The recent introduction of isoniazid in the treatment of tuberculosis adds a new weapon to the struggle against this disease; but by no means does it exclude streptomycin and P.A.S., especially streptomycin, which remains the fundamental antituberculous drug.

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INFECTIOUSNESS OF COMMUNICABLE DISEASES IN THE HOUSEHOLD

(MEASLES, CHICKENPOX, AND MUMPS) *

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MEASLES, chickenpox, and mumps have similarities which link them in a natural group with a number of other diseases. Each is a characteristic communicable illness to which most people are liable, and each usually produces enduring immunity. The causal agent of each is an obligate parasite natural to man which passes direct from sufferer to susceptible, apparently without the need of an intermediate agency. Inapparent infections are rare, at least in measles and chickenpox, infection of a susceptible ordinarily leading to the manifest disease, and the carrier state does not seem to play an important part in distribution.

These properties, with some others, determine the way a disease behaves in a community, and in fact the three diseases resemble one another sufficiently closely in their epidemic and endemic behaviour to justify comparative investigation by similar methods. Nevertheless there are differences. Despite the broad similarity, just as each disease has its peculiar clinical picture, so it has its own epidemiological pattern due to consistent differences of degree in those very attributes which link the diseases together in a natural grouping. Both measles and mumps, for example, tend to attack exposed susceptibles, but measles habitually strikes more readily than mumps, and so it comes about that mumps works its way through a community more slowly than measles, leaving behind more susceptibles to be dealt with at second or third visits. This peculiarity is reflected in the age-distribution of any adequate collection of cases. Communities of various types may vary much in the age at which their members take these diseases, but in a single community over a given period the average age of attack will be somewhat younger for measles than for mumps.

The epidemic pattern depends in part on the natural characters of the parasite, in part on the behaviour of the human host. When investigating a particular property of the parasite it is therefore necessary, so far as possible, to reduce or eliminate any disturbing effects of human behaviour—the human community must be standardised for the purpose. The household has often proved the most suitable community in which to compare and contrast various properties of different human parasites under similar conditions.

Having studied a particular property in one type of community one can repeat the study in other types of human environment, and so, step by step, learn something both of the effect of human behaviour on the biology of the organism, and of those details of the host-parasite relationship with which deliberate human interference may be practicable and desirable. Moreover, the method is fruitful in assessing the results of such interference.

Distinctions between similar diseases may sometimes be qualitative, as when transmission is effected by sputal droplets in one disease and by fæcal contamination in another. More often the differences are quantitative and require numerical assessment and presentation.

* The word "infectious" is used in some parts of the English-speaking world synonymously with our use of the word "infective"; hence in such places "infectious diseases" would mean all those of microbic agency whether naturally communicable or not. For those which are communicable the word "contagious" is used (Dorland 1938). For transatlantic readers the initial word of the title of this paper should be: "Contagiousness."

TABLE I—EXAMPLES OF METHOD OF RECORDING EPIDEMICS FOR CALCULATION OF THE EXPOSURE ATTACK-RATE IN THE HOME (INFECTIOUSNESS)

Case index no.	Generation I			II			III			IV			V		
	Date	Sex	Age (yr.)	Date	Sex	Age (yr.)	Date	Sex	Age (yr.)	Date	Sex	Age (yr.)	Date	Sex	Age (yr.)
Example I:															
A	Jan. 2	F	7	..	..	..	..	..	..	..	..	..	..	..	..
B	..	..	..	Jan. 16	M	10	..	..	..	..	..	..	..	..	..
C	..	..	..	,, 16	F	7	..	..	..	..	..	..	..	..	..
D	..	..	..	,, 17	M	9	..	..	..	..	..	..	..	..	..
E	..	..	..	,, 18	M	6/12	..	..	..	..	..	..	..	..	..
Example II:															
A	Jan. 2	F	7	..	..	..	..	..	..	..	..	..	..	..	..
B	..	..	..	Jan. 16	M	10	..	..	..	..	..	..	..	..	..
C	..	..	..	Esc.	..	..	Jan. 28	F	7	..	..	..	..	..	..
D	..	..	..	Esc.	..	..	,, 29	M	9	..	..	..	..	..	..
E	..	..	..	Esc.	..	..	,, 29	M	6/12	..	..	..	..	..	..
Example III:															
A	Jan. 2	F	7	..	..	..	..	..	..	..	..	..	..	..	..
B	..	..	..	Jan. 16	M	10	..	..	..	..	..	..	..	..	..
C	..	..	..	Esc.	..	..	Jan. 28	F	7	..	..	..	..	..	..
D	..	..	..	Esc.	..	..	Esc.	..	..	Feb. 12	M	9	..	..	..
E	..	..	..	Esc.	..	..	Esc.	..	..	Esc.	..	..	Esc.	M	6/12
Example IV:															
A	Jan. 2	F	7	..	..	..	..	..	..	..	..	..	..	..	..
B	..	..	..	Esc.	M	10	..	..	..	..	..	..	..	..	..
C	..	..	..	Esc.	F	7	..	..	..	..	..	..	..	..	..
D	..	..	..	Esc.	M	9	..	..	..	..	..	..	..	..	..
E	..	..	..	Esc.	M	6/12	..	..	..	..	..	..	..	..	..
B	Feb. 5	M	10	..	..	..	..	..	..	..	..	..	..	..	..
C	..	..	..	Feb. 13	F	7	..	..	..	..	..	..	..	..	..
D	..	..	..	,, 15	M	9	..	..	..	..	..	..	..	..	..
E	..	..	..	Esc.	..	..	Esc.	M	6/12	..	..	..	..	..	..

TABLE II—INFECTIOUSNESS (EXPOSURE ATTACK-RATE AMONG SUSCEPTIBLES AT RISK IN THE HOME)

Age-group (yr.)	Measles	Varicella	Mumps
0–15 :			
Susceptibles	251	238	218
Exposures	266	282	264
Transmissions	201	172	82
Escapes	65	110	182
Exposure attack-rate (infectiousness)	75·6 %	61·0 %	31·1 %
Over 15 :			
Susceptibles	36	64	96
Exposures	47	100	125
Transmissions	7	12	43
Escapes	40	88	82
Exposure attack-rate ..	14·9 %	12·0 %	34·4 %
Total :			
Susceptibles	287	302	314
Exposures	313	382	389
Transmissions	208	184	125
Escapes	105	198	264
Exposure attack-rate ..	66·5 %	48·2 %	32·1 %

Infectiousness, the ability of a disease to spread in a community, is a measurable characteristic and should be susceptible of being expressed precisely. It is insufficient to recognise that measles is more infectious than mumps. How much more infectious is it ? Is it more so than chickenpox ? A means of measuring infectiousness not only adds to our knowledge of the biology of this interesting group of parasitic organisms but also provides an approach to the solution of some practical problems. Does infectiousness vary from time to time, and from place to place ? What other attributes of a disease are quantitatively associated with its degree of infectiousness ? Is change in infectiousness responsible for the waxing and waning of epidemic prevalence ?

The present paper describes studies on the infectiousness of measles, chickenpox, and mumps in households in a semi-rural area of Gloucestershire—a town of some 11,000 inhabitants and the surrounding agricultural area to a radius of 6–8 miles containing a slightly larger population. The records for measles and chickenpox cover the four years from June 1, 1947, to May 31, 1951. Those for mumps include also a further seven months until Dec. 31, 1951.

A member of the epidemiological research unit visited all the cases and contacts several times. Much care was taken to ensure accuracy and to indicate which data were fully reliable and which only approximate. Approximately accurate data, though useful for certain purposes, can be most damaging when associated with more accurate data for other purposes. Close association with a general practice, the ready coöperation of the other general practitioners in the area, and long familiarity with the district gave unusually favourable opportunities. For example, the parent of a child with an attack of measles claimed that five years earlier the child had had a previous attack of measles diagnosed as such by the doctor. Reference to the contemporary notes of the doctor showed that the previous attack was one of rubella. In many such instances it was possible to increase the accuracy of the records.

Method of Calculating Infectiousness

PRINCIPLE

Measurement of infectiousness is based on the attack-rate. Attack-rates are assessed in different days, and to secure comparable figures it is important to define which way is being used. In one which has been much used an estimate is made of the proportion of susceptibles who become infected in homes into which the disease has been introduced : this gives a secondary attack-rate. Attractive because of its convenience and simplicity, this reckoning conceals several sources of error and should be reserved for diseases in which it is impossible to determine the details of spread inside the individual households—e.g., whooping-cough. An excellent example of the use of this method is to be found in the report of the Medical Research Council (1951) on the prevention of whooping-cough with vaccine. The results are not precisely comparable with those of the method used here and tend to give a consistently higher rate.

In determining infectiousness the *susceptible-exposure attack-rate*—i.e., the proportion of exposures of susceptibles leading to a transmission—should be used whenever possible. An exposure takes place each time that a susceptible—one giving no past history of the disease—is at risk with one or more infectious cases. Each susceptible in a household in which another occupant is ill with the disease is deemed to have undergone exposure unless he is simultaneously ill with the same disease. The desirability of counting in this way is clear if one considers families of different sizes. A solitary susceptible escaping an exposure in the home has no further opportunity to catch the disease there, whereas when two susceptibles are simultaneously at risk of whom only one takes the disease the other is exposed a second time. The larger the number of susceptibles the greater is the opportunity for several generations inside the family. Each exposure must therefore be recorded to allow those leading to a temporary escape equal value with those leading to a more permanent escape. Four examples are given to make the method clear :

I, A infects B, C, D, and E.

Exposures	4
Transmissions	4

II, A infects B, but C, D, and E escape. Then B infects C, D, and E.

Exposures	7
Transmissions	4

III, A infects B, but C, D, and E escape. B then infects C, but D and E again escape. Then C infects D, but E again escapes. E also escapes the infective stage of D, so escaping finally.

Exposures	10
Transmissions	3

IV, A fails to infect B, C, D, and E. Five weeks later B gets the disease and infects C and D, but E escapes. Here there are two distinct entries of the virus into the household :

(i)	Exposures	4
	Transmissions	0
(ii)	Exposures	4
	Transmissions	2

Table I shows these four examples set out on the epidemic sheet from which the exposure attack-rate in the home is compiled.

EFFECT OF FAULTY MEMORY

A person who mistakenly represents himself to be a susceptible produces a double error by falsifying both the

TABLE III—EXAMINATION OF POSSIBLE MEASURING-POINTS IN MEASLES

Interval (days)	Between			
	Onsets (137 pairs)	Conj. (44 pairs)	R.I. (162 pairs)	R.II. (203 pairs)
	%	%	%	%
6	2·2	..	1·2	2·0
7	14·0	13·6	3·7	3·9
8	5·8	4·5	6·2	6·9
9	8·8	2·3	14·2	15·3
10	12·4	11·4	21·0	14·3
11	8·0	25·0	17·9	20·8
12	14·7	13·6	9·3	12·3
13	8·0	15·9	11·7	7·8
14	9·5	4·6	8·0	7·8
15	5·8	4·5	2·5	4·9
16	3·6	2·3	3·7	2·0
17	3·6	2·3	..	1·0
18	0·7	..	0·6	1·0
19	2·9	..	..	..
20	..	..	..	..
Total	100	100	100	100

Conj., first day of conjunctivitis.
R.I., ,, ,, ,, rash.
R.II., day of maximum rash.

TABLE IV—EXAMINATION OF POSSIBLE MEASURING-POINTS IN VARICELLA

Interval (days)	Between	
	Onsets (67 pairs)	R.I. (184 pairs)
	%	%
6	..	..
7	4·5	3·8
8	7·5	4·3
9	1·5	2·7
10	1·5	4·9
11	3·0	3·8
12	6·0	6·0
13	9·0	12·0
14	20·8	29·9
15	16·4	10·3
16	6·0	5·4
17	9·0	7·6
18	11·8	3·3
19	1·5	3·8
20	1·5	2·2
Total	100	100

R.I., day of first rash.

number of exposed susceptibles in the family and the proportion of escapes. In example III given above, for instance, if E is not susceptible but immune, the number of presumed escapes is raised from 3 to 7, a serious augmentation. The larger the family the greater is the error, because most immunes at risk will always escape, however often exposed. Increasing age brings forgetfulness of childhood ailments, a source of error which becomes considerable in the elderly. Against measles there appears to be no evidence of increasing immunity apart from an attack of the disease. Epidemics in areas unprotected by endemic disease affect the older equally with the younger members of the population, as was shown in the Solomon Islands and in the Faroe Islands (1846). The position is probably the same for varicella.

TABLE V—EXAMINATION OF POSSIBLE MEASURING-POINTS IN MUMPS

Interval (days)	Between	
	Onsets (105 pairs)	S.I. (142 pairs)
	%	%
9	1·0	..
10	3·8	1·4
11	1·0	..
12	1·9	2·8
13	4·8	2·1
14	8·6	14·1
15	6·6	4·9
16	10·5	10·6
17	12·4	9·9
18	7·6	9·2
19	8·6	8·5
20	6·6	7·0
21	6·6	7·0
22	4·8	5·7
23	1·0	0·7
24	1·9	4·2
25	3·8	4·2
26	1·9	2·1
27	1·9	2·1
28	1·0	2·1
29	..	0·7
30	1·9	..
31	..	..
32	..	0·7
..	..	..
35	1·0	..
36	..	..
37	1·0	..
Total	100·2	100

S.I., first day of swelling.

For measuring infectiousness the attack-rate is therefore calculated on susceptibles aged 14 or less. The rate in alleged susceptibles above that age is very different (table II), and one presumes that this disparity is due in large part to the fading memory of childhood illness. It is not unreasonable to suppose that of the 36 persons aged more than 14 representing themselves to be susceptible to measles only about 10 were so. In mumps the position is different; mumps is less infectious and therefore attacks on an average at a later age. The attack-rate among those aged more than 14 claiming to be susceptible does not differ materially from that in the younger group. At present there seems to be no knowledge of the effect of ageing on susceptibility. The figure for the infectiousness of mumps, 31·1%, reckoned on the susceptibles aged less than 14 differs but little from the attack-rate at all ages (32·1%). It is therefore probably unnecessary to make, as we have done, an adjustment

TABLE VI—INFECTIOUSNESS THROUGHOUT THE SEASONS BASED ON SUSCEPTIBLE EXPOSURE-TRANSMISSION RATE UNDER THE AGE OF 15

—	Measles			Varicella			Mumps		
	Exposures	Transmissions	Infectiousness (%) 3 months' moving averages	Exposures	Transmissions	Infectiousness (%) 3 months' moving averages	Exposures	Transmissions	Infectiousness (%) 3 months' moving averages
January	4	3	62·5	10	7	69·3	3	..	37·5
February	..	..	86·4	51	35	65·1	5	1	44·4
March	18	16	77·4	25	14	68·5	10	7	40·0
April	13	8	80·6	16	14	56·6	15	4	36·0
May	31	26	76·9	42	19	58·6	25	7	26·8
June	73	56	74·7	29	18	50·9	31	8	24·5
July	66	46	75·0	37	18	59·3	53	12	27·6
August	33	27	70·6	15	12	52·6	38	14	28·6
September	10	4	75·5	5	..	60·9	13	4	34·9
October	10	9	70·8	3	2	53·3	32	11	31·5
November	4	4	83·3	22	14	67·3	31	9	35·2
December	4	2	75·0	27	19	67·8	8	5	33·3
Mean			75·7			60·9			33·35

(See also fig. 3.)

of the sort used in measles and varicella to the figures for mumps.

PRIMARY AND SECONDARY CASES

From what has already been written it is seen to be important to distinguish clearly between primary (infecting) cases and secondary (infected) cases. During an epidemic three or four generations of the disease may occur in a family, the second-generation cases in their turn becoming primary to the tertiary, and the tertiary to the quaternary. A right estimate of the number of exposures and transmissions depends on a knowledge of the span of a generation, a measurement peculiar to each disease.

Point of Measurement

It is necessary to define a point in the course of the disease from which to measure the serial interval from case to case. Most diseases present several features that might be used for the purpose, and the principles on which to choose the most suitable have already been discussed (Hope Simpson 1948). The event on which to base a measuring-point must be regularly present, readily recognised, and constant in the time of its appearance in the cycle of the illness. In measles four events have been examined for suitability (table III):

(1) *Onset of symptoms of illness.*—This, though often used, is unsatisfactory because the serial intervals cover a wide range with a shallow mode.

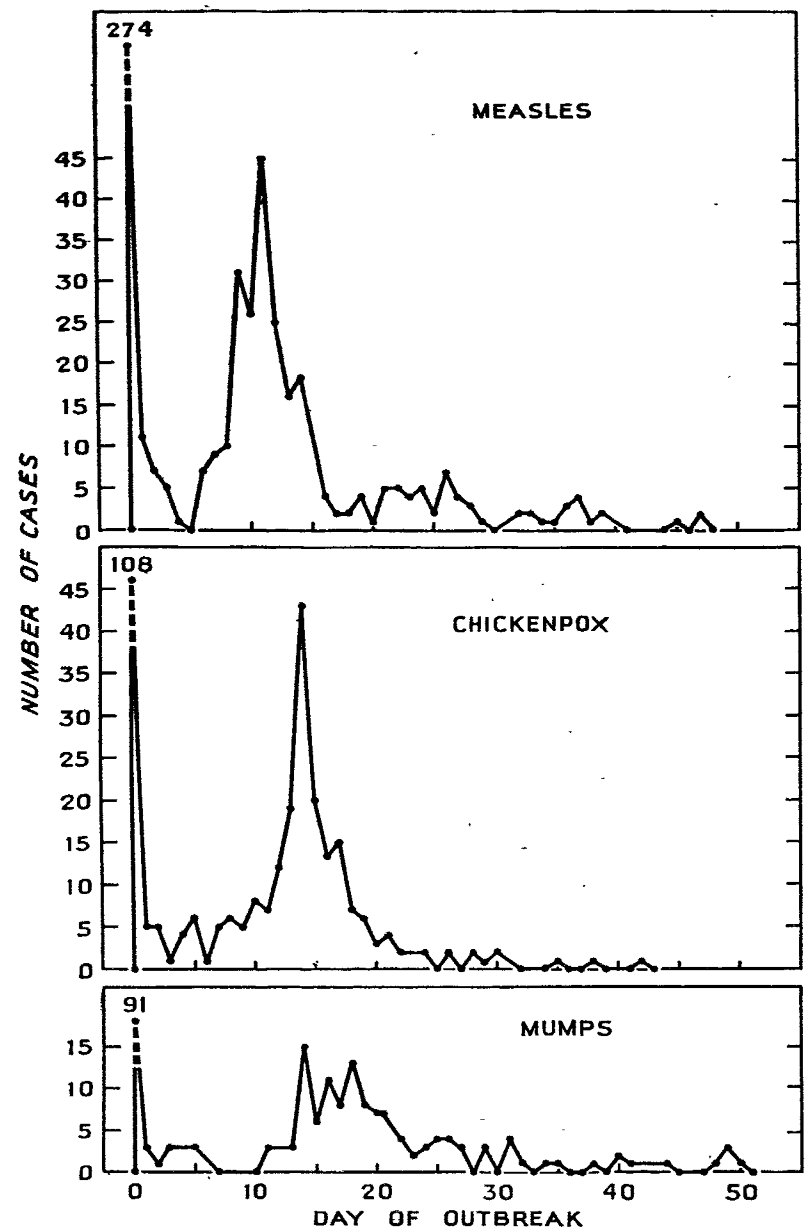

Fig. 1—Primary and secondary cases in outbreaks in households.

(2) *First appearance of conjunctivitis.*—This gives a satisfactory range and mode, but the symptom is often absent or unrecognised, or its day of onset is forgotten.
(3) *First appearance of rash.*
(4) *Day of maximum rash.*

Between these last two there is little to choose. Parents are perhaps less certain of the date of the first appearance. Some parents are more observant than others. We can ourselves confirm the day of fullest development more often than the day of first appearance of the rash. For these reasons we have chosen the day of fullest flowering of the rash. When, as occasionally happens, the rash remains equally florid for more than one day, the first day of maximum rash is used.

Table IV examines the onset and the first day of rash in chickenpox, and table V the onset and the first day of swelling in mumps. The days of measurement used in the present study are as follows:

Measles: maximum rash,
Chickenpox: first appearance of rash,
Mumps: first appearance of swelling.

The point of measurement in each case is midnight after the day of measurement.

First-generation Primaries

It is next necessary to distinguish between those cases in the home which are co-primary with the first case and have been infected outside the household, and second-generation cases infected by the primary case within the household. To do this, the first case in the home is considered as occurring at the zero point, and the intervals between the measuring-point in this and subsequent cases are tabulated. The experience of all the households combined shows a steep decline for the first few days owing to the decreasing number of co-primaries, succeeded by a rise towards the mode of the curve of secondary cases (fig. 1). The lowest point, where the decreasing primaries are intersected by the increasing secondaries, is taken as the division between first and second generations, and at this point primaries erroneously included as secondaries most nearly balance secondaries wrongly considered primary. A small error remains because there are inevitably more secondaries than primaries.

The following are the intervals during which cases are considered co-primary with the first case in the household:

Measles: 6 days, Varicella: 7 days, Mumps: 10 days.

Second Generation

The second generation must be distinguished not only from the first as described above but also from subsequent

TABLE VIII—PERCENTAGE OF SECONDARY CASES ESCAPING TEMPORARILY

Disease	Secondary cases	Percentage escaping temporarily	
		Once	Twice
Measles	201	4·0	0·5
Varicella ..	172	8·1	0·6
Mumps	82	12·2	3·7

Cases which have had two escapes are also included among those which have escaped once.

TABLE VII—INFECTIOUSNESS: EXPOSURE TRANSMISSIONS UNDER THE AGE OF 15
(Three months' moving averages against central month and deviation from mean)

—	Measles			Varicella			Mumps		
	Infectiousness	Deviation from mean	% deviation from mean	Infectiousness	Deviation from mean	% deviation from mean	Infectiousness	Deviation from mean	% deviation from mean
January ..	62·5	−13·2	−17·4	69·3	+ 8·4	+13·8	37·5	+ 4·2	−12·5
February ..	86·4	+10·7	+14·1	65·1	+ 4·2	+ 6·9	44·4	+11·1	+36·0
March	77·4	+ 1·7	+ 2·4	68·5	+ 7·6	+12·5	40·0	+ 6·7	+20·1
April	80·6	+ 4·9	+ 6·4	56·6	− 4·3	− 7·1	36·0	+ 2·7	+ 8·1
May	76·9	+ 1·2	+ 1·6	58·6	− 2·3	− 3·8	26·8	− 6·5	−19·5
June	74·7	− 1·0	− 1·3	50·9	−10·0	−16·4	24·5	− 8·8	−26·4
July	75·0	− 0·7	− 0·9	59·3	− 1·6	− 2·6	27·6	− 5·7	−17·1
August ..	70·6	− 5·1	− 6·7	52·6	− 8·3	−13·6	28·6	− 4·7	−14·1
September ..	75·5	− 0·2	− 0·3	60·9	0	0	34·9	+ 1·6	+ 4·8
October ..	70·8	− 4·9	− 6·4	53·3	− 7·3	−12·0	31·5	− 1·8	− 5·4
November ..	83·3	+ 7·6	+10·0	67·3	+ 6·4	+10·5	35·2	+ 1·9	+ 5·8
December ..	75·0	− 0·7	− 0·9	67·8	+ 6·9	+11·3	33·3	0	0
Mean ..	75·7			60·9			33·3		

(See also fig. 3.)

TABLE IX—EXPOSURE ATTACK-RATE % AMONG FAMILIES WITH DIFFERENT NUMBERS OF SUSCEPTIBLES UNDER THE AGE OF 15

Disease	No. of susceptibles in family				
	One	Two	Three	Four or more	Total
Measles	140 (*77·9*)	68 (*76·0*)	24 (*70·0*)	16 (*70·0*)	248 (*75·6*)
Varicella	104 (*75·0*)	80 (*60·0*)	48 (*48·6*)	15 (*45·5*)	247 (*61·0*)
Mumps	78 (*32·1*)	98 (*38·3*)	81 (*31·1*)	55 (*25·3*)	312 (*31·1*)

Rates are shown in parentheses.

TABLE X—INFECTIOUSNESS AND AGE-DISTRIBUTION

—	Measles	Varicella	Mumps
Infectiousness (%)	75·6	61·0	31·1
Mean age at which infection takes place (yr.)	5·6	6·7	11·5
Standard deviation of age distribution	4·73	5·45	10·50
Age by which 90% of cases have had the disease	8 yr. 4 mos.	10 yr. 8 mos.	29 yr.

generations. Mistaken inclusion of tertiaries reduces the proportion of escapes, and mistaken inclusion of second-generation cases among tertiaries reduces the proportion of transmissions. Epidemic studies are of great assistance in solving this problem. Fig. 2 shows accumulated epidemics with the first case of each recorded at zero point. It is easy to find the mode of generation after generation. From these figures the following intervals have been chosen:

	First generation (days)	*Second generation (days)*	*Tertiaries (days)*	*Quaternaries (days)*
Measles ..	1–6	7–18	19–30	31–42
Varicella ..	1–7	8–21	22–35	36–49
Mumps ..	1–10	11–30	31–50	51–70

(Both days are included in the intervals.)

Certain interesting relationships emerge from this study. It will be seen that the generation-time is twice the interval during which cases are considered to be co-primary with the first case. Further, the generation-time is identical with the mean interval between the modes of successive generations, and indeed this forms the simplest method of estimating it.

Here is a biological measurement of great interest, susceptible of precise estimation, differing consistently from disease to disease in a manner peculiar to each parasite. Domiciled in man for millennia, the causal organism of measles has burst into reproductive activity and sent forth a fresh colony on the average every twelfth day. The figure of twelve days used here for measles is too long, but for present purposes it is impossible to split the day into portions. The reproductive cycle of varicella is almost exactly fourteen days. For mumps the data are as yet insufficient to give a precise figure, and twenty days must be considered as tentative.

The methods used here differ from those used by Wilson et al. (1939), whose paper should be consulted for details of previous usages. The choice of method makes a considerable difference, especially when one is studying attack-rates in families with differing numbers of susceptibles at risk. To compare our figures with those of Wilson et al. we have re-analysed them in table XII by the methods which they used.

Results

Table II shows the infectiousness of the three diseases, the figures for each representing the experience of almost the same families. Measles is evidently the most infectious in the community provided by the household. Mumps is not half as infectious as measles and only just over a half as infectious as varicella. Fig. 3, based on tables VI and VII, shows the infectiousness of the three diseases throughout the seasons, a three-monthly moving average being used. Tests of significance show that the variation in each is not more than would be expected by chance. The degree of infectiousness in the three diseases is also reflected in the proportion of secondary cases that escape once or twice before finally coming down (table VIII).

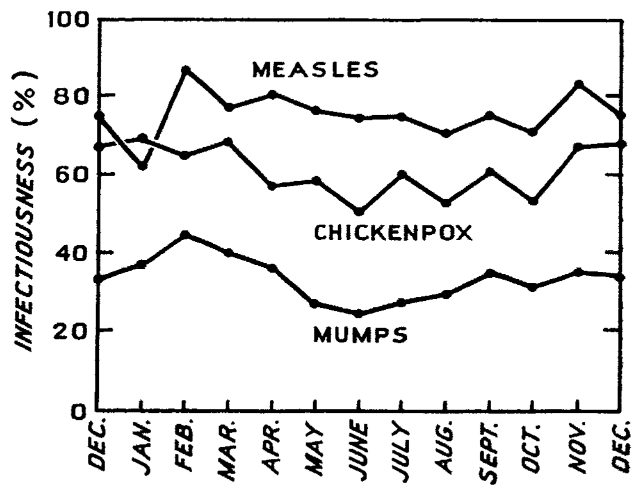

Fig. 3—Infectiousness of measles, chickenpox, and mumps in different seasons.

EFFECT OF SIZE OF FAMILY ON INFECTIOUSNESS

Table IX shows the infectiousness of the three diseases in families with 1–4 or more susceptibles at risk. The numbers of families with more than 3 susceptibles at risk are not large enough to be representative.

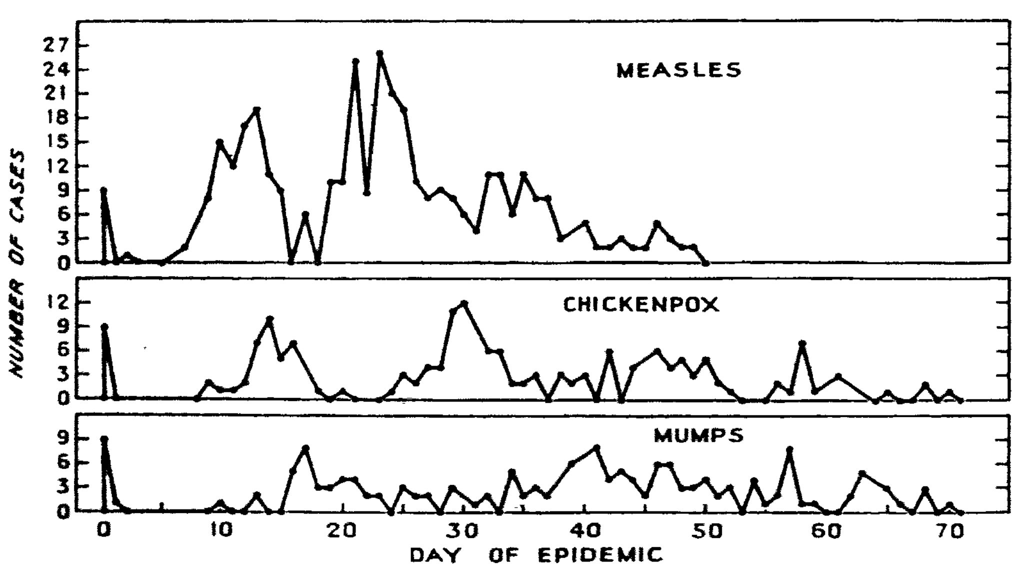

Fig. 2—First, second, and subsequent generations of cases in epidemics.

INFECTIOUSNESS AND AGE OF ATTACK

In diseases which confer life-long immunity the degree of infectiousness is reflected in the age at which a person is most likely to be attacked. The more infectious the disease the younger is the age at which an attack is likely to be received. Table X, which shows the age-distribution and the infectiousness of measles, varicella, and mumps, brings out the closeness of this inverse relationship.

INFECTIOUSNESS AND SEASONAL PREVALENCE IN MEASLES

During the period of this study measles in this area was mainly a disease of spring and summer, 78·6% of the 663 cases in the epidemic studies having fallen during the months from May to August (table XI). In case these figures were unrepresentative, drawn as they were largely from studies of total epidemics in various parts of the area, the fairness of the picture was tested by analysing the measles seen in the same period in a local general practice among some 4000 patients. Of the 229 cases of measles encountered in the practice more than 75% fell in the months from May to August; hence the epidemic figures may be taken as representing the local trend of measles during that period.

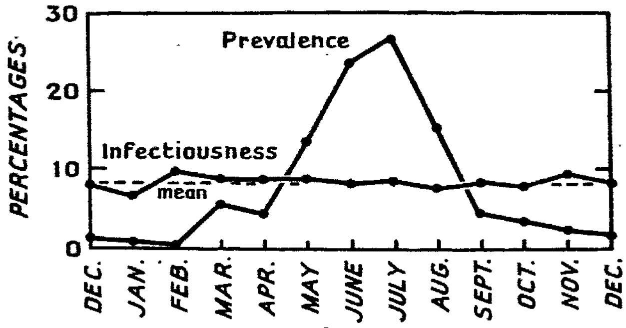

Fig. 4—Comparison of infectiousness and prevalence of measles.

Was the autumn decline in prevalence due to diminished infectiousness of the disease? Comparison of the seasonal infectiousness with the seasonal prevalence in table XI and fig. 4 shows a vivid contrast between the uniformity of the infectiousness and the variation in the prevalence. There is no seasonal waxing and waning in infectiousness such as might explain the vagaries of these epidemics.

RELIABILITY AND UTILITY OF THE PRESENT METHOD

The simple method presented here of assessing infectiousness can be adapted to the study of virus mutation and other factors involving secular changes in infectiousness. The measurement given is absolute and not merely relative, 100% infectiousness representing a disease which attacks every exposed susceptible in the home at the first opportunity. Measles approaches quite near to saturation, and experience suggests that whooping-cough will give an even higher figure. It has been shown above how the method can be used to study seasonal variation in infectiousness, and, in view of its possible usefulness in other spheres, it is well to inquire if the figures produced possess the requisite stability. Were the investigation to be repeated in another part of the country, for example, or here at another time, would different figures emerge? Although further research is needed to decide this, our experience suggests that sufficiently stable figures can be obtained. The measles cases analysed here can be arranged in a form to compare with the admirable studies of Wilson et al. (1939) at Providence, Rhode Island. Reference to table XII shows that their figures fall close to ours in both age-groups.

Several workers have suggested that infectiousness alters during the course of an epidemic and is at a different level in interepidemic periods. This matter can also be investigated simply and directly by the present methods: it would demand a simultaneous collection of records from a wide area and would need to be continued for several years.

TABLE XI—SEASONAL PREVALENCE AND INFECTIOUSNESS IN MEASLES

(The three percentage columns show the proportion of the total occurring in each month)

—	Infectiousness in epidemic studies			Prevalence: In epidemic studies			Prevalence: In general practice		
	Infectiousness	%		Cases	%		Cases	%	
January	62·5	6·9	33·8	5	0·8	10·7	7	3·0	11·7
February	86·4	9·5		2	0·3		1	0·4	
March	77·4	8·5		36	5·4		10	4·4	
April	80·6	8·9		28	4·2		9	3·9	
May	76·9	8·5	32·7	88	13·2	78·6	27	11·7	76·1
June	74·7	8·2		156	23·6		36	15·7	
July	75·0	8·2		176	26·6		49	21·5	
August	70·6	7·8		101	15·2		62	27·2	
September	75·5	8·3	33·5	28	4·2	10·7	11	4·8	12·2
October	70·8	7·8		22	3·3		14	6·1	
November	83·3	9·2		13	2·0		1	0·4	
December	75·0	8·2		8	1·2		2	0·9	
Total	908·7	100·0		663	100·0		229	100·0	

(See also fig. 4.)

Summary

It is possible to give a quantitative expression of the infectiousness of certain diseases by assessing the incidence of cases resulting from every exposure of a susceptible in the home (susceptible-exposure attack-rate). Infectiousness in the diseases studied was:

Measles: 75·6%, Varicella: 61·0%, Mumps: 31·1%.

The mean reproductive cycle of the virus of measles is twelve days, that of varicella fourteen days, and that of mumps about twenty days. Cases are reckoned as co-primary with the first case in the household if they fall within a period of half the reproductive cycle. Subsequent generations are reckoned by adding on to this half-cycle a period equal to one reproductive cycle for each generation. Details are given of the methods used.

The age-distribution of these diseases shows a close inverse relationship with the infectiousness.

The summer prevalence of measles in these areas during the period under review was not due to any increase of infectiousness that could be shown in the home attack-rate.

A numerical expression of infectiousness should prove of value in the study of various problems concerning infectious disease.

TABLE XII—COMPARISON OF THE SECONDARY ATTACK-RATE IN MEASLES IN DIFFERENT AREAS AND AT DIFFERENT TIMES

Age-group (yr.)	Secondary attack-rate: Providence, U.S.A., 1929–34 (Wilson et al. 1939)	Secondary attack-rate: Cirencester, 1947–51
Less than 1	40·6	40·0
Less than 15	81·1	80·1
15 or more	16·7	16·3

It is a pleasure to acknowledge the great help received from every member of the unit during the five years of its existence, and the grant from the Medical Research Council which made the work possible. I have also had help and advice from many people, and I wish especially to mention that received from Prof. A. Bradford Hill. I am glad also to acknowledge the willing coöperation of the school-teachers in this area, and all my general-practitioner colleagues, and the patients who form the subject of this work.

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"... The meaning of the irrational is so ambiguous in recent psychology that the man in the street, as we all know, is inclined to draw the conclusion that, being so full of irrational factors, he cannot be expected in any circumstances to behave rationally and could hardly know that he was behaving rationally even if he did so behave."—*Times Literary Supplement*, Sept. 5, 1952, p. 585.