experience of each batch throughout the whole of the thirty periods of the epidemic is shown in Table 1. The table shows the population of each batch on joining, the number of cases of tonsillitis, and the population of each batch in all succeeding periods. The incidence of tonsillitis in any batch in any period can be found, but a number of batches were summated into a group for the determination of incidence of tonsillitis.

To determine the population of each batch at any given period the following method was adopted:

Let χ = number of boys in a batch.

Let $N_0, N_1, N_2, \ldots, N_t$ be the number of boys of the batch who left with a maximum curtate age of $0, 1, 2, \ldots, t$.

Let $\chi_0, \chi_1, \chi_2, \ldots, \chi_t$ = population of batch in the 1st, 2nd, 3rd, ... $(t+1)$th periods after entry.

The assumption was made that discharges were effected uniformly throughout a fortnightly period.

Then

$$\begin{aligned} \chi_0 &= \chi - \tfrac{1}{2}N_0, \\ \chi_1 &= \chi - N_0 - \tfrac{1}{2}N_1, \\ \chi_2 &= \chi - N_0 - N_1 - \tfrac{1}{2}N_2, \\ &\vdots \\ \chi_t &= \chi - \Sigma N_{t-1} - \tfrac{1}{2}N_t. \end{aligned}$$

The same method was used to find the number of exposure units (boys per fortnight) at the various institution ages.

In the middle of periods 7, 15 and 22 there were holidays of two, one and one periods respectively.

By summation of the columns vertically the total number of cases of tonsillitis, the total population and the incidence of tonsillitis were elicited and shown below the table.

The epidemic of tonsillitis both actually and relatively was at its height during term 2 when the population was approximately 1000, but it continued at a high level during terms 3 and 4.

The epidemic of acute rheumatism, however, reached its peak towards the end of term 3 and during term 4. During the four terms, 2095 youths had been in the institution for periods varying from one month (two periods) to over a year (thirty periods). There occurred 1903 cases of tonsillitis and 115 cases of acute rheumatism.

During the epidemic no detailed bacteriological examinations were made, but during the second term throat swabs were taken from 126 cases of

…tch no.	No. in batch	16 May 1	30 May 2	13 June 3	27 June 4	11 July 5	25 July 6	8 Aug 7	12 Sept. 8	26 Sept. 9	10 Oct. 10	24 Oct. 11	7 Nov. 12	21 Nov 13	5 Dec. 14	19 Dec 15
1	*56*	1 *56*	6 *56*	1 *56*	1 *56*	3 *56*	3 *56*	2 *56*	0 *56*	5 *56*	3 *56*	7 *56*	2 *56*	6 *56*	3 *56*	4 *55*
2	*62*		2 *62*	3 *62*	1 *62*	0 *62*	2 *62*	3 *62*	1 *62*	7 *62*	4 *62*	8 *62*	10 *62*	3 *62*	9 *62*	3 *62*
3	*61*			0 *61*	2 *61*	7 *61*	1 *61*	1 *61*	1 *61*	5 *61*	7 *61*	9 *61*	5 *61*	11 *61*	4 *61*	4 *61*
4	*75*				3 *75*	2 *75*	8 *75*	2 *75*	2 *75*	5 *75*	4 *75*	6 *75*	11 *75*	18 *75*	15 *75*	7 *75*
5	*71*					5 *71*	2 *71*	3 *71*	6 *71*	2 *71*	6 *71*	10 *71*	11 *71*	9 *71*	13 *71*	0 *71*
6	*47*						3 *47*	6 *47*	5 *47*	8 *47*	3 *47*	5 *47*	4 *47*	6 *46*	6 *46*	2 *46*
7	*358*								25 *358*	18 *358*	25 *358*	28 *358*	33 *358*	41 *358*	38 *358*	● 11 *357*
8	*78*									3 *78*	5 *78*	15 *78*	9 *78*	7 *78*	8 *78*	1 *78*
9	*118*										12 *118*	18 *118*	19 *118*	16 *117*	16 *117*	2 *117*
10	*70*											5 *70*	26 *70*	10 *69*	1 *68*	1 *68*
11	*71*												13 *71*	17 *71*	5 *71*	5 *71*
12	*71*													15 *71*	14 *71*	6 *71*
13	*36*														15 *36*	5 *36*
14	*188*															
15	*70*															
16	*72*															
17	*70*															
18	*70*															
19	*69*															
20	*71*															
21	*70*															
22	*70*															
23	*69*															
24	*68*															
25	*34*															
…al	2095	1	8	4	7	17	19	17	40	53	69	111	143	159	147	51
…ulation		*56*	*118*	*179*	*254*	*325*	*372*	*372*	*730*	*808*	*926*	*996*	*1067*	*1135*	*1170*	*1168*
…dence		1 79	6 78	2·23	2·76	5·23	5 11	4·57	5 48	6 56	7·45	11·14	13 40	14·01	12 57	4·37

…tch no.	No. in batch	16 Jan 16	30 Jan. 17	13 Feb 18	27 Feb. 19	13 Mar. 20	27 Mar. 21	10 Apr. 22	1 May 23	15 May 24	29 May 25	12 June 26	26 June 27	10 July 28	24 July 29	7 Aug 30
1	*56*	1 *55*	6 *55*	4 *55*	4 *55*	2 *54*	0 *44*	1 *33*	2 *32*	0 *31*	2 *28*	1 *25*	1 *25*	0 *24*	0 *23*	0 *23*
2	*62*	3 *62*	2 *62*	2 *62*	4 *62*	2 *62*	2 *52*	0 *41*	0 *38*	0 *33*	2 *27*	0 *24*	1 *22*	0 *19*	0 *16*	0 *15*
3	*61*	3 *61*	2 *61*	3 *60*	0 *59*	1 *59*	4 *58*	0 *57*	2 *47*	0 *37*	0 *34*	0 *30*	0 *29*	1 *26*	0 *22*	0 *21*
4	*75*	3 *75*	3 *75*	6 *75*	9 *74*	0 *74*	2 *73*	0 *73*	2 *69*	2 *55*	1 *43*	0 *38*	2 *35*	0 *31*	0 *27*	0 *27*
5	*71*	4 *71*	2 *71*	6 *71*	4 *71*	3 *70*	3 *70*	0 *70*	2 *70*	0 *69*	1 *59*	1 *48*	3 *42*	0 *33*	1 *28*	0 *28*
6	*47*	3 *46*	3 *45*	2 *45*	1 *45*	0 *45*	1 *45*	1 *45*	2 *45*	2 *45*	0 *42*	0 *36*	1 *33*	0 *29*	0 *26*	0 *26*
7	*358*	9 *357*	18 *356*	20 *356*	24 *356*	9 *356*	8 *356*	6 *356*	12 *356*	8 *355*	8 *355*	8 *347*	6 *320*	4 *293*	2 *283*	1 *281*
8	*78*	2 *78*	6 *78*	1 *78*	9 *78*	3 *78*	1 *78*	0 *78*	3 *78*	2 *78*	1 *78*	1 *78*	2 *78*	0 *69*	0 *58*	0 *57*
9	*118*	6 *117*	5 *117*	9 *117*	12 *117*	5 *117*	4 *117*	1 *116*	4 *116*	7 *116*	2 *116*	1 *116*	5 *116*	3 *116*	4 *115*	0 *114*
10	*70*	6 *68*	2 *68*	3 *68*	8 *68*	4 *68*	3 *68*	0 *68*	3 *68*	1 *68*	2 *67*	1 *67*	0 *66*	1 *66*	1 *63*	0 *61*
11	*71*	3 *71*	1 *71*	3 *71*	9 *71*	3 *71*	0 *71*	1 *71*	3 *71*	1 *71*	4 *71*	1 *71*	1 *70*	4 *69*	2 *69*	0 *69*
12	*71*	4 *71*	7 *71*	8 *71*	3 *71*	5 *71*	2 *70*	1 *70*	2 *70*	5 *70*	6 *70*	3 *70*	4 *69*	1 *69*	2 *66*	0 *64*
13	*36*	1 *36*	3 *36*	2 *36*	5 *36*	3 *36*	1 *36*	2 *36*	1 *36*	2 *36*	2 *36*	0 *36*	3 *35*	0 *33*	1 *32*	0 *32*
14	*188*	10 *188*	18 *188*	21 *188*	18 *188*	13 *188*	4 *188*	5 *188*	7 *188*	10 *188*	16 *188*	2 *188*	3 *188*	5 *188*	0 *187*	1 *186*
15	*70*		3 *70*	8 *70*	6 *70*	7 *69*	2 *69*	0 *69*	8 *69*	3 *69*	4 *69*	1 *69*	4 *69*	1 *69*	0 *67*	1 *66*
16	*72*			9 *72*	7 *72*	13 *72*	1 *72*	1 *72*	0 *72*	3 *72*	4 *72*	4 *72*	1 *72*	1 *72*	3 *72*	1 *71*
17	*70*				8 *70*	15 *70*	6 *69*	1 *67*	4 *67*	4 *67*	3 *67*	5 *67*	2 *67*	3 *67*	2 *67*	0 *67*
18	*70*					7 *70*	13 *70*	2 *70*	11 *70*	7 *70*	5 *70*	3 *70*	2 *70*	2 *70*	2 *70*	0 *69*
19	*69*								8 *69*	19 *69*	7 *69*	5 *69*	0 *69*	4 *69*	6 *69*	0 *68*
20	*71*									6 *71*	10 *71*	8 *71*	4 *71*	3 *70*	1 *69*	1 *69*
21	*70*										12 *70*	15 *70*	3 *70*	3 *69*	3 *69*	0 *69*
22	*70*											10 *70*	7 *70*	3 *70*	4 *70*	2 *69*
23	*69*												4 *69*	11 *69*	7 *69*	0 *68*
24	*68*													7 *68*	14 *68*	3 *68*
25	*34*														4 *34*	1 *34*
…al	2095	58	81	107	131	95	57	22	76	82	92	70	59	57	59	11
…ulation		*1356*	*1424*	*1495*	*1563*	*1630*	*1606*	*1580*	*1631*	*1670*	*1702*	*1732*	*1755*	*1758*	*1739*	*1722*
…dence		4 28	5·69	7·16	8·38	5·83	3 55	1·39	4·66	4·91	5·41	4·04	3 36	3·24	3·39	0 64

* Number of cases shown in roman type, populations in italic. † The last period of the session was not a complete fortnight.

tonsillitis and a rich culture of the haemolytic streptococcus was obtained from 112 (Thomson, Glazebrook & Green, 1940). These streptococci belonged to several types. From time to time a number of cases of tonsillitis were swabbed and haemolytic streptococci were recovered in large numbers from the majority.

Epidemic of tonsillitis

Fig. 1 shows the total number of cases of tonsillitis which occurred in the periods.

It will be noticed that the epidemic was a very severe one and that there was a wave of disease during each of the terms 2, 3 and 4. To some extent

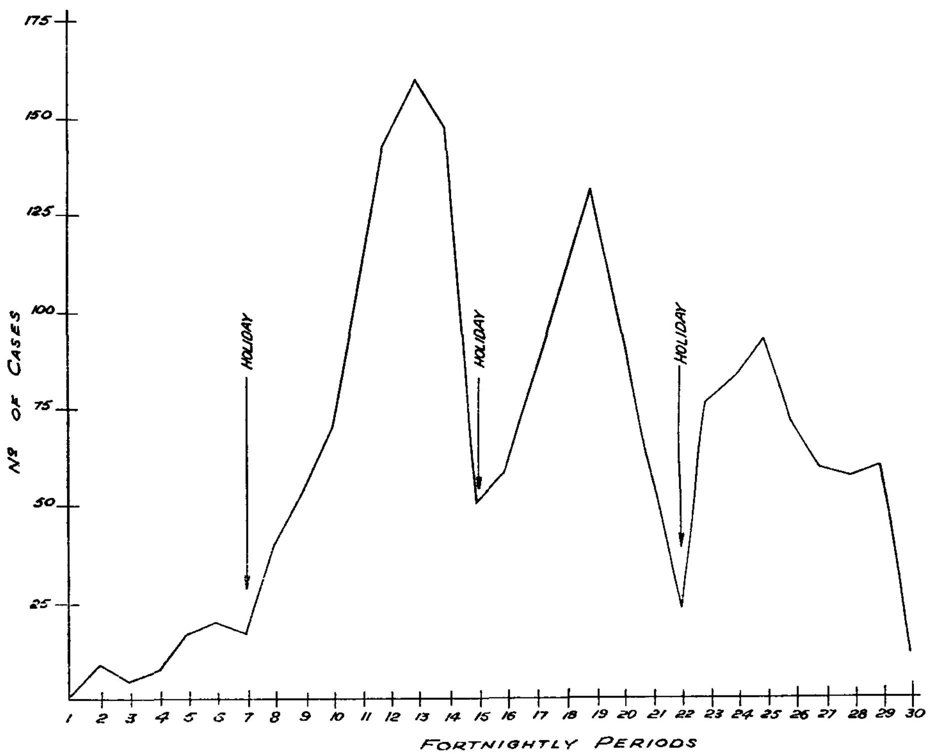

Fig. 1. Number of cases of tonsillitis in fortnightly periods.

the waves were related to and probably due to the dispersal of the population at the holiday periods. Fewer cases of disease might have been expected at the beginning of a term irrespective of the numbers at the end of the preceding one. When the population was reassembled at the beginning of term 3 there were fewer cases per period, so that a dip in the curve appeared on joining the point indicating the events at the end of term 2 to the point at the opening of term 3.

During terms 3 and 4 the number of cases per period increased until the middle of the term and thereafter decreased. There was therefore a rise and

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fall in the graph within the terms, and these waves were not interrupted by a holiday period.

The holiday periods were probably responsible for the production of a lower incidence of infection in the beginning of each term and accordingly were responsible for many of the features of the graph.

Fig. 2 shows the *incidence* of tonsillitis at the various fortnightly periods. The incidence is expressed as number of cases per 100 boys per fortnightly period.

The epidemic was considered to have started in the first term because of an incidence of tonsillitis of 2–6 % per period. The population during the first six periods was built up from 56 to 372. Since the population during periods

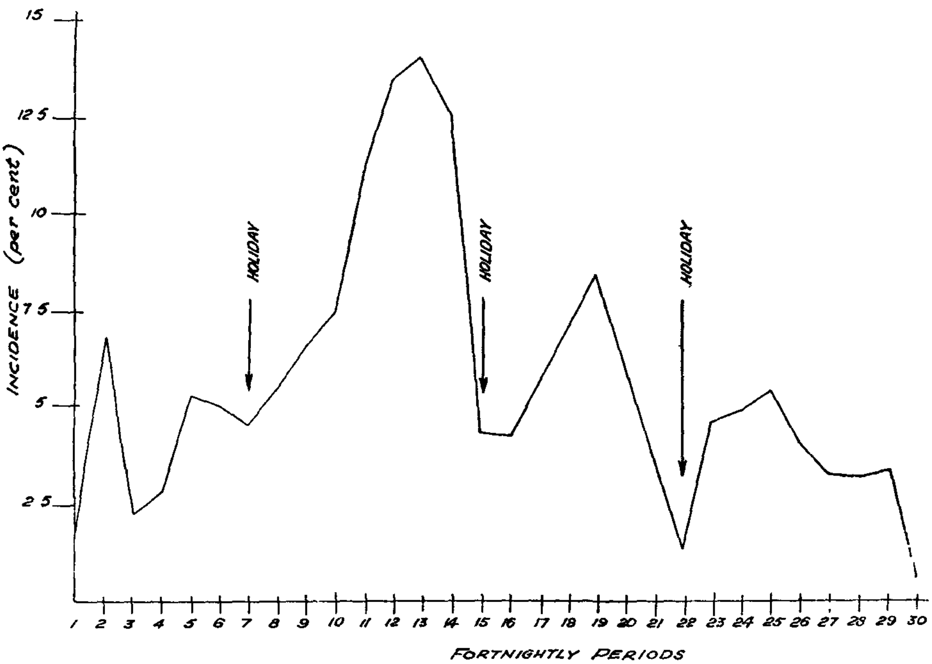

Fig. 2. Incidence of tonsillitis in fortnightly periods.

8–30 was so very much greater, the number of cases occurring in the earlier periods did not show as a definite wave in Fig. 1 where actual numbers of cases were recorded. Fig. 2 again shows the wave of disease each term.

The populations of the individual batches were too small for graphical representation of incidence of disease. Accordingly, several batches were grouped together and each group consisted of those batches which had joined during a term. Groups 1, 2, 3 and 4 were formed of the batches which joined in terms 1, 2, 3 and 4. It might be argued that a batch which joined at the end of one term would be similar to one which joined at the beginning of the following, and that the experiences in two such batches would be similar in future periods. Nevertheless, there might be differences in the experiences of the groups arranged as described above. It has already been described, however, how recruits were not admitted up to and including the last fortnightly period of any term. Table 1 shows that no recruits were admitted in period 7 which was the last period of term 1. Batch 6 was admitted at the beginning of the second last period of term 1 so that all the youths of group 1 had experienced at least 3 weeks of the epidemic in term 1. Similarly, no youths were admitted at the beginning of period 15 so that all the youths of group 2 had experienced at least 3 weeks of the epidemic in term 2. All the youths of group 3 had experienced at least 6 weeks of the epidemic in term 3. All the youths of group 4 had experienced at least 1 month of the epidemic during term 4. Moreover, at the beginning of terms 2 and 3, particularly large batches (358 and 188 respectively) were admitted. On the whole, therefore, the population of any group had experienced more than half of the periods in the term of the same number. The experiences of these groups were interesting, and it was decided to carry this investigation into the next session whose terms were 5, 6 and 7 with groups 5, 6 and 7. Recruits were not admitted at fortnightly intervals during the terms 5, 6 and 7. Group 5 consisted of one batch of 88 youths admitted at the beginning of term 5 (period 31). Group 6 consisted of 255 youths admitted at the beginning of term 6 (period 38), and group 7 consisted of 310 youths admitted at the beginning of term 7 (period 46).

Table 2 shows the number of cases, the population, and the incidence of tonsillitis in each group in all periods 1–53 or terms 1–7. The information given in Table 2 is represented graphically in Figs. 3, 3*a* and 3*b*.

Table 2. *Incidence of tonsillitis in different groups*

Period no.	No. of cases	Population	Incidence	Period no.	No. of cases	Population	Incidence
			Total no. in all groups				
1	1	56	1·79	28	57	1758	3·24
2	8	118	6·78	29	59	1739	3·39
3	4	179	2·23	30	11	1722	0·64
4	7	254	2·76	31	16	1661	0·96
5	17	325	5·23	32	11	1665	0·66
6	19	372	5·11	33	8	1588	0·50
7	17	372	4·57	34	19	1503	1·26
8	40	730	5·48	35	21	1426	1·47
9	53	808	6·56	36	21	1375	1·53
10	69	926	7·45	37	20	1347	1·48
11	111	996	11·14	38	25	1419	1·76
12	143	1067	13·40	39	27	1463	1·85
13	159	1135	14·01	40	11	1411	0·78
14	147	1170	12·57	41	7	1360	0·51
15	51	1168	4·37	42	22	1302	1·69
16	58	1356	4·28	43	16	1261	1·27
17	81	1424	5·69	44	14	1215	1·15
18	107	1495	7·16	45	6	1170	0·51
19	131	1563	8·38	46	5	1287	0·39
20	95	1630	5·83	47	6	1408	0·43
21	57	1606	3·55	48	16	1364	1·17
22	22	1580	1·39	49	24	1306	1·84
23	76	1631	4·66	50	12	1263	0·95
24	82	1670	4·91	51	2	1247	0·16
25	92	1702	5·41	52	12	1245	0·96
26	70	1732	4·04	53	20	1244	1·61
27	59	1755	3·36				

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Table 2 (*continued*)

Period no.	No. of cases	Population	Incidence	Period no.	No. of cases	Population	Incidence
			Group 1. Batches 1–6				
1	1	56	1·79	28	1	162	0·62
2	8	118	6·78	29	1	142	0 70
3	4	179	2 23	30	0	140	0·00
4	7	254	2 76	31	1	85	
5	17	325	5 23	32	0	73	
6	19	372	5·11	33	1	59	
7	17	372	4·57	34	0	51	
8	15	372	4 03	35	1	38	
9	32	372	8 60	36	0	26	
10	27	372	7 26	37	0	22	
11	45	372	12·10	38	2	19	
12	43	372	11 56	39	0	14	
13	53	371	14 29	40	0	9	
14	50	371	13 48	41	0	8	
15	20	370	5·41	42	0	5	
16	17	370	4·59	43	0	2	
17	18	369	4·88	44	0	1	
18	23	368	6 25	45	0	1	
19	22	366	6 01	46	0	1	
20	8	364	2·20	47	0	1	
21	12	342	3 51	48	0	0	
22	2	319	0 63	49	0	0	
23	10	301	3 32	50	0	0	
24	4	270	1 48	51	0	0	
25	6	233	2·58	52	0	0	
26	2	201	1 00	53	0	0	
27	8	186	4 30				
			Group 2. Batches 7–13				
8	25	358	6·98	31	5	631	0·79
9	21	436	4 81	32	1	603	0 17
10	42	554	7·58	33	3	543	0 55
11	66	624	10 58	34	0	475	0
12	100	695	14·39	35	3	427	0 70
13	106	764	13·87	36	5	409	1 22
14	97	799	12·14	37	6	400	1 50
15	31	798	3·88	38	4	384	1 04
16	31	798	3·88	39	1	348	0 29
17	42	797	5·27	40	2	324	0 62
18	46	797	5 77	41	1	313	0 32
19	70	797	8 78	42	2	288	0 69
20	32	797	4·02	43	1	269	0·37
21	19	796	2 39	44	2	263	0·76
22	11	795	1 38	45	1	258	0 39
23	28	795	3·52	46	1	251	0·40
24	26	794	3 27	47	1	244	0 41
25	25	793	3·15	48	0	240	0
26	15	785	1·91	49	1	233	0 43
27	21	754	2 79	50	0	228	0
28	13	715	1 82	51	1	227	0·44
29	12	686	1·75	52	1	227	0·44
30	1	678	0·15	53	0	226	0

Table 2 (*continued*)

Period no.	No. of cases	Population	Incidence	Period no.	No. of cases	Population	Incidence
			Group 3. Batches 14–18				
16	10	188	5 32	35	5	438	1·14
17	21	258	8 14	36	4	423	0·95
18	38	330	11·52	37	4	414	0·97
19	39	400	9·75	38	8	392	2·04
20	55	469	11·73	39	6	363	1·65
21	26	468	5·56	40	1	342	0 29
22	9	466	1·93	41	0	308	0
23	30	466	6·44	42	1	283	0·35
24	27	466	5 79	43	3	273	1 10
25	32	466	6 87	44	1	251	0·40
26	15	466	3·22	45	0	232	0
27	12	466	2 58	46	1	214	0·47
28	12	466	2 58	47	0	198	0
29	7	463	1 51	48	0	190	0
30	3	459	0·65	49	1	179	0·56
31	4	454	0 88	50	0	169	0
32	3	454	0·66	51	0	166	0
33	0	453	0	52	1	166	0·60
34	3	448	0 67	53	0	166	0
			Group 4. Batches 19–25				
23	8	69	11 59	39	7	395	1·77
24	25	140	17·86	40	2	393	0·51
25	29	210	13·81	41	2	388	0·50
26	38	280	13 57	42	5	383	1 31
27	18	349	5·16	43	3	374	0·80
28	31	415	7·47	44	3	357	0 84
29	39	448	8·71	45	1	336	0 30
30	7	445	1·57	46	1	323	0·31
31	6	447	1·34	47	1	312	0 32
32	7	447	1 57	48	2	281	0·71
33	4	445	0·90	49	2	242	0 83
34	12	441	2·72	50	3	214	1·40
35	8	435	1·84	51	1	202	0 50
36	10	429	2·33	52	2	200	1·00
37	8	423	1·89	53	1	200	0·50
38	9	408	2·21				
			Group 5				
31	0	44	0	43	1	88	1 14
32	0	88	0	44	2	88	2 27
33	0	88	0	45	1	88	1 14
34	4	88	4 55	46	0	88	0
35	4	88	4·55	47	0	88	0
36	2	88	2·27	48	1	88	1 14
37	3	88	3·41	49	1	88	1 14
38	1	88	1 14	50	0	88	0
39	0	88	0	51	0	88	0
40	0	88	0	52	0	88	0
41	1	88	1·14	53	1	88	1·14
42	1	88	1·14				
			Group 6				
38	1	128	0·78	46	2	255	0 78
39	13	255	5·10	47	0	255	0
40	6	255	2·35	48	0	255	0
41	3	255	1·18	49	1	254	0·39
42	13	255	5 10	50	1	254	0 39
43	8	255	3·14	51	0	254	0
44	6	255	2 35	52	3	254	1 18
45	3	255	1·18	53	5	254	1 96
			Group 7				
46	0	155	0	50	8	310	2 58
47	4	310	1·29	51	0	310	0
48	13	310	4 19	52	5	310	1·61
49	18	310	5·81	53	13	310	4·19

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It will be seen that group 1 exhibited a wave of disease in term 1 followed by a very large wave in term 2, and a smaller but definite wave in term 3 with no other succeeding wave.

Group 2 experienced a very large wave of disease in term 2 followed by a smaller but definite wave in term 3 and no wave of disease thereafter.

Group 3 experienced a large wave of disease in term 3 when groups 1 and 2 experienced their minor waves, and a minor wave in term 4 when groups 1 and 2 exhibited no wave.

Group 4 experienced a major wave in term 4 when group 3 experienced a minor wave and groups 1 and 2 showed no wave.

During the epidemic year each group showed a very heavy wave of disease in their first term followed by a minor wave in the following term. Group 1 showed a slightly different experience, and the incidence of infection in term 1

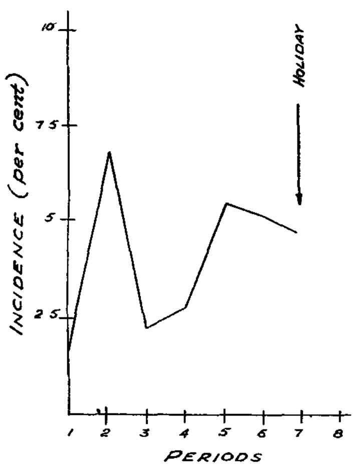

Fig. 3. Incidence of tonsillitis in group 1, periods 1–7.

did not materially alter its future experience as compared with group 2. The experiences of groups 1 and 2, therefore, were the same throughout terms 2, 3 and 4. During the terms 2, 3 and 4 the incidence of disease amongst the recruits would appear to indicate that the virulence of the epidemic or degree of concentration of infection remained at a very high level and that this was fairly constant.

During the following session (terms 5, 6 and 7) the incidence of disease was not sufficiently great to consider it a true continuation of the epidemic. Group 5 consisted of only 88 youths, and although the population is small the table shows an increased incidence of disease amongst them. Groups 6 and 7 showed a wave of disease, in terms 6 and 7 respectively, but the incidence was of the order of the minor waves which appeared in the earlier groups in terms 3 and 4. The waves of infection amongst groups 5, 6 and 7 did not produce any minor waves in groups 1–4 during terms 5–7. It is clear, therefore,

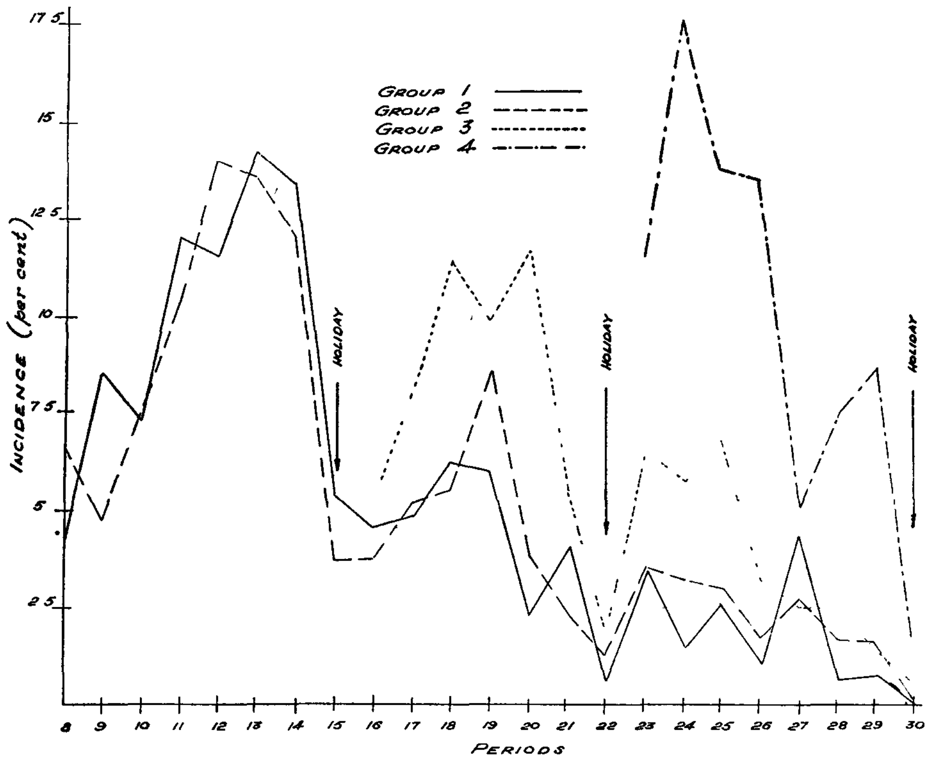

Fig. 3*a*. Incidence of tonsillitis, periods 8–30.

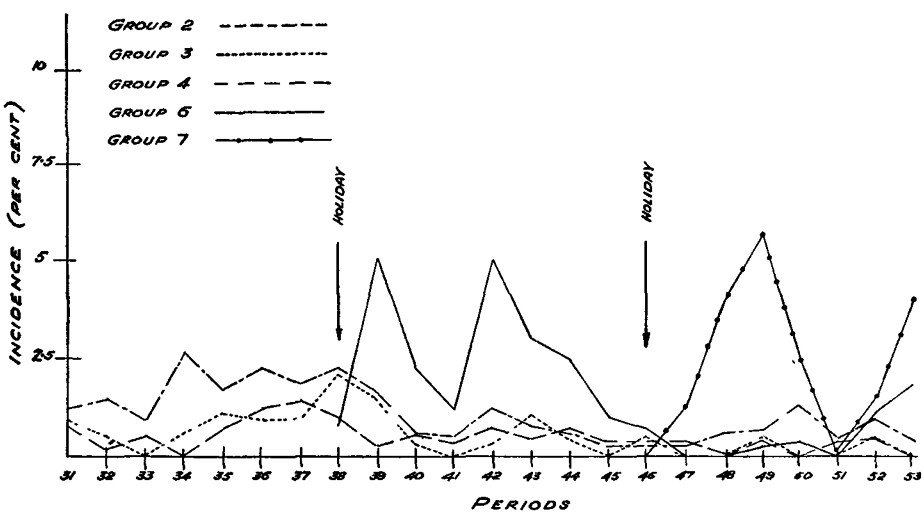

Fig. 3*b*. Incidence of tonsillitis, periods 31–53.

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that some radical reduction in the global epidemic (carriers, latent infections and clinical cases) occurred between terms 4 and 5, i.e. between the two sessions, which were separated by a holiday period of 1 month.

When a fresh population of susceptibles is introduced into an epidemic environment, there is an outbreak of cases amongst the fresh population which rises in incidence greater than that amongst the original population. This is due to the herd resistance which develops in the original population and has been recorded in institutions by Dudley (1926), as well as in experimental epidemics by Greenwood *et al.* (1936).

The experience of group 1 in term 1 did not raise the herd resistance of the group to such a level that its future experience differed from that of group 2.

Group 3, which entered in term 3, was admitted into an infected environment due to residual infection in the population of groups 1 and 2. It is probable that the incidence of actual cases in groups 1 and 2 would have continued to fall during term 3 if group 3 consisting of fresh susceptibles had not been admitted. The global epidemic in groups 1 and 2 at the beginning of term 3 spread into group 3, and there is no reason to assume that at first the global epidemic in group 3 in term 3 was greater than that in groups 1 and 2 in term 3. The incidence of definite clinical cases, however, was greater in group 3 due to the lack of resistance as compared with groups 1 and 2, i.e. the ratio of cases: carriers amongst the recruits was greater than amongst the original population. It is probable that the clinical case is more infectious than the carrier, and some 40% of all the recorded cases of tonsillitis were treated as outpatients. Moreover, those youths who were admitted to the wards were discharged to attend as outpatients. It is well known that cases of streptococcal tonsillitis carry large numbers of haemolytic streptococci in their throats long after the disease is cured clinically. The argument is advanced, therefore, that the wave of clinical cases in the recruits would produce a rise in the total concentration of infection in the institution. This would then produce an increased incidence of clinical cases amongst the old population and thus produce a further rise in the global epidemic in the *whole population*. The minor waves of cases in the graphical representation of the experiences of groups 1 and 2 during term 3 could have been due almost entirely to the dispersal of the population between the terms 1 and 2 as already explained. There was no diminution of the incidence of disease in groups 1 and 2 *before* the end of term 2, so that the production of a secondary minor wave in term 3 could have been produced artificially by scattering the population.

The events in term 4 were of greater interest, because the incidence of tonsillitis in groups 1–3 had fallen *before* the end of term 3. The epidemic of clinical cases was on the wane. There was a heavy incidence of cases of tonsillitis amongst the recruits (group 4). This influx of fresh population with its heavy incidence of cases was probably responsible for the minor wave of

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disease which appeared in group 3 in term 4. There was no wave of disease in term 4 in groups 1 and 2, whose populations had experienced 3 and 2 terms respectively of the epidemic. Presumably the herd resistance of groups 1 and 2 had risen to such a level that the influx of fresh population could no longer produce an outburst of clinical cases. The minor wave of disease in group 3 in term 4 must be regarded as a genuine one. It was not produced artificially by joining the point indicating the events at the end of one term to the point indicating the events at the opening of the succeeding one. The incidence of disease in group 3 in term 3 fell *before the end of the term* to a level much lower than that found in term 4.

The effect on the original population of an epidemic area by the introduction of fresh susceptibles has been noted in experimental epidemics by Greenwood *et al.* (1936) who found that the old population experienced a fresh outburst of cases when the fresh population was admitted. This was found by these workers to obtain in mouse typhoid and ectromelia and is a phenomenon well known in outbreaks of bovine abortion.

In term 5 there was a greater incidence of cases in the small group 5 (88 youths) than in groups 1–4, but the total number of cases was not sufficient to produce a definite wave of disease in the previous groups. It will be noted, however, that there was a slightly greater incidence of cases in group 4 than in groups 2 and 3 during term 5. The graph of the events in term 5 does not show the experiences of groups 1 and 5, as the populations of these groups were rather small.

The small but definite waves of disease in groups 6 and 7 during terms 6 and 7 respectively did not produce any minor waves in the earlier groups, and there was no minor wave in group 6 during term 7. During the second session, therefore (terms 5, 6 and 7: fortnightly periods 31–53), the global epidemic was presumably of a lower order than existed in the first session. It would appear that the concentration of infection in the environment remained fairly constant during the whole of the first session, if the incidence of cases in recruits can be accepted as an indication of this. During the second session the concentration of infection in the institution had fallen to a much lower level.

There can be no doubt that the recruitment of the population in batches at fortnightly intervals did much to continue the epidemic during terms 1–4 and to maintain the global epidemic at a high and fairly constant level. It has been noted that there was a wave of disease in each of the terms 2, 3 and 4. This was partly due to the interruption of the continuity of events by holiday periods. During terms 3 and 4, however, the wave was on a downward trend *before* the end of the term. Recruits were not admitted up to and including the last period of each term, but it is not claimed that the downward trend of the wave towards the ends of terms 3 and 4 was entirely due to this, as the waves were on a downward trend before this could have played an effective part. It is to be remembered also that the population was dispersed for holidays between each term. What effect this had on the epidemic is not clear except that a rise in incidence of disease from the beginning of each term might have been expected.

During the second session recruits were admitted terminally. Only one small group of 88 youths was admitted at the beginning of term 5 so that the population during term 5 was almost solely composed of members of groups 1–4. This probably played an important part in preventing an outbreak of tonsillitis in term 5. About this time also steps were taken to increase the sleeping accommodation.

Factors responsible for the disappearance of the epidemic

There were thus at least four factors responsible for the disappearance of the epidemic between the two sessions, viz.

(1) *Alteration of sleeping accommodation.* Before the end of term 4 more rooms had been taken over for dormitory space, but the population had grown meanwhile. The epidemic was at its height when the population was 1000 yet later in the session the population reached 1750. The dormitories between decks were ventilated by means of scuttles which for the most part were kept closed because the prevailing wind blew straight in. An attempt was made, however, to get better ventilation, and some of the closed decks were taken over as dormitories and were probably more satisfactory than the dormitories between decks.

(2) *Holiday period between the terms* 4 *and* 5. It has been recorded that there was a wave of infection during each term, and that the incidence of disease at the beginning of each term after a holiday period started at a low level.

(3) *Only one small batch of recruits admitted at the beginning of term* 5. The admission of batches at regular short intervals probably did much to maintain the epidemic. During term 5 the ratio of population of former groups to recruits was greater than in previous terms, i.e. the average institution age was greater.

(4) *The high degree of herd resistance in groups* 1–4. This would account for the low incidence of cases in these groups during term 5 and even had there been a severe wave of disease in the small group 5 during term 5 there would probably have been no wave of disease in groups 1–4 (see experience of groups 1 and 2 in term 4).

It is probable that there was a marked diminution in the global epidemic amongst groups 1–4 due to the first three factors above mentioned. If group 5 had been much larger, the course of events in term 5 might have been quite different because any increased incidence of disease in a large group 5 would have started the usual vicious cycle and the epidemic wave might have started all over again.

By the sixth term the global epidemic was of a low order, and the incidence of clinical cases in the recruits produced a wave but not of the size found in the recruits in earlier terms. The events in term 7 were similar to those in term 6.

The effect of admitting fresh population into the epidemic environment has been studied throughout the whole period of the institution's existence, i.e. 7 terms, but the epidemic proper was considered to end at the end of the 4th term. Many points of epidemiological interest were investigated over the period of the epidemic proper (terms 1–4, periods 1–30) but not continued into the terms 5–7 (periods 31–53, session 1938–9).

Incidence of tonsillitis at the various curtate ages

The population exposed at each of the curtate ages was derived as before. The total number of cases of tonsillitis and incidence of disease at each curtate age is shown in Table 3 and recorded graphically in Fig. 4. There was a fall in the incidence of disease as the curtate ages rose. The discrepancy between the incidence of disease at curtate ages 0 and 1 was probably due to two factors. First, each batch of recruits was assumed to have entered on one day, but in fact the youths of a batch entered over a period of 4–5 days. Secondly, the incubation period of the disease would prevent the occurrence of any recorded cases of clinical tonsillitis in the first day or two after entry.

Table 3. *Number of attacks of tonsillitis (all attacks) at the various curtate ages*

Curtate ages	Exposure units	No. of attacks	Attack rate %	Curtate ages	Exposure units	No of attacks	Attack rate %
0	2095	190	9·06	15	1151	39	3 39
1	2078	262	12·61	16	1130	28	2·48
2	2022	185	9·14	17	1079	30	2·78
3	1949	138	7·08	18	1000	28	2 80
4	1880	117	6 22	19	875	16	1 83
5	1810	112	6 19	20	688	9	1 31
6	1739	111	6 38	21	541	6	1 11
7	1668	94	5 60	22	345	6	1 74
8	1633	105	6 43	23	181	4	2·21
9	1632	109	6 68	24	152	3	1 97
10	1597	97	6 07	25	114	3	2 63
11	1527	71	4·65	26	79	1	1 27
12	1455	53	3 64	27	51	0	0
13	1382	43	3 11	28	31	0	0
14	1250	43	3 44	29	23	0	0

The smoothness of Fig. 4 might be used as additional evidence that the exposure risk remained fairly constant over a long period of time. Each batch of recruits attained to a given curtate age at a different period, and these periods were widely separated. For example, the number of cases at curtate age 0 of batches entering in the first term was added to the number of cases occurring at curtate age 0 in recruits who experienced their curtate age 0 in the fourth term and so on. The final result, however, led to a fairly smooth curve. It has already been noted in addition that the incidence of disease in the recruits remained remarkably constant throughout the session (Table 2, Fig. 3).

In analysing epidemiological data of an epidemic which persists over a period of time certain possible secular variations have to be neglected and the assumption made that exposure risks, etc., remain constant. The events described above might be advanced as evidence that this was so in this epidemic.

Incidence of tonsillitis in those not previously attacked

It was decided to ascertain the incidence of attacks of tonsillitis at any given age period amongst those members of the population who had not

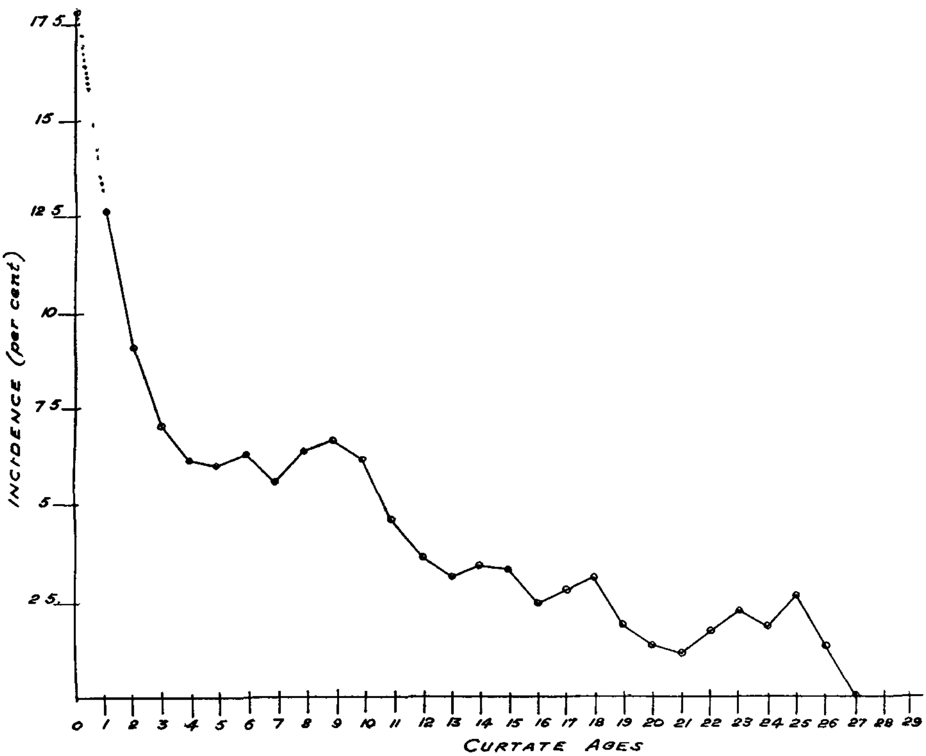

Fig. 4. Incidence of tonsillitis at the various curtate ages.

already had an attack of tonsillitis, i.e. during any given fortnightly age period the institution's population could be divided into two groups, (*a*) those who had had an attack or attacks of tonsillitis, and (*b*) those who had been exposed during previous age periods and escaped.

To find the boys who had not had an attack before a given age, the following method was adopted: Let A_0, A_1, A_2, ..., A_t be the number of youths who had had a first attack of tonsillitis at the various ages 0, 1, 2, .. , t (see Table 4). Let these youths be considered as rejected from the population at the named ages, i.e. when a youth took an attack of tonsillitis he was subtracted from the population so that the incidence of disease in those who had survived until this age could be calculated. In addition, youths were leaving the institution so that the population under consideration at age t was less than the original population minus ΣA_{t-1}. Still to be subtracted from the original population was the number of youths who left the institution before age period t and had not had an attack of tonsillitis. All youths who had left the institution before age period t and had had an attack of tonsillitis were accounted for in the numbers $A_0, A_1, A_2, \ldots, A_{t-1}$.

Let the numbers who left with the various curtate ages without having had an attack of tonsillitis be $B_0, B_1, B_2, \ldots, B_t$, then the number of boys who remained unattacked at the beginning of curtate age t was

$$2095 - \Sigma A_{t-1} - \Sigma B_{t-1}.$$

The number of boys who left the institution and escaped an attack of tonsillitis is shown in Table 4, together with their curtate age on leaving.

This table gives the information necessary to obtain the numbers

$$B_0, B_1, B_2, \ldots, B_t.$$

The above formula, however, did not recognize the fact that cases of tonsillitis were occurring and boys were leaving the institution during the age period t, and an adjustment was made similar to that adopted for Table 3. The final formula used was

$$2095 - \Sigma A_{t-1} - \Sigma B_{t-1} - \tfrac{1}{2}A_t - \tfrac{1}{2}B_t.$$

This gave the exposure units during each curtate age amongst boys who had survived all the preceding ages without experiencing an attack. The number of cases of tonsillitis occurring at the curtate age under consideration amongst these boys previously unattacked is shown in Table 4.

By subtraction from the total number of exposure units at any curtate age the average population at each age of boys who had previously experienced an attack (or attacks) was obtained.

At any given curtate age t the population was divisible into two, viz. those who had survived $t-1$ periods without having had an attack, and those who had had an attack (or attacks) at any of the curtate ages 0 to $t-1$. The population of the latter was built up by serial admissions from the former. After a boy took an attack of tonsillitis he was discarded from the one group and admitted into the other. The method adopted took account of those boys who left the institution from both groups in the periods 0 to $t-1$ and of those boys who left the institution or were transferred from one group to the other *during* the fortnightly age period t under consideration. The average population *during* the age period was obtained for both groups and the number of cases of tonsillitis which occurred in both groups was known. The numbers of cases which occurred in those youths previously unattacked are shown in Table 4, and by subtraction from the total number of cases of tonsillitis at the given curtate age the number of cases which occurred in the second group was found.

The incidence of tonsillitis at a curtate age t in the two groups is shown in Table 4 a–c, and graphically in Fig. 5.

Table 4 a. *Incidence of tonsillitis in exposed but previously unattacked members of the population*

Curtate ages	Population	No. of cases	Incidence %	Curtate ages	Population	No of cases	Incidence %
0	2000	190	9 50	15	378	10	2·65
1	1763	254	14·41	16	368	5	1 36
2	1512	173	11·44	17	346	9	2 60
3	1319	118	8·95	18	313	8	2·56
4	1174	82	6·98	19	270	5	1 85
5	1055	74	7 01	20	221	1	0 45
6	947	67	7 07	21	181	1	0·55
7	855	52	6 08	22	106	1	0 94
8	790	54	6 84	23	48	0	0
9	741	44	5 94	24	38	0	0
10	683	42	6·15	25	26	0	0
11	619	26	4·20	26	21	0	0
12	563	22	3·91	27	14	0	0
13	510	16	3 14	28	8	0	0
14	440	9	2·05	29	3	0	0

Table 4 b. *Incidence of tonsillitis in exposed and previously attacked members of the population*

Curtate ages	Population	No. of cases	Incidence %	Curtate ages	Population	No. of cases	Incidence %
0	95	0	0	15	773	29	3·75
1	315	8	2 54	16	762	23	3·02
2	510	12	2·35	17	733	21	2·86
3	630	20	3 17	18	687	20	2 91
4	733	35	4·77	19	605	11	1·82
5	755	38	5 03	20	467	8	1 71
6	792	44	5 56	21	360	5	1·39
7	813	42	5·17	22	239	5	2·09
8	843	51	6·05	23	133	4	3·01
9	891	65	7·30	24	114	3	2·63
10	914	55	6·02	25	88	3	3·41
11	908	45	4·96	26	58	1	1·72
12	892	31	3·48	27	37	0	0
13	872	27	3·10	28	24	0	0
14	810	34	4·20	29	20	0	0

Table 4 c. *Curtate ages on leaving, of those youths who had no attack of tonsillitis*

Curtate ages	No.	ΣN	Curtate ages	No.	ΣN
0	0	0	15	2	490
1	29	29	16	5	495
2	48	77	17	22	517
3	46	123	18	28	545
4	45	168	19	45	590
5	36	204	20	47	637
6	40	244	21	32	669
7	24	268	22	113	782
8	0	268	23	5	787
9	0	268	24	14	801
10	30	298	25	9	810
11	30	328	26	3	813
12	33	361	27	9	822
13	36	397	28	4	826
14	91	488	29	6	832

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The steady decrease of incidence of tonsillitis at the various institution ages amongst those who had escaped an attack at earlier ages was of interest because the incidence was in the exposed but as yet unattacked population. It therefore represented the rising herd resistance in a community in contact with an infection, but in whom no cases had as yet occurred.

Contact with an infection in the absence of overt disease is known to play a great part in increasing resistance and has been accepted as the process responsible for the immunity to scarlet fever and diphtheria which increases with age. Cf. also the incidence of tuberculosis in different races and resistance

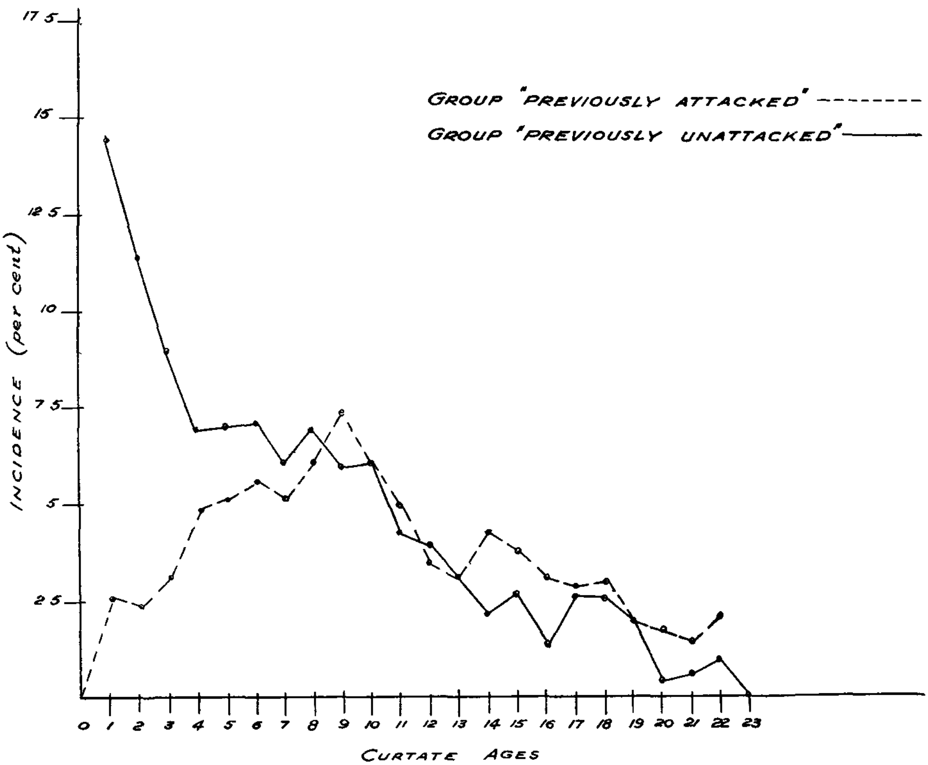

Fig. 5. Epidemic of tonsillitis.

to that infection, etc. The process has not only been shown to have been at work in this epidemic of tonsillitis but an attempt (with some reservations) has been made to measure its effect.

Evidence has been advanced and discussed (p. 581) that the global epidemic probably remained at a fairly constant and high level. Table 4 would appear to indicate that in such an environment the chances of taking an attack of tonsillitis in the exposed but unattacked population fell to one-half in some 14–20 weeks and to one-quarter in 24–30 weeks. A severe epidemic of the type described here would produce disease in all but those who had reached a high degree of immunity.

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The curve of incidence of disease at the successive institution ages in those who had had an attack at a lower institution age rose from 0 to meet the other curve after 8 periods or ages. It was expected that the curve would rise from 0 because at the very low institution ages any previous attack of tonsillitis would be only recently over. If an attack of tonsillitis leaves any resistance to a further attack it would not be anticipated that the incidence of disease amongst those *recently* attacked would be the same as the incidence amongst the remainder. As the age periods advanced, however, the average interval between the institution age of the attack and the institution age under consideration would rise so that the curve showing incidence of disease in this group would be expected to rise also. It was surprising to find, however, that the two curves met after 8 periods, and the experiences of the two groups from then on were similar. This was not entirely to be expected because the one group of boys had been exposed to the disease without having had an attack. The other group had had the same exposure *plus* an attack at a previous period. It was thought that the incidence of disease in the latter group would always be a little lower than that in the former, because of the additional increment of resistance left by the attack, but this did not occur. From the 14th age onwards the incidence of disease amongst those previously attacked was generally a little higher than amongst those not previously attacked.

It might appear, therefore, that in an epidemic of tonsillitis of this severity an attack did not add materially to the resistance produced by the exposure alone.

These arguments, however, do not recognize any effect by the factor of selection. The 'pre-institution experience' of the youths in addition to some other possible factors would play a part in determining their future experience in the institution. The boys who entered with some degree of resistance would tend to remain free from attack in the early periods, and the stimulation of resistance due to contact with the disease would raise their resistance to a higher level. Such boys would tend to remain in the group which did not experience an attack and would form an increasingly larger portion of the population of this group as the age periods advanced.

The following argument therefore is advanced: The resistance of the group 'previously unattacked' was due to contact with the disease *plus* 'selection'. The resistance of the group 'previously attacked' was due to contact with the disease *plus* attacks. After the age period 8 (16 weeks) the influence of selection in the former group balanced the influence of the attacks in the latter.

The curve showing the incidence of tonsillitis amongst those not previously attacked fell rather smoothly and appeared to resemble the curve of a geometrical rather than that of an arithmetical progression.

The curve which was obtained is shown again in Fig. 6, along with the curve of a geometrical progression whose factor is 0·87. The various incidences shown on this latter curve were found by starting at the incidence of 14·41% at curtate age 1 and compiling a geometrical progression where

$$(T_{n+1})/T_n = 0{\cdot}87.$$

On the whole it can be said that the incidence of disease amongst the exposed but previously unattacked population fell with the passage of time. Each event (an event being an exposure for one fortnight) raised the resistance to a higher level, but the successive increments of resistance became smaller.

The above methods of deriving the populations of the two groups made no allowance for boys who were in hospital suffering from an attack of tonsillitis.

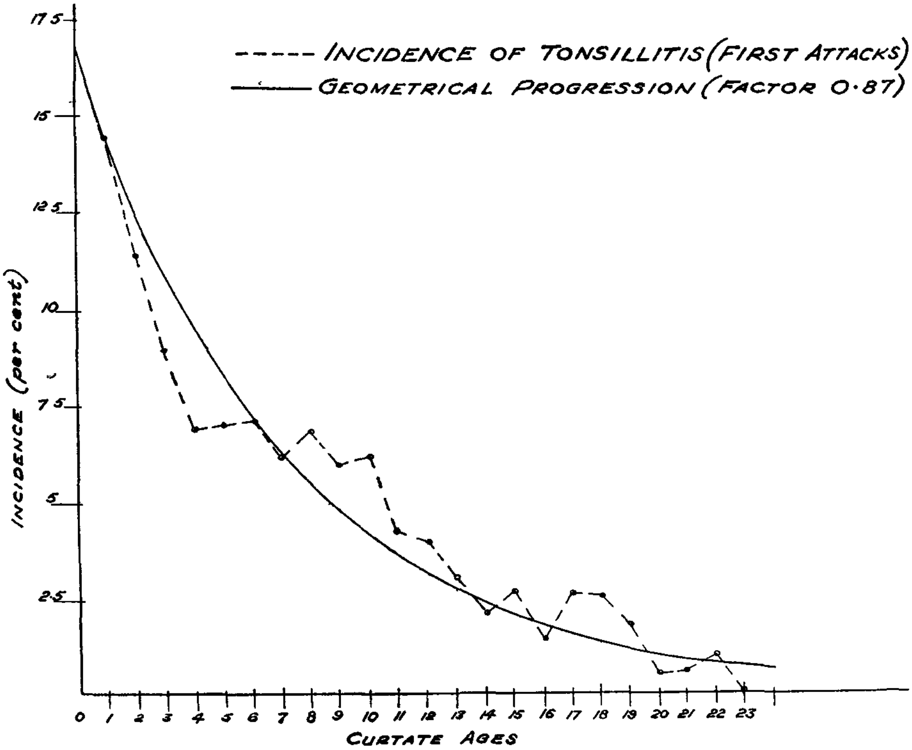

Fig 6.

If a boy took a first attack of tonsillitis at a given institution age he was considered to have taken the attack half-way through the age period when he was taken out of one group and added to the other. It is open to criticism, however, whether such a boy could be properly considered to belong to the group who had previously experienced an attack as from the very day he took his first attack. No second attack could possibly be recorded for some time, and it has already been admitted that two attacks occurring within 10 days of each other were considered to be one attack. Accordingly, the boys who experienced an attack of tonsillitis, whether this was the first or subsequent

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attack at a given age period, were considered to take that attack half-way through the period and were excluded from the population 'previously attacked'

Table 5. *Incidence of tonsillitis in exposed and previously attacked members of the population*

Curtate ages	Population	No. of cases	Incidence %	Curtate ages	Population	No of cases	Incidence %
0	0	0	0	15	753	29	3 85
1	184	8	4 37	16	748	23	3 07
2	417	12	2·88	17	718	21	2·92
3	561	20	3 56	18	673	20	2 97
4	674	35	5 19	19	597	11	1·84
5	699	38	5 44	20	462	8	1 73
6	737	44	5 97	21	357	5	1·40
7	766	42	5 48	22	236	5	2 12
8	790	51	6 45	23	131	4	3 05
.9	836	65	7 77	24	113	3	2 65
10	866	55	6 35	25	86	3	3·49
11	872	45	5·16	26	57	1	1·75
12	866	31	3 58	27	37	0	0
13	850	27	3·18	28	24	0	0
14	789	34	4 31	29	20	0	0

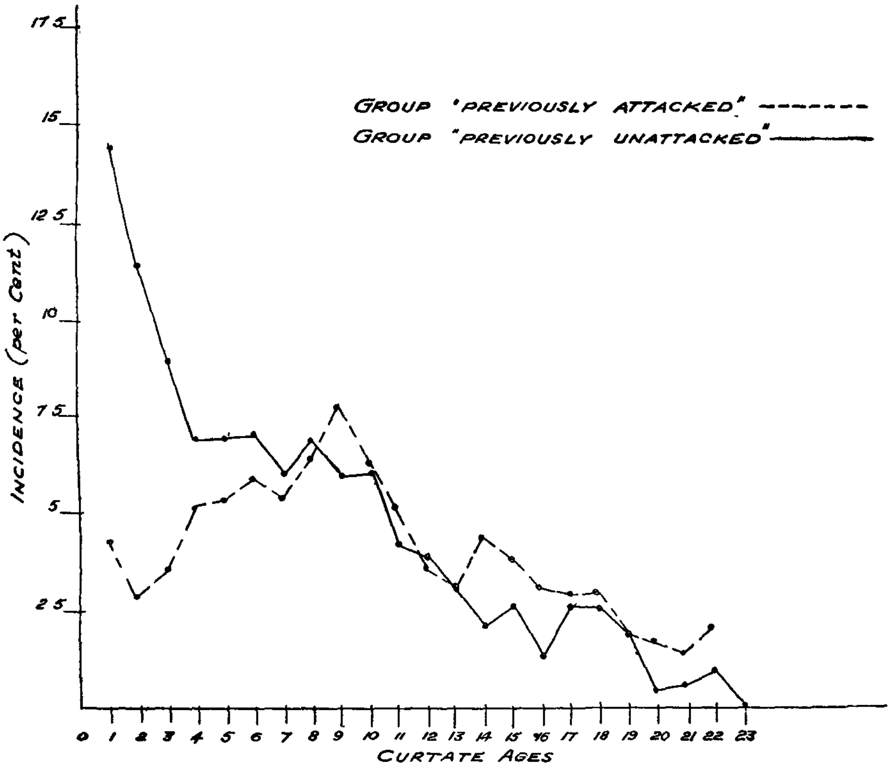

Fig. 7. Epidemic of tonsillitis.

until the end of the age period, i.e. for a period of a week. When this adjustment was made Table 5 and Fig. 7 were obtained for the population who had already had an attack at a lower institution age.

It was found that this made quite a definite change in the incidence rates at the earlier ages and was accepted as being the true representation of incidence of disease amongst those previously affected.

Those boys previously attacked, after adjustment for duration of disease, could have been found in another way.

Let $A_0, A_1, A_2, \ldots, A_t$ be the number of boys who took a first attack of tonsillitis at ages 0, 1, 2, ..., t. Let $B_0, B_1, B_2, \ldots, B_t$ be the number of boys who left the institution at ages 0, 1, 2, ..., t, and who had had an attack of tonsillitis before leaving. Then, the number of boys who experienced an institution age t and had had an attack of tonsillitis at any age period 0 to $t-1$ was $\Sigma A_{t-1} - \Sigma B_{t-1}$.

After adjustment to make allowance for those boys who left during the period t and who had had an attack of tonsillitis at any period 0 to $t-1$, the final formula was $\Sigma A_{t-1} - \Sigma B_{t-1} - \frac{1}{2} B_t$.

This formula gave populations almost identical to those obtained by the second method. The slight differences in the two populations at any given age were due to the inclusion in the population derived from the latter formula of boys who were in the middle of an attack of tonsillitis, where this attack was not the first, i.e. the difference was equal to

$$\tfrac{1}{2}\,(\text{total attacks at age } t - \text{no. of first attacks at age } t).$$

This difference did not alter the table or the figure materially.

Immunity produced by an attack of tonsillitis

The incidence of tonsillitis in boys not previously attacked fell very rapidly as the institution age rose. This was considered to be due to specific immunization produced by contact with the disease *plus* a contribution due to 'selection'. Although the relative influences exerted by these two processes could not be accurately gauged, it was felt that the former was by far the more potent.

An attempt was made to discover the length of time that the increment of resistance due to disease alone influenced the future experience. In the following discussion the influence of any possible selection was not taken into consideration.

Table 6 was compiled to show the number of attacks of tonsillitis at a given institution age along with the interval of time to the succeeding attack.

Table 7 was compiled to show the number of attacks of tonsillitis which were final attacks at the various institution ages along with the interval of time which elapsed before the boy left the institution.

The procedure is illustrated by an example. It is required to find the incidence of tonsillitis at age t amongst those who had had an attack of tonsillitis two periods (one month) previously. The number of boys who took tonsillitis at age $t-2$ was not great enough for these purposes. Accordingly,

Table 6. *Interval between attacks of tonsillitis**

Curtate age	Total no. attacks	1	2	3	4	5	6	7	8	9	10
0	190	8	10	8	8	10	11	11	2	4	2
1	262	2	12	9	15	8	6	11	5	11	3
2	185	0	13	3	13	7	5	9	9	4	1
3	138	4	6	5	6	5	8	7	5	1	4
4	117	4	7	4	6	12	4	3	4	2	2
5	112	2	5	7	8	5	5	3	1	5	0
6	111	2	9	6	7	4	0	1	1	4	3
7	94	5	7	3	7	3	1	2	1	1	2
8	105	5	4	6	*B* 4	4	3	2	1	2	1
9	109	*C* 3	3	3	1	2	4	2	2	2	3
10	97	2	5	3	4	3	3	0	1	1	0
11	71	1	5	2	3	0	1	0	2	1	1
12	53	*A* 0	3	3	2	2	3	0	0	0	1
13	43	0	2	0	0	0	0	0	0	0	0
14	43	1	1	2	1	1	1	0	0	0	0
15	39	0	2	0	1	1	0	0	1	0	0
16	28	1	3	0	0	0	0	0	0	0	0
17	30	1	0	0	1	0	1	0	1	0	0
18	28	0	0	0	0	0	1	1	0	0	0
19	16	0	0	0	0	0	0	0	0	0	0
20	9	0	0	1	0	0	0	0	0	0	
21	6	0	0	1	0	0	0	0	0		
22	6	0	0	0	0	0	0	0			
23	4	0	0	0	0	0	0				
24	3	0	0	0	0	0					
25	3	0	0	0	0						
26	1	0	0	0							

* Only the first ten columns of the table are reproduced.

Table 7. *Interval between final attack of tonsillitis and date of leaving the institution**

Curtate age of final attack	0	1	2	3	4	5	6	7	8	9	10
0	0	4	7	6	10	10	3	8	0	0	5
1	1	21	14	6	14	10	18	0	0	7	9
2	3	13	3	3	7	6	0	0	1	6	11
3	0	4	3	5	5	0	0	9	1	1	5
4	2	3	3	0	1	0	6	3	1	1	8
5	0	2	4	0	0	4	2	0	0	3	0
6	1	6	0	1	2	3	3	6	4	0	4
7	0	1	0	1	5	4	2	7	0	1	3
8	0	0	2	2	*Y* 4	5	7	0	1	0	3
9	*Z* 0	2	3	2	1	16	0	1	1	2	11
10	0	2	1	4	2	0	2	1	3	10	14
11	0	4	1	3	0	2	3	2	2	9	3
12	*X* 1	0	5	1	0	6	1	7	2	1	4
13	1	1	0	3	2	5	3	8	1	4	2
14	1	0	1	3	2	4	12	3	4	0	1
15	0	1	1	1	4	8	0	13	1	0	1
16	0	2	4	1	2	1	8	0	0	0	2
17	0	3	1	4	3	11	1	1	0	1	0
18	1	2	8	2	8	1	1	2	0	0	1
19	0	6	0	5	0	0	0	1	0	2	2
20	0	0	4	0	1	2	0	1	0	0	
21	0	2	0	1	1	1	0	0	0		
22	1	1	0	2	0	1	0	1			
23	0	2	0	1	0	1	0				
24	0	1	0	0	0	2					
25	0	0	1	1	1						
26	0	0	0	1							

* Only the first eleven columns of the table are reproduced.

the number of boys who took an attack at periods $t-3$, $t-2$, and $t-1$ were considered together and their attack of tonsillitis was considered to have occurred two periods previously. In only three isolated instances were two attacks of tonsillitis recorded in the same boy in the same age period. The number of attacks of tonsillitis in an age group therefore represented the number of boys attacked.

Consider the institution age 12 in Table 6. The number of youths attacked at ages 9, 10 and 11 was $109+97+71=277$. This number is too great because some boys have had two or more attacks *within* the age periods 9, 10 and 11 and accordingly have been included more than once in the total. In the triangle ABC, the numbers lying along the side AB show the number of boys attacked at age 12 and who had had an attack at age 9, 10 or 11. These numbers add up to 9. All other numbers within this triangle represent those boys who had two attacks within periods 9, 10 and 11 and are, therefore, counted more than once in the total 277. These numbers add up to 8. The new total population is $277-8=269$.

This new total of 269 assumes, however, that all the boys who experienced an attack of tonsillitis at ages 9, 10 and 11 *stayed in the institution* and experienced an institution age of 12.

Consider Table 7 and triangle XYZ. The numbers lying along the side XY represent boys who had a final attack at ages 9, 10 or 11 and who left during age 12. These numbers add up to 8. These 8 boys are credited with surviving for half a period at age 12. Accordingly, the total of 269 has to be reduced by $\frac{8}{2}$. This gives a new total of 265. All other numbers within the triangle XYZ represent boys who had their final attack at ages 9, 10 or 11 and who did not attain to an age 12. These add up to 7. The final total population is, therefore, 258:

$$\text{Incidence} = \tfrac{9}{258} = 3{\cdot}84\,\%.$$

The incidence of tonsillitis at age 12 amongst those not previously attacked was $3{\cdot}91\,\%$. Therefore, the attack of tonsillitis at institution age $10\,(t-2)$ exerted little or no influence over the experience at age 12 (t). In other words, at age period 10 the additional resistance given by the attack over and above that given by contact alone exerted no apparent influence one month later.

This investigation was extended for all age periods, not only for the attacks of tonsillitis dating back one month but for longer and shorter periods. This latter problem could obviously be solved by altering the size of the two triangles. The following general conclusions were reached.

During any age period 3–8 inclusive, the incidence of tonsillitis amongst those who had experienced an attack two periods (one month) previously was approximately two-thirds of the incidence amongst those who had never at any time suffered from an attack of tonsillitis in the institution.

During curtate ages 9–15 the incidence of tonsillitis was the same in the two groups.

Except at the very early ages an attack of tonsillitis did not influence the future experience 6 weeks later (as compared with those exposed but unattacked by the disease).

Scarlet fever

There were in all 113 cases of scarlet fever during the epidemic which were accepted as cases of streptococcal tonsillitis. Of these, 85 were the first attack of tonsillitis, 22 were the second attack and 6 were third or subsequent attacks. A diagnosis of scarlet fever was made in 6·73% of all first attacks of tonsillitis, in 4·9% of second attacks and in 3·14% of subsequent attacks. Scarlet fever, therefore, was the diagnosis of a diminishing fraction of the successive attacks of tonsillitis, and this suggests that attacks of tonsillitis immunize against the disease scarlet fever. The results of Dick tests on recruits and older members of the population of the institution have already been published (Thomson *et al.* 1940).

The epidemic of acute rheumatism

Introduction

During the epidemic of tonsillitis there occurred 115 cases of acute rheumatism. This epidemic of acute rheumatism is of great interest in view of the much discussed relationship of this disease to streptococcal infections of the upper respiratory tract.

The haemolytic streptococcus is accepted as the causal organism in a number of different clinical syndromes, viz. tonsillitis, scarlet fever, wound infection, erysipelas, puerperal sepsis, etc., and evidence is growing that acute rheumatism should be added to this group. It is accepted that although there are different groups and types of haemolytic streptococci there is no one particular type associated with each of the syndromes.

Coburn (1931) has shown a correlation between the incidence of tonsillitis and rheumatic fever in different countries and found that the normal throat flora of people living in the tropics rarely included the haemolytic streptococcus. He found also that patients who had suffered from rheumatic fever in New York were free of any recrudescence when transported to Porto Rico. On returning to New York many of the patients suffered from further attacks, and this followed the return of the haemolytic streptococcus to the patient's nasopharynx. Langstaff (1904–5) has shown that erysipelas and scarlet fever rise and fall in incidence together in any given district, and Thomson (1938) found a correlation between the incidence of all the notifiable streptococcal diseases including rheumatic fever.

The haemolytic streptococcus has been regarded as the causal organism in rheumatic fever because of the obvious relation of this disease to a preceding attack of acute tonsillitis. This antecedent tonsillitis is known to be caused by the haemolytic streptococcus, and most patients in the early stages of their attack of rheumatism still harbour large numbers of haemolytic streptococci in their throats even although they have recovered clinically from the throat infection (Coburn, 1931; Collis, 1931; Schlesinger, 1930; Green, 1938; McCulloch & Irvine-Jones, 1929). Haemolytic streptococci are recoverable in large numbers from the throat for many weeks after the clinical cure of any uncomplicated attack of tonsillitis.

A number of cases, amounting to minor outbreaks of rheumatic fever, have occurred in institutions, and some of these have been associated with a wave of streptococcal tonsillitis (Bradley, 1932; Glover, 1930; Schlesinger, 1930; Grenet, 1920; Glover & Griffith, 1931).

Such epidemiological evidence in support of the view that the syndrome of rheumatic fever is due to the haemolytic streptococcus is only indirect evidence, but recently Green (1939) and Thomson & Innes (1940) have shown that haemolytic streptococci can be recovered from the damaged but not from the undamaged heart valves of patients dying during the acute stage of this disease.

Criteria of the diagnosis 'acute rheumatism'

The 115 cases of acute rheumatism described here were undoubted rheumatic fever, and 50 of them were admitted to a teaching hospital where the diagnosis was accepted in every case. These cases were not specially selected but were most of those which occurred during a period when the hospital accommodation in the institution was severely taxed. Many more of the cases were removed to other hospitals after the acute stage of their illness had passed. It was felt that some others could justifiably have been added to the list, but it was decided to include only those where the diagnosis would be accepted by other physicians. There were many youths who suffered from 'myositis', 'growing pains', '? rheumatic fever', and it is probable that a number of those were mild cases of rheumatic fever. A dividing line, however, had to be drawn so that the cases accepted would be unchallengeable.

It was admitted that the diagnosis of 'tonsillitis' in the records of the institution was accepted as correct for the purposes of investigating the epidemic of tonsillitis. The majority of these cases were not seen by us personally. The cases of rheumatic fever, however, were treated and investigated during their illness by us. The cases which were admitted to a teaching hospital were under our supervision for prolonged periods.

Many features of more clinical interest in these cases will be described in later publications.

The epidemic wave of acute rheumatism

The number of cases of rheumatic fever which occurred at the various fortnightly periods did not run parallel to the number of cases of tonsillitis. Neither were there waves of cases of acute rheumatism following the waves of tonsillitis, as might have occurred if a certain fraction of all the cases of tonsillitis had developed into rheumatic fever after an interval or silent period of 2–4 weeks.

The numbers of cases of tonsillitis and acute rheumatism which occurred at each of the fortnightly periods are shown in Fig. 8.

This distribution of cases of rheumatic fever might have arisen if the silent period between an attack of tonsillitis and the onset of rheumatic fever had been very variable and had been shortening as the epidemic continued. This, however, was not the explanation, as an examination of the curtate ages of the cases of rheumatic fever at the onset of their illness will show.

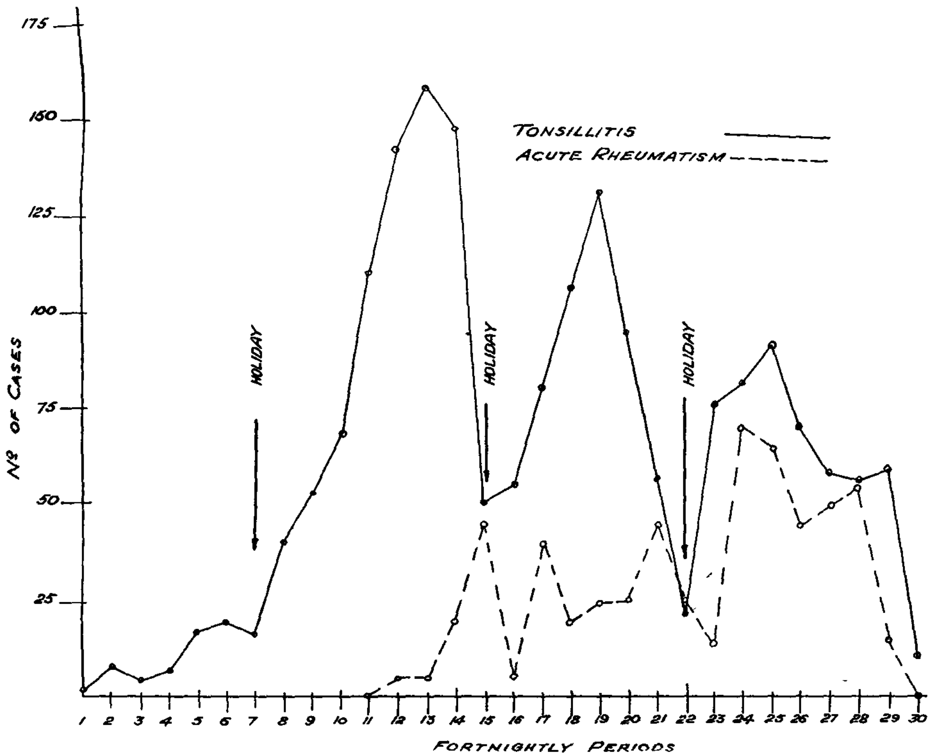

Fig. 8. Number of cases of tonsillitis and acute rheumatism (×5) in fortnightly periods.

Table 8. *Curtate ages of acute rheumatism*

Curtate age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
No.	8	7	4	12	11	9	5	10	7	4	4	5	6	6	2	2	6	4	3

This table shows that the cases of rheumatic fever occurred at the lower curtate ages. This showed that the cases occurred in those boys who had more recently joined the institution, because the average curtate age during the third and especially during the fourth term when most of the cases occurred, was considerably greater than this. Of the 115 cases of rheumatic fever, 8 (2·15%) occurred in youths who joined in term 1 (group 1), 49 (6·11%) in group 2, 33 (7·02%) in group 3, 25 (5·54%) in group 4.

Acute rheumatism has been considered a syndrome produced by the reaction of the body to repeated streptococcal infections, i.e. a manifestation of hypersensitivity. Accordingly the cases of rheumatic fever which occurred in the third and fourth terms might have been expected to occur in those youths of the higher institution ages who had experienced repeated attacks of tonsillitis. This was not the case and in fact the reverse was true.

The relationship between the two diseases as they occurred in this institution was not obvious, except that the two epidemics occurred at the same time, and it is doubtful if this investigation can add any *new* evidence to support the view that the syndrome of acute rheumatism is a type of reaction to the haemolytic streptococcus.

Incidence of disease in relation to the boys' home county

The boys were recruited from all parts of Great Britain and Northern Ireland, but the majority came from the north midlands of England and from Scotland.

The numbers of boys who came from various counties or districts are shown in Table 9 along with the incidence of tonsillitis and acute rheumatism in each group.

Table 9. *The incidence of tonsillitis and acute rheumatism in groups from different counties*

County	No. of boys	No. who had tonsillitis	Incidence %	No. who developed rheumatism	Incidence %
Northumberland	178	123	70	13	7 34
Durham	286	189	66	26	9 09
Lancashire	228	149	65	8	3 51
York	185	100	54	12	6 49
Lanark	127	77	60	5	3·91
Lothians and Scottish Borders	161	102	63	9	5·59
Scottish Highlands	148	81	55	7	4·73
Fife and Kinross	75	49	65	2	2 67
Northern Ireland	164	86	52	5	3 05
Devon and Cornwall, and Dorset and Hants	149	75	50	9	6·04
Others	371	223	59	18	4·77
Unplaced	23	9	39	1	4 35
Total	2095	1263	60	115	5 49

Of the 2095 boys who lived in the institution during the epidemic year 1263 (60%) took tonsillitis and 115 (5·49%) took an attack of acute rheumatism.

The number of boys from the various districts who took tonsillitis ranged from 50 to 70%. There was therefore not a great variation in the incidence of tonsillitis between the different groups.

In the case of acute rheumatism, however, the incidence ranged from 3·05 to 9·09%. There was a heavier incidence of rheumatism amongst boys recruited from Durham, Northumberland and York. There was, however, no sharp demarcation between the incidences found in these boys and the others. There was a gradual diminution in incidence rates from the highest (9·09% in the Durham boys) to the lowest (3·05% in the boys from Northern Ireland).

If the total population was divided into two groups, viz. boys from Northumberland and Durham and others, the difference in the incidence of acute rheumatism in the two groups would be highly significant statistically. When the population was subdivided into all the groups considered in Table 9, the higher incidence rates as found in boys from Northumberland and Durham would be obtained once in five times in the absence of any real differences in the groups.

It was of interest to note that the boys from the north-eastern counties of England showed a heavy incidence of gingivo-stomatitis on admission (Roff & Glazebrook, 1939). All boys on admission were examined by the dentists attached to the institution and it was found that boys from Northumberland and Durham showed an unduly heavy incidence of this condition. The gingivo-stomatitis extended back into the pharynx, and this condition did not clean up after routine methods of dental treatment.

Such a condition was suspected of predisposing to infection but there was no increase in the incidence of tonsillitis in these boys. An investigation was made, however, into the possibility that this condition predisposed to acute rheumatism or at least gave evidence of a condition which predisposed to acute rheumatism.

It was considered possible that the generalized gingivo-stomatitis was a manifestation of a mild deficiency in vitamin C. The possibility of a relationship between vitamin C deficiency and acute rheumatism has been reported by Rinehart & Mettier (1934) and Rinehart (1935). Accordingly, experiments were planned to investigate this phenomenon. These experiments were carried out in the post epidemic year (session 1938–9, terms 5–7) and are described in full in a subsequent publication.

In order to show that boys from all areas were admitted throughout the whole of the period under observation Table 10 has been constructed. This shows the number of boys from each area who joined with each batch, and has been constructed to show that there was not a particularly large number of boys from one of the areas, admitted at a time favourable to the development of acute rheumatism.

DISCUSSION

Epidemics of diseases spread by droplet infection are liable to occur in institutions whose populations consist of young people.

The epidemics described here occurred in a large institution whose population of 1000–1500 adolescents slept in crowded, poorly ventilated dormitories. The outbreak of tonsillitis reached tremendous proportions and was maintained for a long period of time.

There could be little doubt that the admission of recruits in batches at fortnightly intervals played an important part in maintaining the epidemic which persisted for over a year. The records showed there was always a high incidence of disease amongst those more recently recruited and that this

Table 10. *Home county of all boys of each batch of recruits*

	Batch no.																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Northumberland	4	8	5	7	7	4	23	8	8	11	6	5	0	14	7	10	3	7	6	10	6	9	6	2	2	178
Durham	13	10	15	12	9	5	26	7	19	15	5	6	10	10	15	12	14	18	8	10	19	12	8	5	3	286
Lancashire	6	6	7	11	14	10	26	12	11	12	10	11	2	7	9	11	8	7	6	8	4	6	14	3	7	228
York	4	7	7	6	5	4	24	10	8	5	11	12	2	8	9	4	9	7	2	4	5	13	7	7	5	185
Lanark	3	6	4	8	0	2	17	9	4	2	4	7	4	8	3	7	6	4	7	3	3	3	3	7	3	127
Lothians and Scottish Borders	4	1	5	6	5	7	22	9	9	2	7	2	3	12	4	7	8	7	9	7	6	6	7	4	2	161
Scottish Highlands	9	7	5	7	5	1	5	6	7	5	9	3	5	15	5	9	6	2	7	7	12	5	3	2	1	148
Fife and Kinross	4	0	4	3	3	5	14	3	7	4	1	3	1	3	3	3	1	3	2	5	0	2	0	1	0	75
Northern Ireland	4	5	2	8	6	3	27	4	8	3	4	5	2	7	7	0	6	8	11	6	9	9	11	5	4	164
Devon and Cornwall	0	0	0	0	0	0	51	0	4	0	0	0	0	20	0	0	0	0	0	0	0	0	0	14	0	89
Dorset and Hants	0	0	0	0	0	0	33	0	4	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	60
Others	4	12	7	7	17	6	88	9	29	10	13	16	7	59	8	7	9	7	8	9	5	5	8	15	6	371
Unplaced	1	0	0	0	0	0	2	1	0	1	1	1	0	2	0	2	0	0	3	2	1	0	2	3	1	23
Total	56	62	61	75	71	47	358	78	118	70	71	71	36	188	70	72	70	70	69	71	70	70	69	68	34	2095

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reflected in an increased incidence of disease amongst the older members of the population.

These conditions persisted for over a year before steps were taken to give the boys more sleeping accommodation and at the same time the regular admission of recruits at fortnightly intervals was discontinued.

It was unfortunate that detailed bacteriological examinations were not made during the epidemic. From time to time throat swabs were taken from a number of cases and the haemolytic streptococcus was demonstrated to be the causative organism. The types of streptococci responsible for the cases at different periods of time were not determined but it was known that several types were present when the epidemic was at its height in the second term. It is possible that the predominating types changed from time to time but this was not considered to be likely unless the various types of streptococci produced a high degree of cross-immunity. It was known that at any given period the incidence of disease was much less amongst those members of the population who had been in the institution for some time. If the recruits had imported new types of streptococci and if very little cross-immunity existed between the different types this result would not have been found.

The holiday periods interfered with the continuity of events. During each holiday period a number of carriers would cease to harbour the causative organism with the result that the global epidemic at the opening of the new term would be lower than that which existed at the close of the previous one. This would reflect in the production of fewer clinical cases at the opening of each term with the result that a depression would appear in the graphical representation if the events were considered to be continuous. There is no doubt that this was responsible for some of the features of the rise and fall of incidence of infection during the year. During two of the terms, however, the incidence of disease fell to a very low level *before* the end of the term and accordingly true waves were produced.

The incidence of disease at the various institution ages fell as the institution ages rose.

This was true also for those members of the population who survived the previous institution ages without suffering from an attack. As the institution age rose the incidence of disease fell in a geometrical progression. There is no doubt that exposure to a disease with its resultant subclinical infections plays an important part in the production of a state of resistance. This was considered to be the important factor in determining the result obtained but the possibility of the effect of selection was also considered. It was not possible to separate the two factors and for some of the arguments the possible interplay by selection was neglected. It was found for example that the rate of immunization by contact with this virulent epidemic was so great that an attack of the disease added a surprisingly small increment to the resistance. These arguments, however, have all to be considered in the light of the virulence of the epidemic where all but those enjoying a very high degree of resistance would succumb to an attack. It is not intended to minimize the effect of the attack but rather to emphasize the effect of the contact with the infectious environment.

The occurrence of 115 cases of rheumatic fever was of singular importance. Cases of this disease have frequently appeared during epidemics of tonsillitis but never so many as to constitute an epidemic. There is already much evidence to associate these two diseases. The cases of rheumatic fever occurred fairly late in the epidemic of tonsillitis and very definitely affected those who had recently entered the institution. There is a view that rheumatic fever is a syndrome dependent upon a state of hypersensitivity to the haemolytic streptococcus. If this view explains the disease the cases would have been expected to occur amongst those who had experienced multiple attacks of tonsillitis in the institution, but this was not so.

PART II. COMMON COLDS

Introduction

During the period of two years sufficient cases of common cold occurred to permit of an investigation to be made similar to that on tonsillitis.

There were a total of 1243 cases of common cold; of these, 662 occurred in the first four terms (the period of the epidemic of tonsillitis consisting of the opening summer term and a complete session with three terms) and 581 in the following three terms (the second session). The attack rate, therefore, remained the same in both sessions and this contrasted greatly with the attack rate of tonsillitis which showed a great reduction in the second session.

The incidence of common cold rose and fell greatly with the seasons of the year and the incidence of this disease in the institution was probably no greater than that in the general population of the country. It was felt, however, that the investigation might shed some light on the epidemiology of this disease.

Incidence of common cold at fortnightly periods

The incidence of colds at the successive fortnightly periods is shown in Table 11, and graphically in Fig. 9 which shows that the incidence of common cold was greater in the winter than in the summer months. The dispersal of the population at holiday periods did not have the same effect on the incidence of common cold as on that of tonsillitis. This, of course, was expected since there did not exist an epidemic of colds where the incidence of disease would be dependent upon the 'concentration of infection' in the institution as compared with the general population of the country.

The greatest incidence of common cold occurred in January of the second winter (periods 39 and 40), but on the whole the incidence in the first winter was more sustained. The curve of incidence was higher but narrower in the second winter than in the first.

Table 11. *Incidence of common cold at fortnightly periods*

Period	No. of cases	Population	Incidence	Period	No. of cases	Population	Incidence %
1	0	56	0	28	18	1758	1·02
2	1	118	0·85	29	16	1739	0·92
3	5	179	2·79	30	3	1722	0·17
4	1	254	0·39	31	6	1661	0·36
5	1	325	0·31	32	9	1665	0·54
6	8	372	2·15	33	18	1588	1·13
7	9	372	2·42	34	24	1503	1·60
8	15	730	2·05	35	25	1426	1·75
9	21	808	2·60	36	34	1375	2·47
10	31	926	3·35	37	32	1347	2·38
11	34	996	3·41	38	37	1419	2·61
12	52	1067	4·87	39	117	1463	8·00
13	43	1135	3·79	40	81	1411	5·74
14	48	1170	4·10	41	21	1360	1·54
15	17	1168	1·46	42	42	1302	3·23
16	34	1356	2·51	43	33	1261	2·62
17	52	1424	3·65	44	9	1215	0·74
18	42	1495	2·81	45	4	1170	0·34
19	27	1563	1·73	46	7	1287	0·54
20	35	1630	2·15	47	11	1408	0·78
21	23	1606	1·43	48	11	1364	0·81
22	16	1580	1·01	49	13	1306	1·00
23	37	1631	2·27	50	17	1263	1·35
24	24	1670	1·44	51	1	1247	0·08
25	29	1702	1·70	52	6	1245	0·48
26	13	1732	0·75	53	23	1244	1·85
27	7	1755	0·40				

INCIDENCE OF COMMON COLD IN DIFFERENT GROUPS

The incidence of common cold at the various periods was determined in various groups of boys. Groups 1–7 were composed of the boys who entered in terms 1–7 respectively. The results are shown in Table 12 and expressed graphically in Fig. 10.

With the exception of the high incidence of disease in group 6 in term 6 the incidence amongst those recently recruited was the same as that in the others who had been in the institution for some time. It is doubtful if the heavy incidence of disease in group 6 in term 6 was due to the same factors as were responsible for the increased incidence of tonsillitis amongst the recruits. All the groups experienced their heaviest incidence of disease at periods 39–40. The heavy incidence of disease in groups 1–5 at period 39 was obviously independent of the admission of recruits (group 6). There was obviously no mutual influence between groups 1–5 on the one hand and group 6 on the other at period 39. Moreover, the incidence of disease at period 39 in the groups 1–5 was not related to the lengths of time the populations of the groups had been in the institution.

INCIDENCE OF COMMON COLD AT INSTITUTIONAL AGES

Since the incidence of disease in the groups recently recruited was the same as that in the other groups the attack rate at the higher institution ages must have been the same as that at the lower ages. The incidences of common cold at curtate ages 0–46 are shown in Table 13 and graphically in Fig. 11.

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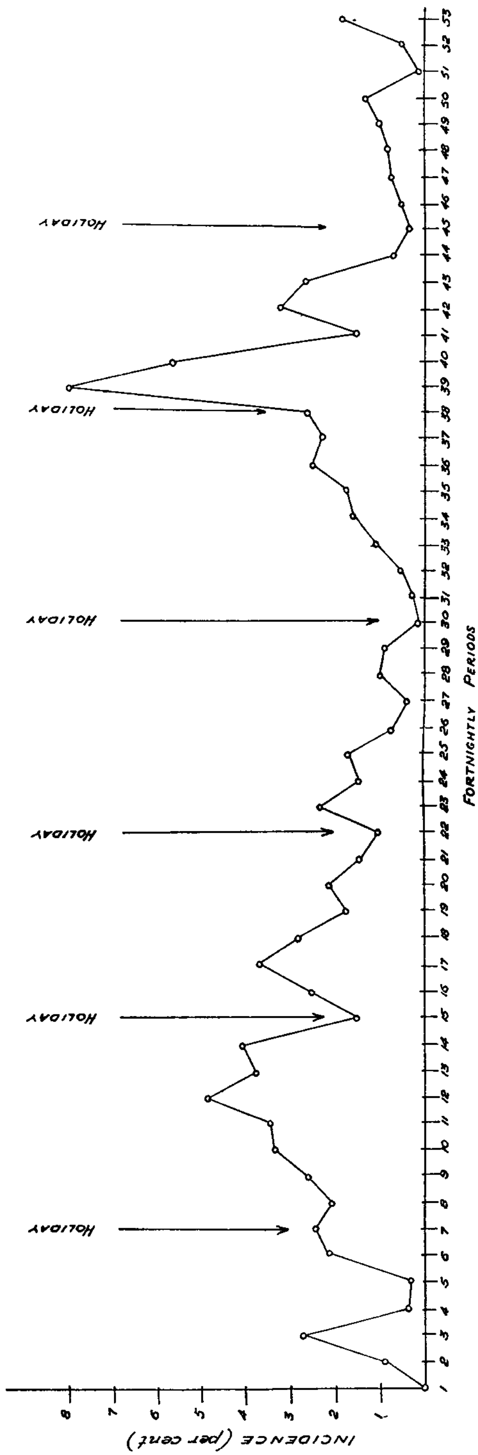

Fig. 9. Incidence of common cold at fortnightly periods.

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Table 12. *Incidence of common cold in different groups*

Period no.	No. of cases	Population	Incidence	Period no.	No. of cases	Population	Incidence
			Group 1				
1	0	56	0	28	2	162	1·23
2	1	118	0·85	29	3	142	2·11
3	5	179	2·79	30	0	140	0·00
4	1	254	0·39	31	0	85	
5	1	325	0·31	32	0	73	
6	8	372	2·15	33	1	59	
7	9	372	2·42	34	2	51	
8	6	372	1·61	35	0	38	
9	13	372	3·50	36	1	26	
10	15	372	4·03	37	0	22	
11	11	372	2·96	38	0	19	
12	19	372	5·11	39	1	14	
13	15	371	4·04	40	0	9	
14	20	371	5·39	41	1	8	
15	5	370	1·35	42	0	5	
16	11	370	2·97	43	0	2	
17	14	369	3·79	44	0	1	
18	15	368	4·08	45	0	1	
19	9	366	2·46	46	0	1	
20	9	364	2·47	47	0	1	
21	4	342	1·17	48	0	0	
22	4	319	1·25	49	0	0	
23	5	301	1·66	50	0	0	
24	6	270	2·22	51	0	0	
25	6	233	2·58	52	0	0	
26	3	201	1·50	53	0	0	
27	1	186	0·54				
			Group 2				
8	9	358	2·51	31	2	631	0·32
9	8	436	1·83	32	3	603	0·50
10	16	554	2·89	33	5	543	0·92
11	23	624	3·69	34	4	475	0·84
12	33	695	4·75	35	6	427	1·41
13	28	764	3·66	36	7	409	1·71
14	28	799	3·50	37	7	400	1·75
15	12	798	1·50	38	13	384	3·38
16	19	798	2·38	39	28	348	8·05
17	31	797	3·89	40	13	324	4·01
18	18	797	2·26	41	1	313	0·32
19	12	797	1·50	42	6	288	2·08
20	12	797	1·50	43	5	269	1·86
21	12	796	1·50	44	0	263	0
22	5	795	0·63	45	3	258	1·16
23	18	795	2·26	46	0	251	0
24	13	794	1·64	47	1	244	0·41
25	12	793	1·51	48	2	240	0·41
26	3	785	0·38	49	0	233	0
27	4	754	0·53	50	0	228	0
28	10	715	1·40	51	0	227	0
29	4	686	0·58	52	1	227	0·44
30	0	678	0·00	53	2	226	0·88

Table 12 (*continued*)

Period no.	No. of cases	Population	Incidence	Period no.	No. of cases	Population	Incidence
			Group 3				
16	4	188	2·13	35	4	438	0·91
17	7	258	2·71	36	7	423	1·66
18	9	330	2·73	37	7	414	1·69
19	6	400	1·50	38	9	392	2·30
20	14	469	2·99	39	26	363	7·16
21	7	468	1·50	40	12	342	3·51
22	7	466	1·50	41	1	308	0·32
23	11	466	2·36	42	7	283	2·47
24	4	466	0·86	43	9	273	2·30
25	10	466	2·15	44	4	251	1·59
26	4	466	0·86	45	0	232	0·00
27	0	466	0·00	46	0	214	0·00
28	3	466	0·64	47	1	198	0·51
29	2	463	0·43	48	0	190	0·00
30	0	459	0·00	49	0	179	0·00
31	4	454	0·88	50	0	169	0·00
32	4	454	0·88	51	0	166	0·00
33	5	453	1·10	52	0	166	0·00
34	4	448	0·89	53	1	166	0·60
			Group 4				
23	3	69	4·35	39	22	395	5·57
24	1	140	0·71	40	14	393	3·56
25	1	210	0·48	41	5	388	1·29
26	3	280	1·07	42	20	383	5·22
27	2	349	0·57	43	4	374	1·07
28	3	415	0·72	44	3	357	0·84
29	7	448	1·56	45	0	336	0
30	3	445	0·67	46	2	323	0·62
31	0	447	0	47	2	312	0·64
32	2	447	0·45	48	3	281	1·07
33	6	445	1·34	49	2	242	0·83
34	11	441	2·49	50	2	214	0·84
35	10	435	2·30	51	0	202	0·00
36	16	429	3·73	52	2	200	1·00
37	12	423	2·84	53	4	200	2·00
38	11	408	2·70				
			Group 5				
31	0	44	0	43	3	88	3·41
32	0	88	0	44	0	88	0
33	1	88	1·14	45	0	88	0
34	3	88	3·41	46	0	88	0
35	4	88	4·55	47	0	88	0
36	3	88	3·41	48	2	88	2·27
37	6	88	6·82	49	1	88	1·14
38	2	88	2·27	50	2	88	2·27
39	14	88	15·91	51	0	88	0
40	6	88	6·82	52	0	88	0
41	1	88	1·14	53	1	88	1·14
42	2	88	2·27				
			Group 6				
38	2	128	1·56	46	2	255	0·78
39	26	255	10·20	47	3	255	1·18
40	36	255	14·12	48	3	255	1·18
41	12	255	4·71	49	1	254	0·39
42	7	255	2·75	50	2	254	0·78
43	12	255	4·71	51	1	254	0·39
44	2	255	0·78	52	0	254	0·00
45	1	255	0·39	53	6	254	2·35
			Group 7				
46	3	155	1·94	50	11	310	3·55
47	4	310	1·29	51	0	310	0
48	1	310	0·32	52	3	310	0·97
49	9	310	2·90	53	9	310	2·90

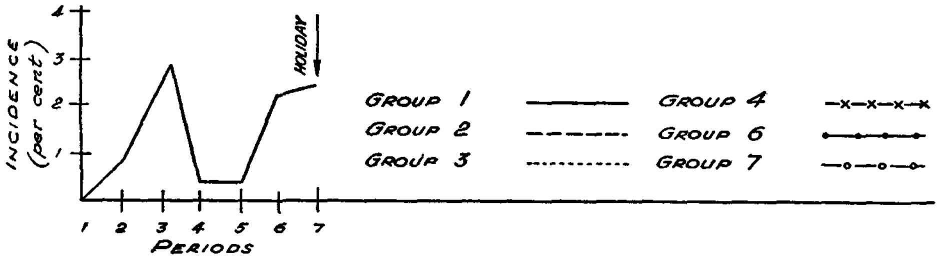

Fig. 10.

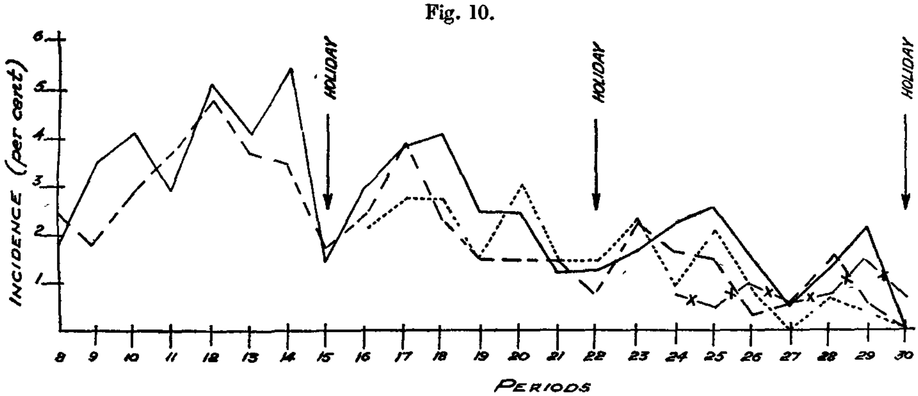

Fig 10*a*

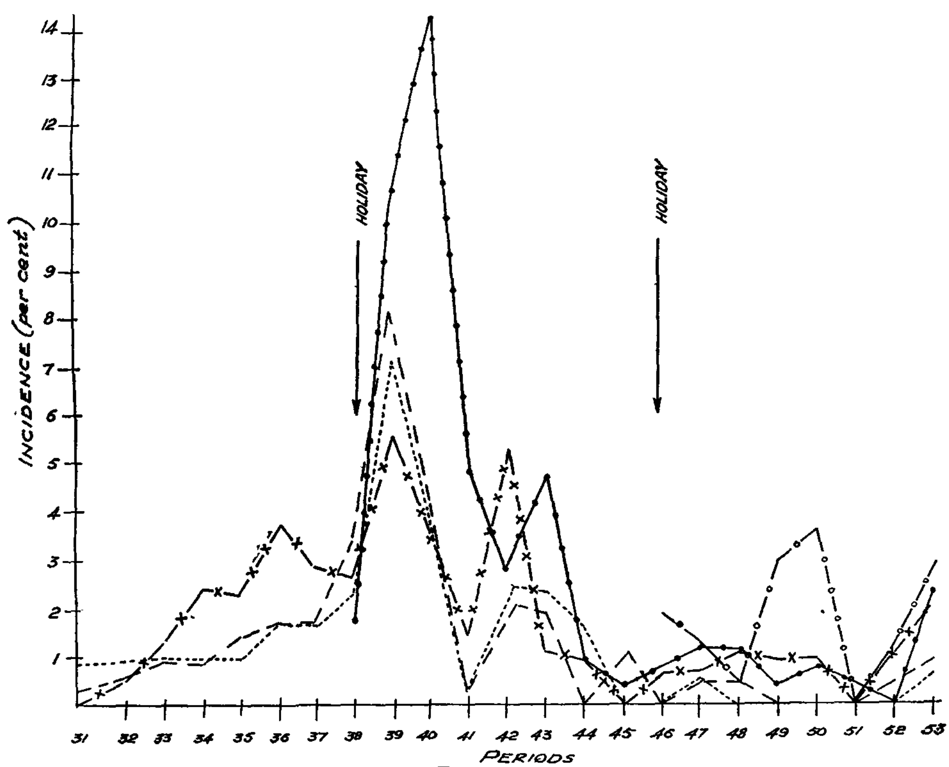

Fig 10*b*.

Figs. 10, 10*a* and 10*b*. Incidence of common cold at fortnightly periods in different groups.

In the similar investigation in the case of tonsillitis evidence was obtained that the epidemic remained at a fairly high and constant level for a long period of time (over a year). Because of this the determination of incidence of tonsillitis at the institution ages was justified. The incidence of tonsillitis in a batch which attained to a curtate age t at period x was compounded with the incidence which occurred in another batch which attained to the age t at period y. There were no great secular changes in the epidemic of tonsillitis.

The seasonal fluctuations in the incidence of common cold would, however, reflect to some extent in the incidences at the institution ages. With these reservations Table 13 and Fig. 11 have been produced.

Table 13. *Incidence of common cold (all attacks) at curtate ages*

Curtate age	Exposure units	Cases	Incidence %	Curtate age	Exposure units	Cases	Incidence %
0	2748	55	2·00	24	1160	17	1·47
1	2740	74	2·70	25	1045	8	0·77
2	2740	84	3·07	26	929	12	1·29
3	2739	68	2·48	27	829	17	2·05
4	2737	71	2·59	28	740	15	2·03
5	2737	64	2·34	29	668	8	1·20
6	2734	58	2·12	30	576	11	1·91
7	2725	53	1·94	31	529	24	4·54
8	2410	71	2·95	32	496	9	1·81
9	2403	49	2·04	33	473	4	0·85
10	2387	42	1·76	34	425	6	1·41
11	2371	44	1·86	35	407	2	0·49
12	2367	49	2·07	36	386	0	0·00
13	2359	43	1·82	37	369	1	0·27
14	2349	40	1·70	38	242	0	0·00
15	2338	49	2·10	39	235	1	0·43
16	2076	33	1·59	40	231	3	1·30
17	2070	32	1·54	41	226	0	0·00
18	2047	18	0·88	42	223	0	0·00
19	1961	19	0·97	43	220	1	0·45
20	1793	19	1·06	44	176	1	0·57
21	1580	18	1·14	45	176	1	0·57
22	1421	19	1·34	46	1	0	0·00
23	1233	29	2·35				

The incidence of common cold remained at a fairly constant level for some 30 fortnightly age periods. A large number of the boys who reached curtate ages 31 and 32 reached these ages at calendar periods 39 and 40. The high incidence of disease at these ages therefore was due to the high incidence of disease at calendar periods 39 and 40. The populations which attained to curtate ages 34–46 were largely composed of boys who attained to these ages in the summer of the second session when the incidence of disease was low. There was, therefore, a low incidence of disease at the high institution ages and this was related more to the events at calendar periods of time than to the institution ages. But for this it is probable that the incidence of disease at the institution ages would have remained at a more constant level, i.e. entry into the institution did not increase the chance of taking an attack of common cold and living there for a period of time did not decrease it. This, of course, is merely another way of stating that there was no institutional epidemic.

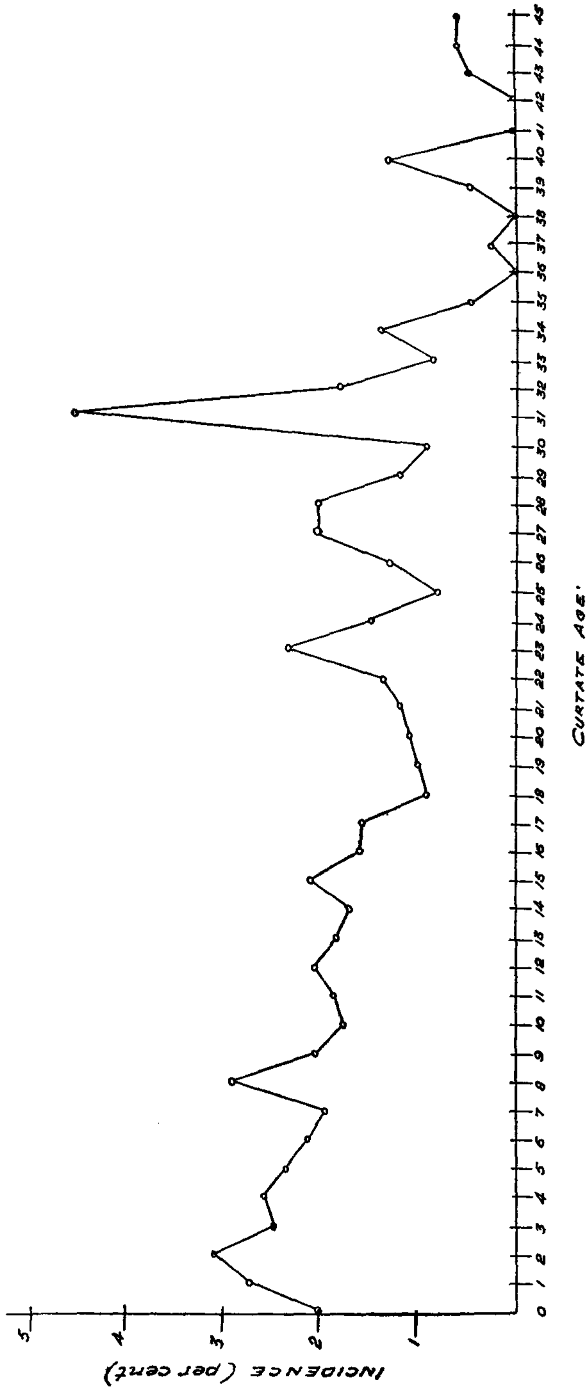

Fig. 11. Incidence of common cold at curtate ages.

INCIDENCE OF COMMON COLD IN THOSE NOT PREVIOUSLY ATTACKED

The method adopted was the third method described for a similar analysis of the cases of tonsillitis.

Let $A_0, A_1, A_2, \ldots, A_t$ be the number of attacks of common cold which were first attacks at ages 0, 1, 2, ..., t.

Let $B_0, B_1, B_2, \ldots, B_t$ be the number of boys who left the institution at ages 0, 1, 2, ..., t, and who had had an attack of common cold at any age.

Then the number of boys who attained to an age t and who had had an attack of common cold at any age 0 to $t-1$ was $\Sigma A_{t-1} - \Sigma B_{t-1}$.

Table 14. *Incidence of common cold*

Previously attacked				Not previously attacked			
Curtate age	No. of attacks	Exposure units	Incidence %	Curtate age	No of attacks	Exposure units	Incidence %
0	0	0	0	0	50	2095	2 39
1	0	50	0	1	44	2028	2·17
2	2	90	2 22	2	44	1932	2·28
3	4	130	3 08	3	40	1819	2·20
4	6	169	3 55	4	42	1711	2 45
5	6	208	2 88	5	40	1602	2·50
6	11	243	4·53	6	32	1496	2·14
7	8	269	2·97	7	30	1399	2·14
8	13	296	4 39	8	34	1337	2·54
9	9	330	2·73	9	22	1302	1·69
10	11	346	3 18	10	14	1251	1·12
11	8	349	2·29	11	14	1178	1·19
12	17	352	4·83	12	15	1103	1·36
13	12	354	3·39	13	15	1028	1·46
14	10	344	2·91	14	11	906	1·21
15	17	336	5·06	15	9	815	1·10
16	6	338	1·78	16	11	792	1·39
17	7	336	2 08	17	7	743	0·94
18	4	320	1·25	18	5	680	0·74
19	5	282	1·77	19	4	593	0·67
20	3	227	1·32	20	2	461	0·43
21	3	183	1·64	21	1	358	0·28
22	2	121	1·65	22	1	224	0·47
23	2	72		23	2	109	1·83
24	1	65		24	3	87	3 45
25	0	55		25	0	59	0
26	0	38		26	0	41	0
27	2	22		27	0	29	0
28	1	13		28	0	18	0
29	0	5		29	0	7	0

The number of exposure units (boy per fortnight) *during* age period t amongst those who had previously experienced an attack of common cold was therefore $\Sigma A_{t-1} - \Sigma B_{t-1} - \frac{1}{2}B_t$.

This investigation was made for the first session only (terms 1–4, groups 1–4).

Table 14 shows the incidence of disease at ages 0–22 amongst those previously attacked and amongst those not previously attacked. The data for the latter incidence were obtained by subtraction from the total number of cases and total exposure units at the curtate ages. The result is also expressed graphically in Fig. 12.

The incidence of common cold in those not previously attacked was maintained at a constant level for the first ten fortnightly age periods. Thereafter it fell gradually but again it will be noted that the higher ages were reached in the summer months at the end of the first complete session (term 4), when the incidence of disease was low. It is doubtful if the fall after the 10th age was in any way dependent upon the institution age.

Of greater interest, however, was the high incidence of disease in the group which had previously experienced a recorded attack in the institution. It would appear that the attack of common cold not only leaves no measurable

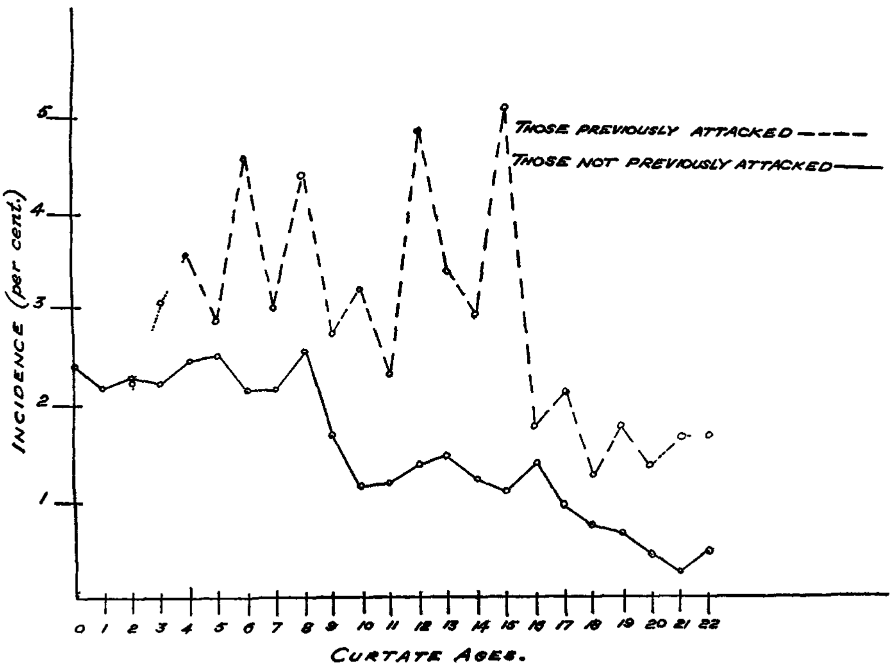

Fig. 12. Incidence of common cold at curtate ages. (Graph drawn thus ...... if attack rates were calculated in populations less than 200)

degree of resistance behind it but that there is a susceptibility to a further attack. It may be, however, that some people always take a severe attack and boys of this class would report sick. Others may be only mildly upset and may not report sick.

DISCUSSION

During a period of two years in the institution whose average population numbered some 1400 there occurred 1243 cases of common cold. This attack rate was considered to be no greater than that which existed in the general population.

The incidence of disease was higher in the winter months than in the summer months. This also is true of the incidence of common cold in the general population and this has been related to the conditions of living in the winter months as compared with the summer months. In this institution, however, whose population formed a semi-closed community, conditions of overcrowding existed all the time. The epidemic of tonsillitis, which reached tremendous proportions, persisted for over a year, and was not related to the season of the year. It might have been expected, therefore, that if the infections of common cold were acquired in the institution the attack rate would not have been related to the weather. Nevertheless, this relationship did exist and it was also surprising to find that there was no epidemic of common cold although the conditions favourable to spread the infection were present.

Prolonged stay in the institution did not reduce the attack rate as compared with entrants presumably because the incidence of disease amongst the general population was as high as that which existed in the institution.

It was found that the incidence of disease amongst those who had previously had a recorded attack was higher than amongst those who had no previously recorded attack. Many boys who had a mild attack may not have reported sick and it may be that there are some people whose attack of common cold is always of such severity as to incapacitate them. Boys of the latter category would of course always report sick. This may or may not have explained the difference between the two groups and it would appear that the attack of common cold leaves very little resistance behind it.

SUMMARY AND CONCLUSIONS (PARTS I AND II)

1. In an institution whose average population was approximately 1200 there occurred 1903 cases of tonsillitis and 115 cases of rheumatic fever in the course of a year.

2. The population was built up by the admission of recruits at fortnightly intervals and this played an important part in continuing the epidemic.

3. The incidence of tonsillitis fell as the institution ages rose. As the institution ages rose the incidence of tonsillitis amongst those not previously attacked fell in a geometrical progression.

4. It was felt that violent exposure to streptococcal tonsillitis in the absence of clinical attack raised the resistance to a high level in a very short time.

5. The cases of acute rheumatism did not appear amongst those who had been in the institution for a long time and had experienced several attacks of tonsillitis. Acute rheumatism appeared amongst those who had been in the institution for a short time.

6. There was no real difference in incidence of the two diseases in boys drawn from different parts of the country.

7. Attacks of tonsillitis produce an immunity to scarlet fever.

8. There was no epidemic of common cold in an institution where conditions were favourable to the spread of infection. There was a very severe epidemic of tonsillitis during the period of investigation.

9. In the institution the incidence of common cold was related to the seasons, yet the conditions of living were the same all the year round.

10. The attack of common cold left little or no resistance behind it.

11. There was no 'silent' immunization against the attack of common cold.

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