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FAMILY STUDIES OF RESPIRATORY INFECTIONS

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Surveys of morbidity in countries with temperate climates have established the pre-eminent importance of acute respiratory infections as a cause of sickness at all ages. The more severe forms take a heavy toll of life among the very young and the elderly, and, particularly in infancy and early childhood, the mortality from bronchitis and pneumonia has a strong association with social conditions. The Payling Wrights (1945), in their study of aetiological factors in bronchopneumonia among children under 2 years of age in London, found a strong correlation between mortality and substandard housing, social index, and the percentage below the poverty line. The factors associated with poverty and poor environment are, however, so intertwined that it is difficult to assess the relative contributions of such elements as poor housing, overcrowding, malnutrition, inadequate clothing, or parental neglect to the incidence and severity of respiratory infections among children.

A more detailed assessment of social and environmental factors that may be specifically related to the incidence and severity of respiratory disease seemed to us necessary before rational preventive measures could be recommended. Previous studies, such as those of Dingle *et al.* (1953), have not been particularly concerned with the domestic environment. We here describe the methods and results of a survey designed to clarify some of the relationships between personal and environmental factors and the experience of respiratory disease of families living in different social circumstances.

PLAN OF SURVEY

The object of the survey was to study the introduction and spread of respiratory disease among families of the same size and structure living in the same district at the same time but under varying domestic conditions. To the methods of clinical epidemiology was added the use of regular sampling and "typing" of readily recognizable organisms in the nasopharynx as an indicator of the spread of infection within the family. We were interested in developing methods for such family studies as well as in the results obtained.

The collection of data was carried out, on the clinical side, by a paediatrician and a qualified nurse, with some part-time clerical assistance, and, on the laboratory side, by a junior bacteriologist and an experienced laboratory technician with day-to-day supervision by a more senior member of the team.

Selection of Families

All the families included in the survey were recruited from those who brought a child to Paddington Green Children's Hospital for medical advice. Only families consisting of father, mother, and three children (of whom one was under 5 years of age) were included in the survey. If the family size was altered—for example, by a member leaving home or the arrival of a new baby—the family could no longer be retained. Only families living as a separate and independent household with their own living and sleeping accommodation, whether in their own house, self-contained flat, or tenement accommodation, were included in the survey. To ensure equality of climatic exposure and ease of visiting, only families living within three miles of the hospital were accepted. Families in whom any member was found to be suffering from an allergic disorder, such as hay-fever or allergic rhinitis, which might cause confusion with acute respiratory infection were excluded.

The almoner's department records details of the environmental and social background of every child who is admitted to the hospital or who attends the out-patient department (excluding the casualty department). Through the almoners' co-operation the survey team was notified seriatim of every family which seemed to satisfy the requirements for inclusion in the survey following the attendance of one of the children at the hospital. From this serial list, recruitment to the survey was made without any further attempt at selection. The nurse investigator visited the home and explained in detail the purpose and methods of the survey, and at the same time made certain that the family satisfied the criteria for inclusion. Visits were made to 90 families who proved eligible for inclusion in the survey, and 72 agreed to take part. Of these 72 families, 6 soon failed to co-operate adequately or withdrew their consent within a few days. The remainder either stayed in the survey until its termination or had to withdraw for one of the following reasons: birth of additional child, 6; break-up of family, 2; death of mother, 1; removal from district, 8; serious illness in one child, 1.

As a family became ineligible for any of the reasons mentioned, so another family was recruited from the serial list. In this way the number of families under surveillance at any one time was maintained at 45–50 during the two years of the survey.

Before the survey began in March, 1952, the intentions and methods were explained to the local public health authorities and the families' general practitioners. At the first interview with the family it was carefully explained that members of the survey team would act entirely as observers and that they would in no way take the place of either the preventive health workers or the general practitioner and the district nurse in times of illness.

The information obtained was of two kinds: (1) basic data concerning the environment of the family and of their health before the survey was begun; and (2) serial data concerning the clinical infections and bacteriological findings encountered during the course of the survey.

Records: Basic Data

The basic information obtained can be classified into three sections—housing conditions, social conditions, and medical history and examination.

Housing Conditions.—The types of dwelling were divided into three groups—namely, self-contained houses, self-contained flats, and rooms in tenement dwellings. The degree of crowding was assessed from the number of rooms available. A five-member family (*a*) living and sleeping in one or two rooms (excluding a small kitchen not used as a living-room) was "overcrowded"; (*b*) living in three rooms was "crowded"; and (*c*) living in four rooms or more was "uncrowded." The size of the rooms was not taken into account in this method of classification. The number of rooms used at night was also noted. A general assessment of the house structure was made from observations gradually collected during the survey: these included the state of repair, degree of dampness, ventilation, cubic capacity of rooms, the sanitary services available—for example, private or shared bathrooms, lavatories, and water supplies. The degree of dampness was assessed as (1) none, (2) slight patches of damp in walls or ceilings, and (3) considerable dampness in the accommodation generally. The housing data obtained by the survey team about families who lived within the Borough of Paddington were checked against reports from the local health inspectors.

Social Conditions.—These included the occupation and amount of outside contacts made by the father; the amount of money handed over to the mother for housekeeping purposes; the degree of cleanliness of the household; the mother's ability to run her house; the state and suitability of the children's clothes; the quality and variety of food provided; and the standard of maternal care and supervision. The assessment and grading of families in relation to these social factors were based largely on personal opinion, but they were made only after long-continued observation of the individual family and cross-checking between the nurse and the paediatrician.

Family Medical History.—A full medical history was recorded for each member of the family. The presence or previous history of serious respiratory disease in either parent was noted. For each child a record was made of the birth weight, type of infant feeding, state of health during the first year with details of any immunization procedures, and a history of specific infections—for example, measles, whooping-cough, pneumonia, or other serious illness or physical defect which might predispose to chronic or repeated respiratory infection. Note was taken of a history of the removal of tonsils and adenoids and the age at which this had been done. The state of nutrition of each child was gauged by the paediatrician, who, besides noting objective data such as height and weight, attempted to make a more general assessment, which was classified as good, average, and poor. Similarly, the adequacy of the children's clothing was noted and classified in regard to its suitability for the prevailing climatic conditions.

Great differences in outlook and in manner of living existed among the survey families. Many of these differences were not easily measurable, yet they may well have had some effect upon the incidence and cross-infection rate of respiratory infection. The limitation on the interpretation of the data imposed by the coarse grading used must therefore be emphasized.

Records: Serial Data

The serial data obtained were of two kinds, clinical and bacteriological. Throughout the period that any individual family was in the study the homes were visited by either the nurse investigator or the paediatrician at least once a fortnight. At each of these fortnightly visits a detailed history of any respiratory or other illness in any member of the family during the previous two weeks was taken, and observations were recorded of any signs of respiratory or other infection at the time of the visit. Throat and per-nasal swabs were taken from all five members of the family every fortnight. The absence of some members of the family at the time of the routine visit necessitated further visits, often in the evening, within the fortnight until swabs had been taken from the whole family. Each member of the family was thus personally and regularly seen by a member of the team, usually at intervals of less than 14 days, so that the accuracy of the reports given by the mother could be checked.

Throughout the survey period the average fortnightly yield of swabs was 95% of the entire survey population.

Clinical Data

The serial records kept by the survey team, both of the nature and onset of symptoms as given at interview and of the signs noted at the times of the visits, were entirely descriptive. No attempt was made at a diagnostic classification. Thus a typical record might read as follows: "22/2/53: onset of slight tickle in throat. 23/2/53: slight headache, clear discharge from nose, slight cough. 24/2/53: seen by paediatrician—clear nasal discharge, throat not inflamed, no enlargement of tonsillar glands; has slight cough. 27/2/53: symptoms subsided."

The clinical syndromes were recorded simply in terms of the signs and symptoms observed. Although gastro-intestinal upsets and other minor infections were included in the records, the syndromes mainly dealt with in this analysis are upper respiratory infections defined as follows: (*a*) Respiratory catarrh with nasal discharge, acute in onset with "tickly" but not grossly inflamed pharynx and with or without malaise and fever—that is, "acute coryza." (*b*) Persistent nasal discharge without signs of acute infection or other disease—that is, "chronic catarrh." (*c*) Soreness and obvious inflammation of the throat with or without malaise, fever, and glandular enlargement or tonsillar exudate—that is, "acute sore throat." (*d*) Respiratory catarrh with cough as the major presenting symptom.

On a number of occasions members of the family with respiratory illnesses were admitted to hospital, where observation was continued through hospital notes, *x*-ray reports, and the laboratory findings.

In addition to respiratory illness, records were kept of all other illnesses, including acute specific fevers, gastro-intestinal upsets, skin infections, etc.

The nose and throat swabs were inoculated in the laboratory on to the various culture media within two hours of being taken. The bacteriological techniques used are to be described elsewhere.

SUMMARY OF RESULTS

From the individual records of sickness experience during the period of observation incidence rates were calculated. The present analyses are concerned particularly with the syndromes acute coryza, chronic catarrh, and sore throat.

Acute Coryza

The age and sex distribution of acute coryza is set out in Table I. Age groups were chosen to give exposure, counted in terms of person-months, of reasonable size and

TABLE I.—*Age and Sex Incidence of Acute Coryza*

Age	Attack Rate per 100 Person-Months		No. of Person-Months Exposure	
	Males	Females	Males	Females
0–4	43	36	770	537
5–9	29	29	630	683
10–16	40	25	119	305
20–29	25 ⎫	31 ⎫	166	275
30–39	17 ⎬ 19	28 ⎬ 27	539	618
40+	20 ⎭	17 ⎭	328	135

divided into the stages of life which would appear to be relevant—pre-school (0–4 years), early (5–9) and late (10–16) school careers, and three successive periods in adult life from 20 years of age. There were no individuals in the survey between the ages of 17 and 19 years. Table I shows quite clearly that the age–sex specific rates for acute coryza differ appreciably; males tend to have higher rates in later school life, while the female rates for adults are higher than those for males of the same age except in the oldest age group. In both sexes the inception rates tend to decline with age.

Fig. 1 gives the week-to-week trends, smoothed by taking three-weekly moving averages, in the incidence of acute coryza and sore throat. The sharp rise of colds in September each year is the most noteworthy feature.

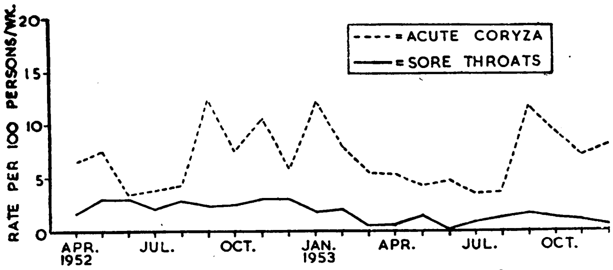

FIG. 1.—Incidence of acute coryza and sore throats.

The basic data on every individual record for each family were grouped together so that the introduction of respiratory disease and its subsequent spread throughout the household could be studied in relation to contemporary features of the environment, climatic or domestic, or the family status of the persons involved in the family outbreak ("status" here refers to position in the family—that is, father, mother, oldest, middle, or youngest child).

Methods of Analysis of Family Epidemics

The intervals in days between the date of onset in successive cases of acute coryza in the same household were tabulated for a sample of families to obtain the distribution seen in Fig. 2. Inspection shows that the intervals tend to be grouped between one and four days and that few of them were more than nine days. On this basis it was assumed that cases occurring at intervals of more than nine days were unlikely to be due to domestic cross-infection. Respiratory illnesses occurring either singly or in groups after a lapse of more than nine days from the onset of a previous case in the same household were counted as fresh "introductions" of infections. Following the usual conventions, this fresh introduction is labelled "the primary case(s)" and the dates of onset of further or "secondary" cases in the same household are set on a time scale in days in which the date of onset of the index or primary case is "day 1." These minor epidemics or episodes may, in a family of five, take several forms; the time chart in Fig. 2 shows the primary case followed in two successive stages by three secondary infections among the rest of the family.

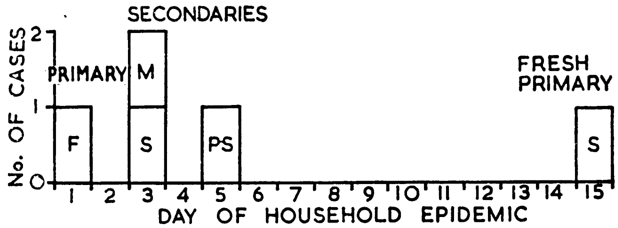

FIG. 2.—Family epidemic of acute coryza. F=Father. M=Mother. S=School age. PS=Pre-school age.

Two basic measures of epidemic behaviour were calculated from these data. The "introduction rate" as here used means the number of fresh "introductions" into the household per 100 family months of exposure; for example, the appearance of 15 new introductions in 20 families observed over a period of three months gives an introduction rate of 25 per 100 family months.

The "secondary attack rate" is here used as a measure of transfer of infection, and is the percentage of individuals exposed to a single index case in the household who develop similar signs and symptoms of respiratory infection during the course of the ensuing episode. The episode was considered to be over when no fresh cases appeared before the lapse of nine days from the onset.

Seasonal Trends in Introduction and Secondary Attack Rates

Mean introduction and secondary attack rates were calculated for all the families observed in each week of 1953. The small numbers made interpretation difficult, but values smoothed by the use of a three-weeks moving mean are depicted in Fig. 3. Both measurements clearly follow the trend in incidence noted in Fig. 1. At the beginning of September, not only are more infections introduced into the households but the ease of spread of infection within the household is apparently increased at the same time. The rising incidence at this time of year would thus appear to be compounded of both factors.

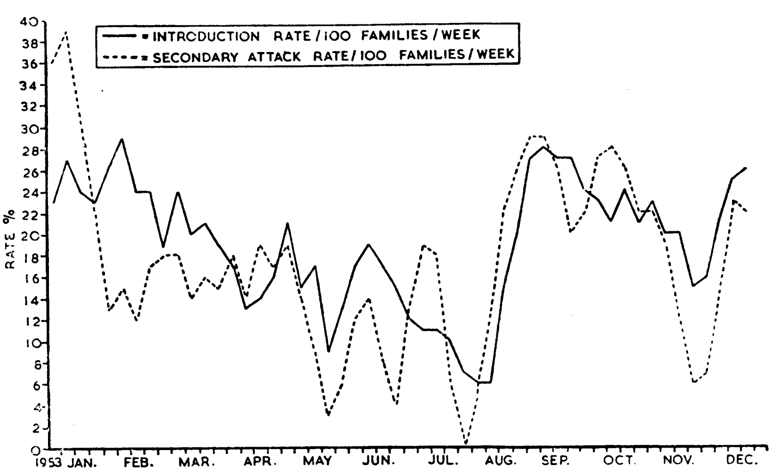

FIG. 3.—Incidence of acute coryza.

Social Factors in the Epidemiology of Acute Coryza

Table II sets out the incidence rates for acute coryza in the different social circumstances and according to the broad assessment of factors, personal and familial, which

TABLE II.—*Social Factors in Incidence of Acute Coryza (incidence of colds per* 100 *person-months)*

		No. of Person-Months Exposure
Domestic Crowding		
Type of crowding:		
Uncrowded	27·0	1,818
Crowded	29·0	1,960
Overcrowded	33·9	1,332
No. of rooms used during day:		
Three	23·3	373
Two	29·2	3,353
One	32·0	1,384
No. of rooms used during night:		
Three	28·8	789
Two	28·7	2,955
One	31·6	1,366
Condition of House		
Dry	29·0	2,334
Damp	30·4	2,202
Wet	28·7	574
Clean	27·2	2,474
Average	32·8	2,003
Dirty	29·1	618
Adequacy of Diet		
Good	28·2	2,677
Average	30·9	2,225
Poor	34·5	87
Range of Outside Contact		
No. of other persons in building:		
0	28·9	1,199
1–10	26·3	1,231
11–15	32·5	1,947
16+	28·6	709
Father's occupation (liability to extrafamilial contact):		
Little	28·2	737
Average	29·7	3,087
Much	28·9	1,169
Mother working:		
No	28·7	3,437
Yes	31·3	1,673
Standards of Child Care		
Mother's ability to handle child:		
Good	32·3	1,013
Average	34·7	1,720
Poor	33·9	316
State of nutrition (children only):		
Good	34·1	1,425
Average	33·2	1,413
Poor	35·5	197
State of child's clothes:		
Good	31·7	1,818
Average	37·0	1,161
Poor	41·4	70

might influence the frequency of respiratory infection. Of them all only the adequacy of the child's clothing and the degree of overcrowding, or the number of rooms used during the day seem to have any importance. Even within the same "crowding group," the better-clad children have fewer attacks of acute coryza—that is, these factors act independently. However, as the data on overcrowding are more precise we have studied this factor more intensively.

From Table III it appears that although there is no consistent difference in the rate at which infections are introduced into the three types of home, infection is transferred

TABLE III.—*Introduction and Secondary Attack Rates of Acute Coryza by Type of Crowding*

	Uncrowded	Crowded	Overcrowded
No. of introductions	276	280	216
Introduction rate per 100 weeks	18·8	17·6	20·5
Secondary attack rate	13·5%	16·4%	17·4%

more readily in the more crowded homes. The similar trend in the incidence rate shown in Table II probably comes from this difference in transmission risk inside the home rather than from any variation in exposure to infection outside it.

Familial Introduction and Spread of Acute Coryza

The route of introduction and spread of infection in family groups can be studied by an extension of the methods outlined above. In this context, however, we have studied

TABLE IV.—*Introduction and Secondary Attack Rates of Acute Coryza by Family Status of Primary Case*

	Father	Mother	School Child (5–16 Years)	Pre-school Child (0–4 Years)
No. of introductions	109	145	323	321
Total introduction rate per 100 weeks	2·65	3·53	4·60	6·05
Secondary attack rate following introduction by father, etc.	16·5%	10·5%	19·2%	13·7%

family epidemics where there was only a single primary case and measured the secondary attack rate only in the first stage of the family outbreak. Table IV shows that the number of apparent introductions per 100 person-weeks of observation is the highest for the pre-school child and lowest for the father. The secondary attack rate among the remaining members of the household also depends, directly or indirectly, on the status of the index case; it is highest when infection is introduced by the school child and lowest when the mother is the primary source of the familial outbreak.

Paths of Infection Within the Family

The level of the secondary attack rates corresponding to the status of the primary case given above depends on several variables such as the susceptibility of the remainder of the family and the habits of, and intimacy of contact with, the introducing case. Some indication of the route of spread of infection through the family may be obtained from the study of the time relationship of cases. In the family epidemic depicted on the time scale in Fig. 2 the infections in the mother and school child, arising within the likely incubation period, are clearly secondary to the father's introduction of infection into the household. The accumulation of such epidemic experience makes possible an estimate of the chance of cross-infection between, for example, mother and father. The risk of cross-infection between father as donor and mother as recipient is given by the ratio—

$$\frac{\text{Number of maternal coryzas occurring during second stage of family epidemic following a paternal introduction}}{\text{Total number of paternal introductions}}$$

These secondary attack rates are set out in Table V, but their interpretation is complicated by the fact that the risk of acquiring a clinically obvious infection will depend both

TABLE V.—*Estimated Cross-infection Rates of Acute Coryza*

Introducing Case	Secondary Attack Rate % in Exposed				
	Father	Mother	Oldest	Middle	Youngest
Father	—	14	6	8	17
Mother	7	—	9	9	11
Oldest child	8	8	—	15	20
Middle child	5	9	16	—	21
Youngest child	7	4	11	13	—

on the family status and age of the index case and on the susceptibility of the exposed individual. Strictly speaking, direct comparisons cannot be made between the average secondary attack rate among, for example, mothers and infants, since the composition of the group of infectors to whom they are each exposed must inevitably differ. This difficulty can be partly overcome by assuming a similar closeness of contact and comparing the average of the secondary attack rates in mother (14, 8, 9,) and infant (17, 20, 21) when they are exposed to the three remaining members of the family—the father and the older children. If this comparison is then made between the mother and each of the family in turn, the ratio of these average attack rates, father to mother, eldest child to mother, etc., will indicate

TABLE VI.—*Family Status and Introduction and Spread of Infection*

Family Status	Relative Susceptibility Ratio	Relative Communicability Ratio	Apparent Introduction Ratio	Adjusted Introduction Ratio
Father	0·95	1·07	0·86	0·91
Mother	1·00	1·00	1·00	1·00
Oldest child	1·22	1·59	1·29	1·06
Middle child	1·38	1·56	1·42	1·03
Youngest child	1·87	1·24	1·83	0·98

the relative susceptibility to clinical infection when exposed to the same index cases. These relative susceptibility ratios, which are set out in Table VI, indicate a greater susceptibility of the younger compared with the older children.

The same basic data can also be used to estimate the communicability of infection according to the index case when members of the family are compared in turn with the mother. In this instance, the three other members of the family form the group of susceptibles exposed to the index source of infection and their average attack rates are computed. The relative communicability ratios given in Table VI suggest that the older children disseminate infection more effectively than the youngest child and the fathers slightly more than mothers.

When the apparent introduction rates according to family status given in Table IV are expressed in the same way and reviewed in the light of these results, again it is clear that the appearance of the first case in a family is commonest among its more susceptible members. As Badger *et al.* (1953) have suggested, the relevance of contacts outside the home can be estimated by comparing introduction and susceptibility ratios. Equality in these ratios implies an equality in exposure outside the home ; an increased frequency of introduction not related to susceptibility means an excessive degree of extrafamilial contact with infection. If the apparent introduction ratios are adjusted by dividing each by the corresponding susceptibility ratio the adjusted ratio gives a fairer indication of the part played by outside contacts in determining the introduction of fresh infection. The ratios seen in Table IV suggest that although the youngest and most susceptible child is most often the primary case, the load of infection to which the older but less susceptible children are exposed is likely to be at least as great.

Familial and Personal Factors in the Incidence of Coryza

Individuals in families who had been under continuous surveillance from March to September, 1953, inclusive, were divided into those affected during the September outbreak of colds and those not attacked. The mean number of colds in the previous six months was 1.6 among those attacked and 1.1 in those apparently escaping infection: this difference, which was unlikely to be due to chance ($P<0.05$), suggests that, in general, immunity does not last for more than a few months and that certain individuals are unduly susceptible to clinically evident infection. This was confirmed by an analysis of the experience of the 11 families under observation for the whole of the two years March, 1952, to 1954. The number of colds suffered in 1952–3 was found to be positively and significantly related to the number suffered by the same individuals in 1953–4. For all individuals, the correlation coefficient was larger than might be explained by chance ($+0.40\pm0.14$) ; but for children alone it was $+0.55\pm0.18$, while for adults the relationship was insignificant ($r=0.23\pm0.22$). In other words, children who have many colds in one year tend to have a more than average number in the next, and vice versa—that is, children differ significantly in their susceptibility to clinical infection. When the experience of family groupings whether both parents, all the siblings, or the family as a whole was reviewed in the same way, no significant relationship was found between the total number of colds suffered by those family units in one year and the next.

Epidemiological Behaviour of Other Clinical Syndromes

Table VII summarizes the age and sex incidence of the prolonged catarrhal type of respiratory illness. In general, the pattern seen in the acute coryza syndrome is repeated and the seasonal swing seen in Fig. 4 is also similar. This is hardly surprising, since, when the period of exposure has been taken into account, there is a significant association between the number of each type of syndrome suffered by each individual child—$r=+0.37$ ($0.01>P>0.001$). In fact, the chronic catarrh tends to follow the more acute type of infection and the excessive incidence among mothers is particularly marked. There is also a definite suggestion, seen in Table VIII, of an increased incidence of the condition in overcrowded homes, though the mean duration of symptoms is apparently unaffected by housing conditions.

TABLE VII.—*Age and Sex Incidence of Chronic Catarrh*

Age	Attack Rate per 100 Person-Months		No. of Person-Months Exposure	
	Males	Females	Males	Females
0– 4	24	22	770	537
5– 9	16	17	630	683
10–16	13	7	119	305
20–29	7	18	166	275
30–39	8 } 8	18 } 17	539	618
40+	10	10	328	135

TABLE VIII.—*Incidence and Duration of Chronic Catarrh*

	Uncrowded	Crowded	Overcrowded
No. of person-months exposure	1,818	1,960	1,332
Incidence per 100 person-months	14·7	14·0	19·1
Duration (in weeks)	3·8	3·9	3·6

Syndromes where a cough was the most obvious symptom were the only remaining illnesses of numerical importance.

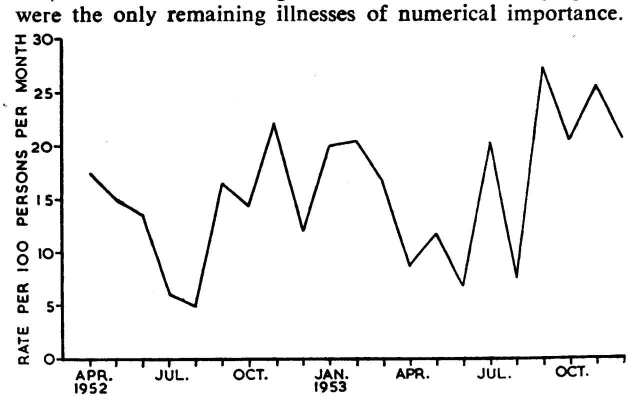

FIG. 4.—Incidence of chronic catarrh.

Cough is frequently associated with acute coryza, and, as Table IX shows, the trends of incidence and duration in relation to overcrowding are similar to those already noted.

TABLE IX.—*Incidence and Duration of Cough*

	Uncrowded	Crowded	Overcrowded
No. of person-months exposure	1,818	1,960	1,332
Incidence per 100 person-months	14·6	15·6	18·8
Duration (in weeks)	2·4	2·8	2·7

Respiratory illnesses where sore throat is the major presenting symptom were, as indicated in Table X, much less common than either acute coryza or the more chronic nasal catarrh. These sore throats differ from the other syndromes in the pattern of their age and sex incidence and in the seasonal trend of the attack rate. Sore throats arise in summer as well as in winter (Fig. 1). They are particularly common in the older male school child and in females in adult life. Both family introductions and secondary attack rates are low, and the latter show only a slight increase in the overcrowded homes.

TABLE X.—*Age and Sex Incidence of Sore Throat*

Age	Attack Rate per 100 Person-Months		No. of Person-Months Exposures	
	Males	Females	Males	Females
0– 4	7	9	770	537
5– 9	9	10	630	683
10–16	15	10	119	305
20–29	5	16	166	275
30–39	7	10	539	618
40+	6	13	328	135

This division of the cases into syndromes is rather arbitrary, and it is important to know whether such a separation is reasonable. In the calculation of secondary attack rates for different syndromes we have included as secondaries only cases presenting with the same clinical syndrome during the course of the family episode. Sometimes other types of respiratory illness follow a sore throat type of primary syndrome, and a study of the clinical nature of such following cases may indicate the degree of specificity of these clinical divisions. If all sore throats were specific responses to a particular infecting organism the secondary cases would usually, if not invariably, be of the same clinical type. In fact, as Table XI shows, only 34%

TABLE XI.—*Relation of Primary to Secondary Syndromes*

Type of Primary	Type of Secondary. Percentage Distribution of Secondaries with Symptoms of:			
	Coryza		Sore Throats	
	Observed	Expected	Observed	Expected
Coryzal	81	65	8	19
Sore throat ..	45	65	34	19
Mixed	69	65	17	19

of the cases secondary to sore throats were of the same clinical type. On the other hand, only 8% of the cases following a coryzal introducing case had sore throats; most (81%) were also coryzal in nature. To some extent, therefore, these syndromes tend to "breed true"; but when the introducing case is of a mixed type, presenting with both coryza and sore throat, it is more likely to be followed by coryza than by sore throat. Thus, although there is some epidemiological justification for differentiating sore throats from the more usual coryzal form of respiratory illness, this syndrome is likely to result from more than one type of infection.

BACTERIOLOGICAL RESULTS

Regular swabbing of the nose and throat of each member of the families visited gave the age and sex distribution of the proportion of positive findings for pneumococci, staphylococci, and streptococci seen in Table XII. There is a clear distinction between the age distribution for pneumococci which falls quite markedly with increasing

TABLE XII.—*Age and Sex Distribution of Bacteriological Swab Results*

Age	Percentage of Positive Findings					
	Pneumococci		Streptococci		Staphylococci	
	M	F	M	F	M	F
0– 4	45	45	14	12	20	22
5– 9	35	30	20	16	34	33
10–16	25	22	19	20	37	34
Adult	18	18	11	10	24	30

age, and the other bacterial pathogens where the peak is reached in later childhood and the adult rates fall almost to the levels observed in early childhood. Fig. 5 illustrates the seasonal distribution of the isolation rates for the three types of organism. Although the correlation with mean weekly temperatures falls short of significant levels in all three, the tendency suggested by the seasonal curve is towards a winter excess of pneumococci and a summer excess of staphylococci.

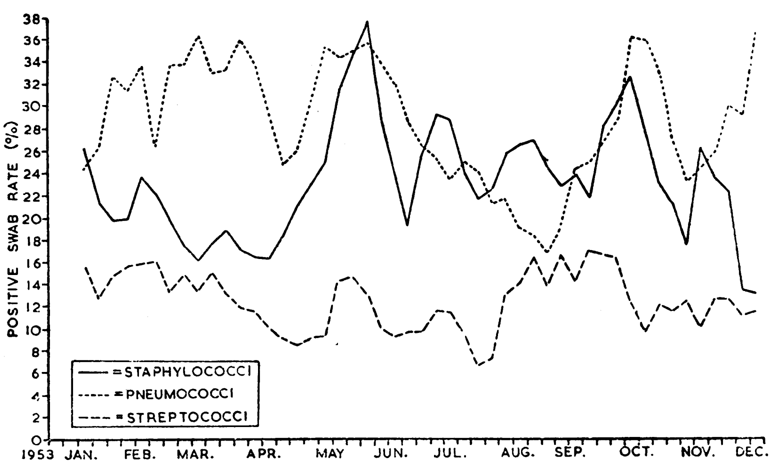

FIG. 5.—Nose and throat carrier rates of bacterial pathogens.

Acute Coryza and Pneumococcal Swab Results

Although no causal relationship is implied between pneumococcal carriage and the presence of acute coryza, the age and sex distribution of positive pneumococcal swab rates seen in Table XII can be compared with the corresponding distribution of acute coryza given in Table I. Although the patterns are in general quite similar, the positive swab rates, unlike the clinical attack rates, are equal in adult life. This may mean that, although the exposure to infection in general is the same for both parents, the wife more frequently shows a clinical response to the same degree of infection or is readier to report minor affections in general.

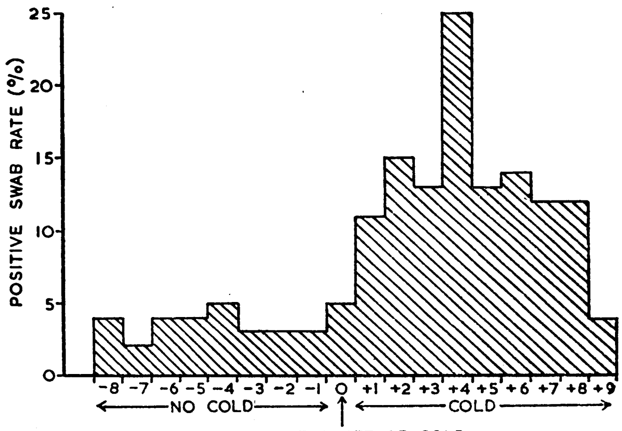

FIG. 6.—Relationship between finding of pneumococcus and onset of syndrome A.

Fig. 6 gives the results of an analysis of the frequency with which pneumococci were found in the days before and after the onset of the acute coryzal type of respiratory illness. Clearly, there is no rising frequency of infection before the clinical onset such as might be expected if the pneumococcus was in fact a cause of such illnesses. It seems rather that the physical changes produced by infection in the nasopharynx make the isolation or acquisition of pneumococci easier. This association may explain, if only in part, the general correspondence between the age and seasonal distributions of both the incidence of acute coryza and the pneumococcal isolation rates. Straker *et al.* (1939) found that increased nasal carriage of pneumococci occurred after the onset of colds, and the nasal carrier rate of pneumococci showed a much greater seasonal variation (highest in the first quarter, lowest in the third) than did the naso-pharyngeal carrier rate.

Use of Bacteriological Findings as Epidemiological Indices

Although the pneumococci play no direct part in the causation of coryza, their frequent presence in the nose and throat of the various groupings of the population observed may be of value in confirming or denying the indications about epidemic behaviour given by the clinical data. The appearance of type-specific pneumococci in families has been analysed according to the same pattern as the study of the familial introduction and spread of respiratory infection described above. Instead of clinical syndromes, the appearance of a specific type of pneumococcus—for example, type 14—in a family is classed as the epidemic incident. A fresh introduction is the first isolation of a specific type which has not appeared in any member of the family during the previous eight weeks. Similarly its appearance in other members of the family within eight weeks of the last positive swab in the "primary" introduction is counted as a "secondary" transmission. The size of this family "bacterial epidemic" is rated by the percentage of the remaining members of the family from whom the type specific organism was isolated. This rating of transfer of organisms can then be used, like the clinical secondary attack rate, to indicate the effect of differing domestic environment on the passage of infection within the family. Table XIII shows that this percentage or "transfer rate" rises significantly with the degree of crowding much as the secondary attack rate did in Table III—an interesting and valuable confirmatory finding.

TABLE XIII.—*Transfer of Pneumococci*

	Primaries	No. of Secondaries					"Transfer" Rate
		0	1	2	3	4	
Uncrowded ..	201	151	26	11	10	3	11·2%
Crowded ..	247	175	33	22	11	6	13·8%
Overcrowded	181	123	24	19	6	9	16·0%

In the study of the paths of cross-infection within the family, the consecutive appearance in the serial fortnightly swabbings of the same type-specific pneumococcus in different members of the household is assumed to indicate transfer. Table XIV shows the apparent probability of donation and reception between the various possible pairs within the family of five based on bacteriological and clinical measures. The most obvious discrepancy is between the estimates of the risk of the youngest child receiving infection; for the risk based on clinical data is for each type of index case consistently higher than the estimate derived from the rate of bacterial transfer. This may be due to a more obvious clinical response to the same dose of infection among the very young.

TABLE XIV.—*Cross-infection Rates Per Cent. (Clinical and Bacteriological)*

Index	Father		Mother		Oldest Child		Middle Child		Youngest Child	
	C	B	C	B	C	B	C	B	C	B
Father	—	—	14	5	6	5	8	11	17	8
Mother	7	7	—	—	9	12	9	10	11	5
Oldest child	8	6	8	11	—	—	15	18	20	10
Middle child	5	4	9	1	16	13	—	—	21	18
Youngest child	7	6	4	5	11	9	13	16	—	—

The bacteriological data can be analysed in much the same way as the clinical material to take exposure into account in the study of the introduction and spread of infection within the household. In Table XV are compared the relative introduction rates of new bacterial strains (where no coryza is present in the index case) and the estimates of exposure to extrafamilial infection already made on clinical grounds in Table VI. The importance of extrafamilial contacts with new infections in fathers and schoolchildren is emphasized by the bacteriological findings.

TABLE XV.—*Clinical and Bacteriological Measures of Introduction and Spread of Infection*

Family Status	Introduction		Transfer	
	C	B	C	B
Father	0·91	1·37	1·07	0·89
Mother	1·00	1·00	1·00	1·00
Oldest child	1·06	1·33	1·59	1·55
Middle child	1·03	1·61	1·56	1·46
Youngest child	0·98	1·30	1·24	1·07

Again, the relative effectiveness of each member of the family as a disseminator of bacterial infection can be judged from the "transfer" rates in members of the family exposed to them. Here there is a closer agreement between bacteriological and clinical estimates of the relative importance of the schoolchildren in the spread of infection within the household.

Despite major differences in the time scale of observation, the bacteriological findings can also be used to study the seasonal patterns of household introduction and transfer of infection. Fig. 7 shows the trend of the values, smoothed by taking three-monthly moving means, of bacterial introduction and transfer rates. There is a clear parallelism between the seasonal changes in the rate of introduction of new types of pneumococci and the introduction of clinically evident illness. The bacterial transfer rate within the household also follows the trend in the clinical secondary attack rate, but much less closely. This may be due to the crudity of the bacteriological measure (although it was sensitive enough to detect differences in cross-infection risks in different degrees of overcrowding). It is possible, on the other hand, that seasonal changes in the clinical secondary attack rate reflect changes in host susceptibility rather than in ease of physical transfer of infection.

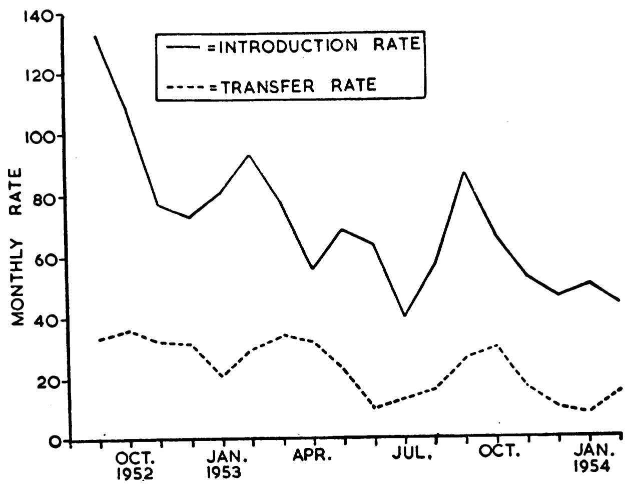

FIG. 7.—Family introduction and transfer of pneumococci.

Sore Throats and Streptococcal Swab Rates

The analysis of the clinical data has already suggested that sore throats cannot be completely differentiated on grounds of epidemic behaviour from the commoner acute coryzas. The age and sex distribution of positive streptococcal swabs certainly agrees with the corresponding distribution of the clinical syndrome, and Table XVI shows that streptococci are more often found in the family when

TABLE XVI.—*Distribution of Secondary Cases After a Primary Sore Throat According to Presence or Absence of Streptococci in the Family*

Secondary Case	No. of Episodes		
	Streps. in Family	No Streps. in Family	Total
Coryzal	5	10	15
Sore throats	10	4	14
Total	15	14	29

Using Fisher's exact method, P=0·046.

TABLE XVII.—*Distribution of Streptococci Among Primary Cases of Sore Throats, Colds and Sore Throats, and Colds*

Type of Primary	No. of Primaries	Percentage Carrying Haemolytic Streptococci
Acute coryza	45	24·4
Sore throat	66	24·2
Mixed	31	12·9

the cases following sore throat in the primary are also sore throats. In a random sample of primary cases presenting either as sore throat or acute coryza, however, the proportion of positive streptococcal swabs in the two groups was similar (Table XVII). This finding confirms the views that the sore throat syndrome has more than one cause and that the presence of streptococci in the throat need not have clinical significance.

Experience of Tonsillectomized Children

An interesting by-product of this investigation is the information it gives on the clinical attack rate and frequency of isolating organisms from the throat in children whose tonsils have been removed. Table XVIII summarizes the experience of children over the age of 5, divided into tonsillectomized and non-tonsillectomized groups and paired by age, sex, and period of observation in the survey. The complete equality in the attack rates from the various syndromes studied is obvious. On the other hand, frequency of isolating organisms differs between the two groups although the difference is technically significant only for streptococci. Since the ease of finding organisms in the non-tonsillectomized group cannot be explained by an increased frequency of clinical infection, it seems reasonable to suppose that the effect is related to the likelihood of tonsillar tissue allowing streptococci to persist in the crypts. The higher carrier rates of haemolytic streptococci in non-tonsillectomized children is in keeping with the findings of Holmes and Williams (1954).

TABLE XVIII.—*Tonsillectomy and Clinical Attacks and Bacteriological Swab Results*

Syndrome	Mean No. of Attacks	
	Tonsillectomy	No Tonsillectomy
Acute coryza	5·7	5·9
Chronic catarrh	2·6	2·1
Sore throat	2·1	2·2
Cough	3·2	3·0
Organism	**Mean No. of Positive Swabs**	
Streptococci	2·64	6·56 (sig., $P < 0·01$)
Pneumococci	6·67	9·62 (not sig.)
Staphylococci	14·22	9·78 " "

DISCUSSION

The family is the basic epidemiological unit in a civilian community, and it might therefore be expected that study of the nature, incidence, and spread of infection within families would yield information that could be useful in its control. Our main objective in the present study was to develop methods of studying the relation of social and environmental factors to the incidence and spread of respiratory infection and illness in families. In contrast to the investigations of other workers (Lidwell and Sommerville, 1951 ; Dingle *et al.*, 1953 ; Buck, 1956). This survey concentrated on the experience of self-contained households in a circumscribed working-class area with families of identical size and structure living in contrasting domestic circumstances. Although this concentration may restrict the general applicability of the results, the simultaneous control of important variables such as family size simplifies their analysis and interpretation. To the traditional methods of clinical epidemiology was added the repeated swabbing of nose and throat during regular fortnightly interrogations about each individual's clinical experience. Rates of apparent introduction and transfer of type-specific organisms, calculated in the same way as the rates for clinically evident infection, then gave useful supplementary information on the relative importance of exposure and susceptibility in family outbreaks of coryzal infections.

The results may best be discussed by relating host susceptibility and exposure to infection to social conditions and climate.

1. Susceptibility and Extrafamilial Exposure

The family studies by Dingle *et al.* (1953) in Cleveland established a rising incidence rate for the common respiratory infections from birth until 3 years of age and then a steady decrease with age. We have found the incidence of colds and chronic catarrh to be highest in the 0–4 age group. Detailed analysis failed to show any obvious peak occurring within that age period. In both the Cleveland study and the work of Lidwell and Sommerville (1951), the school child was judged on clinical grounds to be the most frequent introducer of infection into the family. In our study, the pre-school child appeared to be the main culprit. The incidence of clinical infection will, of course, depend on at least two factors—host susceptibility and exposure to infection.

Most of our families were living in tenements, flats, or subdivided houses in crowded neighbourhoods, so that pre-school children were likely to be heavily exposed to the risk of infection. By contrast, in the Cleveland study the families mostly belonged to the upper social strata living in separate homes; and Lidwell and Sommerville were working in a country villiage. Some of the differences in clinical infection rates in the youngest children might reflect the increased chance of exposure in the urban *milieu*. When, however, adjustments were made in our families for the greater susceptibility of the youngest child, it appeared that even in the crowded city the middle and oldest children, who were mostly attending school, were also heavily exposed to extrafamilial infection; and the bacteriological measurements of the introduction of new infections supported that finding. Similarly, within the household the older children appeared, from both sets of results, to be the most effective sources of epidemic spread.

Although the downward trend of incidence with age suggests the gradual acquisition of immunity, there is little evidence among the children that an attack of coryza confers even a short-term immunity. On the contrary, the undue susceptibility of certain children already noted (Reid, 1952 ; Buck, 1956) has been confirmed. This predisposition is apparently individual rather than familial.

The high incidence of both acute coryza and chronic catarrh in the mothers is noteworthy. The higher prevalence of colds in the adult female than in the male has been noted in other studies; those at the Common Cold Unit indicate that women are more susceptible than men to experimental infection with the common cold virus (Andrewes, 1951). It is possible that mothers reported the subjective symptoms of colds and catarrhs more readily than did fathers, although at each visit the members of the family, including the father, were seen and questioned individually about any infections occurring within the previous two weeks. The frequency of finding new pneumococcal strains is similar in both, so that exposure to infections is not likely to be greater among the mothers; but it is noteworthy that, despite the association between nasal discharge and higher pneumococcal carrier rates, the rates for mothers and fathers were the same.

The sore throat syndrome and the frequency of streptococci in nose and throat were more common in the school than in the pre-school age group, and this may reflect the greater risk of exposure in the larger community of the schoolroom to an infection which was much less prevalent than the common cold.

2. Social Conditions and the Transfer of Infection

An attempt was made to find if any one of many different social factors of working-class homes was related to the incidence and spread of acute respiratory infections among the families. It was difficult to evaluate accurately such factors as the state of nutrition of the family, the quantity and quality of food used, and the heating and comfort of the home without much more detailed and objective analyses than could be made in the present study. The fortnightly visits by the paediatrician and nurse and the independent assessments made on certain points by the health visitors and sanitary inspectors did allow a reasonably accurate assessment of the family budget, father's occupation and outside contacts, mother's qualities as a mother and as a housewife, family morale, the children's clothing, and the cleanliness, degree of dampness, and state of repair of the house. When families were graded according to these social factors the incidence of respiratory infections was shown to be related to only two of them—namely, degree of crowding and the state of the children's clothing. Overcrowding may be complicated by other adverse circumstances, such as poor ventilation and lighting.

The analyses in Table IV, however, show that in our families none of the other social factors which were examined appeared to be relevant, and it seems likely that persistently close contact is *per se* an important factor in the spread of the common cold. The studies at the Common Cold Unit indicated that neither close personal contact nor exposure to air-borne infection for a limited period of time gives a high proportion of "takes" among volunteer subjects. This may mean that both dosage and variations in time of host susceptibility are contributory factors to clinical infection.

It may be noted that, whereas the secondary attack rate of acute coryza showed some correlation with the degree of crowding, the introduction rates in overcrowded and uncrowded families were very similar. Again, the incidence was not affected by the total number of persons in the associated building. These points support the conclusion that crowding *within* the family is a more important factor than repeated casual contacts in the spread of acute respiratory infection.

3. Climate and Susceptibility

The high winter incidence of acute respiratory infection compared with the summer months is generally accepted, but, as with poverty, it has proved difficult to apportion blame among the variables that make up our climate (temperature, humidity, fog, etc.). A strong correlation between sharp falls in the mean daily temperature and mortality from bronchitis and pneumonia among young children and old people has been demonstrated by Young (1924) and the Payling Wrights (1945); the latter workers showed that the weekly mortality rates for infants were most strongly correlated with low temperatures two weeks earlier—that is, about the time of the *onset* of the acute respiratory infection.

Gover *et al.* (1934), from observations on over 5.000 students living in widely different climates in the U.S.A., found that a mean temperature below normal, especially in early autumn, was associated with an abnormally high rate of acute coryza, while Van Loghem (1928), from family studies involving some 7.000 people in Holland, concluded that sudden increases in the incidence of colds ran parallel with a fall in the air temperature. Reid *et al.* (1953) have shown that the first winter peak of acute respiratory infection among Post Office workers coincided with the first sharp fall in temperature, which in 1949 came much later than usual. In our families, a sharp increase of acute coryza occurred in September in both 1952 and 1953 about the time when temperatures were falling, but not markedly. This sharp rise, however, also coincided with the reopening of the schools when, after a low summer incidence of colds, the community may have lost any short-term immunity acquired in the previous winter.

It is not clear how lowered temperature, if it is a factor, affects resistance. Attempts to increase the infection rate among volunteers by inoculating them with common-cold material under unfavourable conditions (damp clothing, cold draughty rooms, etc.) have not been very successful. On the other hand, the work of Leonard Hill and later of Mudd *et al.* (1921) indicated that chilling of the body resulted in a reflex vasoconstriction and lowering of temperature in the respiratory mucosa, which might in turn affect local susceptibility to infection. Cralley (1942), studying the rate at which rabbits exposed to various climatic conditions could dispose of inhaled bacteria, found that the most adverse conditions were a high temperature and low humidity before infection, followed by a low temperature and high humidity. These conditions are often simulated in the life of anyone in this country, and it is noteworthy that among the children in our families there was some association between inadequate clothing (and, presumably, greater susceptibility to climatic changes) and the incidence of acute respiratory infections.

SUMMARY AND CONCLUSIONS

A clinical and bacteriological study of respiratory illness was carried out in families of the same size and structure (two parents and three children) living in various types of house in a working-class area of London. The study, which lasted two years, included regular visits by a paediatrician or nurse, who, besides making clinical and social observations, took fortnightly throat and pernasal swabs from all members of the family. Observations on the spread of "indicator" organisms within the family groups were used to confirm or modify the epidemiological indications about the introduction and spread of infection given by traditional clinical methods.

Of some twelve social and environmental factors examined—for example, maternal care, range of outside contacts, and dampness of the house—only overcrowding and, with less certainty, inadequate clothing were found to be related to the incidence of acute coryza and chronic catarrh. The increased clinical secondary attack rate in conditions of continued close contact observed in the more crowded families was confirmed by the higher rate of apparent transfer of type-specific pneumococci in these families.

On clinical grounds alone, infections appeared to be most often introduced by the youngest or pre-school child—that is, the most susceptible member of the family. Corrections for differences in susceptibility gave results which suggested that even in congested working-class districts the school child is the most frequently exposed to extrafamilial infection and the most vigorous spreader of infection within the family. The greater frequency of transfer of pneumococci and the higher carrier rates of haemolytic streptococci among the schoolchildren supported this conclusion. Pneumococcus carrier rates were raised following the onset of acute coryza, but there was no evidence that the pneumococci were causally related.

Climatic changes appear to affect both the frequency of introduction of colds into households and the ease of transfer; our own findings and those of other workers suggest that this association is at least partly due to changes in host susceptibility following abrupt seasonal changes in temperature and other climatic factors. Undue susceptibility to colds was shown to be a characteristic of individual children but not of families as a whole.

Although some differentiation of syndromes presenting as "acute coryza" and "sore throat" was possible on epidemiological ground, sore throats often occurred without the presence of haemolytic streptococci in members of the family, and it seems likely that this syndrome results from more than one type of infection. A comparison of the experience of tonsillectomized and other children showed that, although streptococci were found

less often in the throats of the tonsillectomized children, the incidence of coryza and sore throats was identical in the two groups.

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ASSESSMENT OF AGE, SEX, AND HEIGHT FROM IMMATURE HUMAN BONES

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We have been unable to find any reports of medico-legal identification which, in the absence of all soft parts, had to be based on the estimation of age, sex, and height from portions of immature human bones.

In the present case the material available for examination was a skull, mandible, loose teeth, and 128 separate pieces of bone, many partially destroyed, found scattered over an area of a few hundred square yards of hillside in the West of Scotland. We were able to say that the bones were all part of one human skeleton, and, from the state of dentition and the recognition of separate pieces as bone epiphysis, that the skeleton was not that of an adult. The assessment of age, sex, and, in particular, height, however, was more difficult, presenting special problems, which we thought should be put on record.

Inventory of Bones

Skull: Complete except for the mandible. 76 | 67 teeth fixed in the maxilla. Mandible with 76 | 67 fixed in the bone. Loose teeth: 5 321 | 12345, 5432 | 12345, plus | DE.

Vertebrae: All the vertebrae recovered as separate bones—incomplete spines and transverse processes (late secondary centres), semilunar ridged areas on upper and lower surface of bodies (for attachment of annular epiphyses). Sacrum:—three separate bones: (1) the first segment, (2) the second segment, and (3) the third, fourth, and fifth segments. Coccyx:—one segment.

Ribs: All ribs except first left, second and twelfth right, all minus heads and tuberosities (late secondary centres).

Sternum:—six separate bones: (1) manubrium, (2) first segment, (3) second segment, (4) half of third segment, (5) half of third segment, and (6) fourth segment.

Clavicles: Right and left—no sternal ends (late secondary centres).

Scapulae: (1) Right and left scapulae, no acromion processes, vertebral borders, or inferior angles (late secondary centres). (2) Right and left coracoid processes.

Humerus: (1) Right and left diaphysis. (2) Right and left complete upper epiphysis. (3) Right lower epiphysis as three separate bones: (*a*) capitulum—plus lateral half of trochlea and lateral epicondyle, (*b*) medial half of trochlea, and (*c*) medial epicondyle.

Ulna: Right and left diaphysis.

Radius: Right and left diaphysis. Right upper epiphysis.

Hand Bones: Right capitate, right hammate, first, second, and fourth right metacarpals, six phalanges.

Innominates: (1) Right and left ileum, no crests or spines (late secondary centres). (2) Right and left ischio-pubic bones, no ischial tuberosities—acetabular separation of ischium and pubis (Figs. 1 and 2).

Femur: (1) Right and left diaphysis, minus distal 2–3 in. (5–7.5 cm.) (Fig. 3). (2) Right and left head epiphysis. (3) Right and left great trochanter epiphysis. (4) Left lower epiphysis.

Tibia: (1) Right and left diaphysis, minus upper 1 in. (2.5 cm.) of right diaphysis. (2) Right and left upper epiphysis. (3) Right and left lower epiphysis.

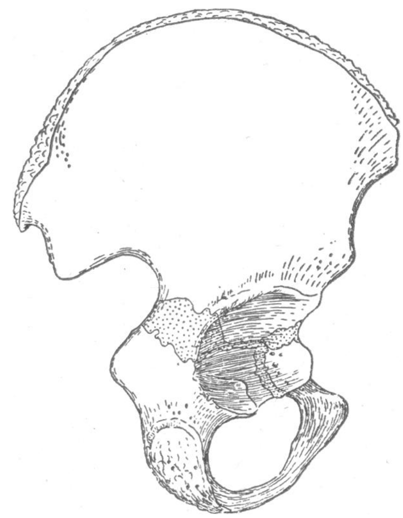

FIG. 1.—Reconstructed right innominate bone, stippled area = reconstructed plasticine triradiate cartilage.

Fibula: (1) Right and left diaphysis. (2) Left lower epiphysis.

Foot Bones: (1) Right and left os calcis, right and left epiphysis. (2) Right and left talus. (3) Left navicular, cuboid, and three cuneiforms.

Metatarsals: First left with separate epiphysis, second, third, and fourth right and left.

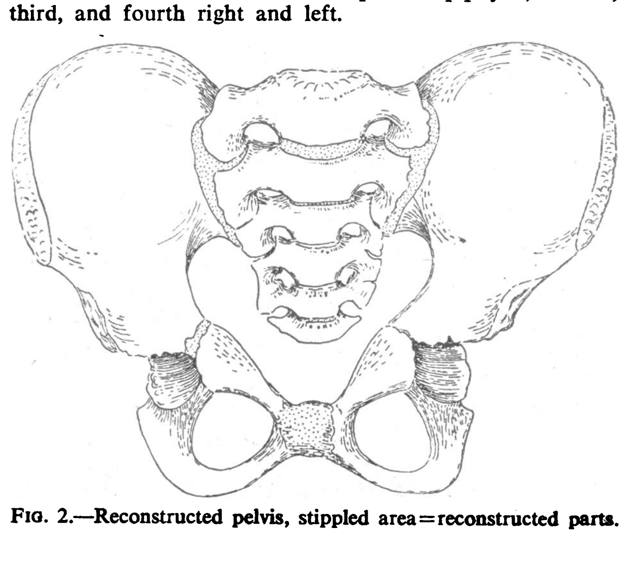

FIG. 2.—Reconstructed pelvis, stippled area = reconstructed parts.