Measles in Detroit, 1935*†

I. Factors Influencing the Secondary Attack Rate Among Susceptibles at Risk

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IN spite of the ubiquity of measles, epidemiological knowledge of the disease is based upon surprisingly few published studies. Among these Panum's monumental work in the Faroe Islands,[1] has by all odds contributed most. Conditions were unparalleled for determining the incubation period, the variation in the duration of prodromes and other factors which he investigated; yet the observations were made under unusual conditions in a community where measles had been absent for 65 years and where the population was highly susceptible to the infection. Chapin's contribution [2] is a study of measles occurring over 66 years (1858–1923 inclusive) in Providence, R. I. English workers such as Hamer,[3] Brownlee,[4] Soper,[5] and Stocks,[6] have contributed a considerable literature to the theory of the epidemic cycle; Stocks and Karn [7] studied certain phenomena noted in a series of epidemics in St. Pancras. In this country, Collins [8] and Hedrich [9] furnish data concerning completeness of reporting and the age distribution of cases, while Emerson [10] has evaluated the effect of current administrative practice on the incidence, fatality, and death rates of measles. The recent publications on measles from the London County Council [11] deal with administrative and prophylactic measures applied within its jurisdiction.

In general, much which we profess to know about measles is dependent upon clinical impression and inadequate field investigations, without benefit of statistical treatment. Measles is more communicable than most infections. The opinion is quite general that most measles contacts will develop the disease. In fact, parents often consider it unfortunate when all susceptible children in the family do not take the disease at one time, reasoning that it is more convenient to be done with it at once.

It has been stated that 90 to 95 per cent of all children have contracted measles by the time they reach the age of 15 years.[8,9,12,13] Granting this, is it not possible that the communicability of measles may be influenced by certain conditions which have been demonstrated to influence less communicable diseases? Chapin [2] found that 76.2 per cent of susceptible contacts at all ages developed measles when exposed. Stocks [6] states (he contends that in St. Pancras, reporting was only 10 to 15 per cent under the actual occurrence

* Read before the Epidemiology Section of the American Public Health Association at the Sixty-sixth Annual Meeting in New York, N. Y., October 8, 1937.

† This study was made possible through assistance of WPA Project Number 82-4-120—A Survey of Health Conditions in Detroit.

of the disease) that for every reported case of measles there are 3 susceptible persons exposed who do not contract it. He considers them to be temporarily immune, but again susceptible by the time the next epidemic occurs 2 years later. In the light of these contentions it would seem that there is ample justification for a further study of measles as it occurs in epidemic cycles in an urban community large enough to give an adequate number of cases.

SOURCE OF MATERIAL

During 1935, 27,430 cases of measles were reported in Detroit. The cases were classified by families: (1) families in which one or more susceptible contacts received some prophylactic agent, (2) families, no member of which received a prophylactic agent. This report is based on the second class. There were too many families in this class to make follow-up visits feasible. It was therefore determined to study thoroughly a small group—approximately one-fifth of all the families. A random selection was made by taking every fifth family record from the files. From the group thus selected the following were excluded for obvious reasons:

1. Families with no susceptible contacts
2. Families with an incomplete case record
3. Families in which a change of diagnosis was made
4. Children from orphanages and boarding homes
5. Families which could not be located on subsequent follow-up visits

Beginning August, 1936, follow-up visits were made to those families of the sample group in which one or more susceptible contacts had not been reported as having developed measles, to determine the accuracy of history of previous measles and the number of cases which had not been reported.* After eliminating all families which could not be located on this visit, there remained a group of families no member of which had received prophylaxis, who serve as a sample of the larger untreated group.

Families in this sample group which were thoroughly investigated were shown not to differ materially from the larger group when compared with respect to: (1) age of the primary case (p. = .35), (2) age distribution of susceptible contacts (p. = .13) and (3) the proportion of susceptible contacts in each age group reported as developing measles (p. = .72).

FACTORS CONSIDERED IN THIS STUDY

There are many factors which might affect the secondary attack rate among exposed susceptibles. Many are related to the nature of the infectious agent, in this instance probably a filtrable virus, and are outside the scope of this investigation. Certain aspects relating to the host and his environment are considered in the following questions which might have a bearing on the secondary attack rate:

A. Does the age or sex of the primary case affect the number of secondary cases developing among susceptible contacts?

B. What influence do age and sex of the susceptible contact exert on the secondary attack rate?

C. What is the relationship of the period in the seasonal cycle to the secondary attack rate?

D. What is the relationship of the number of primary cases per family to the secondary attack rate?

E. What variation of secondary attack rates is occasioned by exposure of susceptible contacts to repeated exposure to a constant intensity and differing intensities of exposure at one time?

DEFINITIONS

Before attempting an answer to the questions proposed certain terms are defined according to their use in this study.

* A visit was deemed unnecessary to families in which all susceptible contacts were reported as having contracted measles.

TABLE I

Attack Rates Among Susceptible Contacts According to Age and Sex of Primary Case

Age of Primary Case	*Sex of Primary Case*	*Number Contacts*	*Number Secondary Cases*	*Attack Rate*
Under 1	M.	5	2	(40.0)
	F.	7	4	(57.1)
1– 4	M.	104	77	74.0
	F.	140	101	72.1
5– 9	M.	633	551	87.0
	F.	679	602	88.7
10–14	M.	18	14	77.8
	F.	30	20	66.7
15+	M.	12	7	58.3
	F.	5	2	(40.0)
All ages	M.	772	651	84.3
	F.	861	729	84.7
	M. & F.	1,633	1,380	84.6

Primary Case—The first case in a family presumably resulting from extra-familial exposure over 30 days after any previous case. Subsequent cases, the rash of which occurred within 6 days of the rash of the first case, were also called primary cases. Rash dates were used in determining the 6 day interval.

One-primary Family *—A family in which one primary case occurred.

Multiple-primary Family—A family in which 2 or more primary cases occurred.

Susceptible Contact—Any child under 10 years of age reported as not having had measles previously who was exposed to a case of measles within the family. Susceptible contacts were limited to ages under 10 because children above the 6th grade were allowed to go to school and were not recorded as contacts.

Secondary Case—A case of measles developing more than 6 days after the onset of the 1st case in the family. The study included both reported secondary cases and those determined by subsequent investigation.

Exposure Period—An arbitrary period during which effective contact could have taken place. The number of days a measles case was infectious was arbitrarily placed at 8 days. This was arrived at as follows: 1 day before the prodromes plus 4 days of prodromes plus 3 days of rash.

Person-days of Exposure—The total number of days a contact was exposed. This was reckoned as follows: One person exposed to 1 case was considered as 8 person-days of exposure; 1 person exposed to 2 cases was considered as 16 person-days of exposure, whether exposure was simultaneous or in sequence.

Month—The month refers to the date of onset.

ANALYSIS AND DISCUSSION OF FACTORS

Age and Sex of Primary Case—Among 1,253 one-primary families, 1,380 secondary cases occurred with 651 attributable to male primary cases and 729 to female primary cases (Table I). The attack rate for contacts exposed to males is 84.3 and to females, 84.7.

The effect of age of the primary case on the secondary attack rate is shown in Table II. There are too few contacts under 1 and over 14 years of age to warrant consideration. Primary cases 5 to 9 years of age had the greatest number of contacts exposed of all primary age groups considered, with a total of 1,312 or 80.3 per cent of all contacts; furthermore, the contacts exposed to this age group had the highest attack rate in each contact age group.

* Unless otherwise noted, data relate to susceptible contacts in one-primary families.

TABLE II

Attack Rates Among Susceptible Contacts According to Age of Primary Case and Age of Contact

Age of Primary Case	Age of Contact: Under 1 — No. Contacts	Under 1 — No. Cases	Under 1 — Attack Rates	1–4 — No. Contacts	1–4 — No. Cases	1–4 — Attack Rates	5–9 — No. Contacts	5–9 — No. Cases	5–9 — Attack Rates	0–9 — No. Contacts	0–9 — No. Cases	0–9 — Attack Rates
Under 1	0	0	(—)	9	3	(33.3)	3	3	(100.0)	12	6	50.0
1– 4	51	20	39.2	119	105	88.2	74	53	71.6	244	178	73.0
5– 9	110	56	50.9	826	778	94.2	376	319	84.8	1,312	1,153	87.9
10–14	2	1	(50.0)	18	13	72.2	28	20	71.4	48	34	70.8
15+	2	1	(50.0)	11	6	54.5	4	2	(50.0)	17	9	52.9
All ages	165	78	47.3	983	905	92.1	485	397	81.9	1,633	1,380	84.6

The primary age group, 1 to 4, in comparison, had but 244 contacts, 14.9 per cent of the total. The attack rates for the respective primary age groups vary somewhat when considered for each age group of contacts but the differences do not appear to be highly significant (p. = .1).

Age and Sex of the Contact—Of 1,633 susceptible contacts in one-primary families 786 were males and 847 were females (Table III). The respective attack rates were 84.4 and 84.7. Differences in attack rates between sexes are slight for each age group of contacts.

Of all contact age groups that of 1 to 4 contains 983 individuals or 60.2 per cent of the total (Table II). For each age band of primary cases, the contact age group, 1 to 4, shows a greater number of susceptibles exposed, except for the primary case group, 10 to 14, with a higher attack rate in each instance. When all three of the contact age groups are compared, the attack rates vary considerably and are significantly different (p. = .0000). When the contact age groups, 1 to 4, and 5 to 9, are compared, the difference is not very significant for a sample of this size. The attack rate in children under 1 year, however, is significantly lower than the attack rates in the older children.

Apparently, neither the sex of the primary case nor that of the susceptible contact influences the secondary attack rate. The age of the primary case has not been shown to influence very sig-

TABLE III

Attack Rates Among Susceptible Contacts by Age and Sex of Contact

Age of Contact	Sex of Contact	Number Contacts	Number Cases	Attack Rates
Under 1	M.	77	32	41.6
	F.	88	46	52.3
1– 4	M.	472	441	93.4
	F.	511	464	90.8
5– 9	M.	237	190	80.2
	F.	248	207	83.5
0– 9	M.	786	663	84.4
	F.	847	717	84.7
	M. & F.	1,633	1,380	84.6

nificantly the secondary attack rate, though the 5 to 9 primary age group gave the highest secondary attack rates. A significantly lower attack rate was found among susceptible contacts under 1 year of age.

Relationship of the Period in the Seasonal Cycle to the Secondary Attack Rate—The number of susceptible contacts by month appears in Table IV.

TABLE IV

Attack Rates Among Susceptible Contacts by Age and Month

Month	Number Contacts	Number Cases	Attack Rates
January	38	33	86.8
February	136	120	88.2
March	589	511	86.8
April	620	532	85.8
May	196	156	79.6
June	45	26	57.8
July	6	...	(0.0)
August	...	...	(...)
September	3	2	(66.7)
Totals	1,633	1,380	84.6

Early in the epidemic cycle, namely, during January and February, there were fewer contacts than noted for the immediate succeeding months, but the attack rate was as high in these as during March, April, and May. The attack rate for the individual months varies but slightly although toward the end of the epidemic cycle, in May and June, there is a relative but not highly significant decrease (p. = .15). Such differences as exist might be explained by infection of the more highly susceptible children earlier in the epidemic year.

Relationship of the Number of Primary Cases per Family to the Secondary Attack Rate—It is conceivable that more than one primary case in a family might increase the attack rate among susceptible contacts in the family. In Table V, data are presented showing the attack rates among susceptible contacts exposed in families with 1, 2, and 3 primary cases. In one family with 5 primary cases there was 1 susceptible contact, but measles did not develop. The number of contacts exposed in three-primary families is too small to consider but they are included to give the complete picture. When the data for one- and two-primary families are examined, it will be noted that with one exception, the age group, 1 to 4, the attack rates are higher in one-primary families than in the two-primary families. The variation is so slight, however, that it is not of much consequence. The number of contacts in the

TABLE V

Attack Rates Among Susceptible Contacts According to Number of Primary Cases in the Family

	Number of Primary Cases in Family *								
	1			*2*			*3*		
Age of Contact	*Number Contacts*	*Number Cases*	*Attack Rates*	*Number Contacts*	*Number Cases*	*Attack Rates*	*Number Contacts*	*Number Cases*	*Attack Rates*
Under 1	165	78	47.3	24	9	37.5	4	1	(25.0)
1	178	164	92.1	12	10	83.3	4	3	(75.0)
2	246	225	91.5	10	8	80.0	1	1	(100.0)
3	304	284	93.4	22	22	100.0	2	2	(100.0)
4	255	232	91.0	23	22	95.7	1	1	(100.0)
	—983	—905	—92.1	—67	—62	—92.5	—8	—7	
5	207	180	87.0	18	17	89.5	1	0	(0.0)
6	107	89	83.2	4	2	(50.0)	0	0	(.....)
7	75	60	80.0	8	5	(62.5)	2	2	(100.0)
8	56	44	78.6	2	1	(50.0)	0	0	(.....)
9	40	24	60.0	4	3	(75.0)	1	1	(100.0)
	—485	—397	—89.1	—36	—28	—77.8	—4	—3	
0–9	1,633	1,380	84.6	127	99	78.0	16	11	68.8

* In the 1 five-primary family there was one susceptible contact—measles did not develop.

TABLE VI

Attack Rates Among Susceptible Contacts Exposed to One-Primary Cases by Number of Exposure Periods, Person-Days of Exposure, and Age of Contact

Number Exposure Periods	Person-Days of Exposure	Age of Susceptible Contact: Under 1 — Number Contacts	Under 1 — Number Cases	Under 1 — Attack Rates	1–4 — Number Contacts	1–4 — Number Cases	1–4 — Attack Rates	5–9 — Number Contacts	5–9 — Number Cases	5–9 — Attack Rates	0–9 — Number Contacts	0–9 — Number Cases	0–9 — Attack Rates
1	8	125	74	60.2	937	877	93.6	457	385	84.2	1,517	1,336	88.1
2	16	32	3	9.4	35	22	62.9	21	8	38.1	88	33	37.5
3	24	0	0	(....)	1	0	(0.0)	0	0	(....)	1	0	(0.0)

two-primary families is small and larger totals might alter the result. However, it is remarkable that the attack rates for two-primary families is not notably higher than for one-primary families. It might appear unusual that exposure of susceptibles to 2 primaries should result in attack rates of the same or lower magnitude than encountered for similar age groups among one-primary families—on second thought, however, a plausible explanation appears. The attack rates for individual ages from 1 to 9 years, inclusive, vary between 60 and 93 per cent. If an attack rate of 85 per cent is taken as the mean for all ages considered, the hazard of exposure to additional primaries could possibly affect only 15 per cent of susceptible contacts. Thus, secondary attack rates in multiple primary families could not be much larger than for one-primary families. Again, it is possible that the remainder in multiple-primary families might be more resistant on account of selection—some of the subsequent primary cases being, in fact, secondary cases.

The Effect on Secondary Attack Rates Occasioned by Repeated Exposure to a Constant Intensity—A measles case was considered to be infectious for 8 days—arrived at as noted in the definition of " exposure period " given above. In Table VI, susceptible contacts are classified by age, exposure periods, and person-days of exposure. The majority of contacts had one exposure. Very few contacts remain who were exposed for two periods, and but one contact was exposed for three periods. In the one-exposure group, the secondary attack rate for all contacts exposed is 88.1. For contacts exposed twice, a period of 16 days, the attack rate was 37.5. Evidently the few contacts who escape measles after one exposure have a decidedly smaller probability of contracting measles when exposed a second time but the additional hazard is still real. Whether part of the decreased risk at second exposure is due to sub-clinical infection with development of temporary immunity resulting from first exposure, is conjectural. It is possible, in the light of Panum's observations, that a considerable number of contacts who do not contract the disease on second exposure may have given an incorrect reply when questioned regarding an attack of measles in the past. Again, the highly susceptible may have been eliminated by the one-period exposure which would tend to make the attack rate lower in the two-period group.

The Effect on Secondary Attack Rates Occasioned by One Exposure to Various Intensities—The effect on the secondary attack rate of exposure to multiple primary cases is considered above and leads to further investigation

TABLE VII

Attack Rates Among Contacts by Number of Primary Cases, Person-Days of Exposure, and Age of Contact

Number of Primaries	Person-Days of Exposure	Age of Susceptible Contact: Under 1 — Number Contacts	Under 1 — Number Cases	Under 1 — Attack Rates	1–4 — Number Contacts	1–4 — Number Cases	1–4 — Attack Rates	5–9 — Number Contacts	5–9 — Number Cases	5–9 — Attack Rates	0–9 — Number Contacts	0–9 — Number Cases	0–9 — Attack Rates
1	Under 8	...	..	(....)	5	3	(60.0)	3	2	(66.7)	8	5	(62.5)
	8	123	74	60.2	937	877	93.6	457	385	84.2	1,517	1,336	88.1
	16	32	3	9.4	35	22	62.9	21	8	38.1	88	33	37.5
	17+	10	1	10.0	6	3	(50.0)	4	2	(50.0)	20	6	30.0
2	Under 16	..	..	(....)	2	2	(100.0)	3	3	(100.0)	5	5	(100.0)
	16	21	9	42.9	63	58	92.1	31	25	80.6	115	92	80.0
	17+	3	..	(0.0)	2	2	(100.0)	2	..	(0.0)	7	2	(28.6)
3	24	2	1	(50.0)	8	7	(87.5)	4	3	(75.0)	14	11	78.6
	25+	2	..	(0.0)	..	..	(....)	..	..	(....)	2	..	(0.0)
5	40	..	..	(...)	..	..	(....)	1	..	(0.0)	1	..	(0.0)
Totals		193	88	45.6	1,058	974	92.1	526	428	81.4	1,777	1,490	83.8

of the possible effect of intensity of exposure (Table VII). An exposure period of less than 8 days is possible if the primary case was removed to hospital during the 8 day period. Therefore, in families in which there was 1 primary case, susceptible contacts may have been exposed for less than 8 days, for 8 days, or if exposed to additional members of the family as they developed measles, for more than 8 days. Each additional exposure to another measles case in the family was considered as an additional 8 days of exposure. Thus, a child in a one-primary family may have been exposed for 16 days—8 days to the primary case and 8 days to another member of the family. The great majority of contacts were exposed for 8 days. The few remaining contacts are principally in the 16 person-days of exposure group. Table VI is almost a duplicate of that part of Table VII which deals with contacts to one-primary cases; the differences are the result in Table VI of exclusion of contacts exposed to more than 1 additional familial case in 1 exposure period.

When two-primary families are considered, the majority of contacts were exposed for 16 days, that is, exposed to 2 primary cases but to no subsequent secondary cases. No comment is warranted for contacts to families with 3 primaries, for their number is too small.

To determine adequately the effect of intensity of exposure in the same period of time, the attack rates resulting from exposure for an 8 day period in one-primary families, a 16 day period in two-primary families, and a 24 day period in three-primary families should be compared (Table VIII). In other words, a comparison is being made between contacts in one-primary, two-primary, and three-primary families who were not subsequently exposed to a secondary case. The attack rate for contacts exposed in a family with 1 primary case is 88.1, for those exposed to 2 primary cases 80.0, and for 14 contacts exposed to 3 primary cases, 78.6. There is little difference between the secondary attack rates. A variation in intensity of exposure as measured by the number of cases in the family to which a susceptible is exposed during the same period of exposure (8 days), therefore, appears to exert no significant effect upon the secondary attack rate.

TABLE VIII

Attack Rates Among Susceptible Contacts Exposed to One-, Two-, and Three-Primary Cases During One Exposure Period

		Age of Susceptible Contact											
		Under 1			1–4			5–9			0–9		
Number of Primaries	Person-Days of Exposure	Number Contacts	Number Cases	Attack Rates	Number Contacts	Number Cases	Attack Rates	Number Contacts	Number Cases	Attack Rates	Number Contacts	Number Cases	Attack Rates
1	8	123	74	60.2	937	877	93.6	457	385	84.2	1,517	1,336	88.1
2	16	21	9	42.9	63	58	92.1	31	25	80.6	115	92	80.0
3	24	2	1	(50.0)	8	7	(87.5)	4	3	(75.0)	14	11	78.6
5	40	..	..	(....)	..	..	(....)	1	..	(0.0)	1	..	(0.0)

Similar considerations apply here as with Tables V and VI. It may be that on account of error in the dates given or for other reasons, some of the cases called primary were really secondary so that the multiple-primary contacts represent in part those from whom the most susceptible had been selected out by the first primary exposure. In addition, it might be that some multiple-primary families represent instances in which the entire number of contacts in the family were exposed at once, in which case the remaining susceptible contacts represent a selected, less infectable group.

Of the two factors, number of times exposed, and intensity of exposure, the former is of importance and from a practical point of view. There is a greater hazard to exposure to 2 cases separated by an 8 day interval. The bearing this has on the possible use of prophylactic agents or upon removal from the family of susceptible contacts 3 years and under is obvious.

SUMMARY

An analysis of certain factors which might affect the secondary attack rate in a random sample of families, no member of which received prophylactic therapy, in the 1935 measles epidemic in Detroit, resulted in the following conclusions:

1. The sex of the primary case or that of the susceptible contact is unimportant.
2. Age of the primary case may exert an influence on the secondary attack rate. Further investigation of this factor would appear desirable.
3. The age of the susceptible contact influences the secondary attack rate significantly.
4. Secondary attack rates are not greatly affected by the period in the seasonal cycle in which measles first appears in the family.
5. The number of primary cases per family does not affect the secondary attack rate among susceptibles in the family.
6. There is an additional hazard when a contact is exposed to measles a second time.
7. Intensity of exposure as measured by the number of cases in the family at one time does not appear to influence appreciably the secondary attack rate among susceptibles at risk.

NOTE: The author gratefully acknowledges the assistance of George F. Badger in the preparation of this paper.

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Syphilis Meeting

ASSEMBLY of Laboratory Directors and Serologists, Hot Springs National Park, Arkansas, October 21–22, 1938—A meeting under the auspices of the Committee on Evaluation of Serodiagnostic Tests for Syphilis, of the U. S. Public Health Service, with Surgeon General Thomas Parran, Chairman, is scheduled for October 21 and 22, 1938, at Hot Springs National Park, Ark.

The aims and purposes of the assembly will be to consider means and methods to improve and to make more generally available the serologic tests, which are so important in syphilis control work. Tentative arrangements call for the presentation of the program in four sections.

The first section will consider the need for adherence to conventional technic in the routine performance of reliable serodiagnostic tests. Need for training of laboratory personnel will be the subject of the second section. The third section will discuss the prosecution of the studies to evaluate the performance of serologic tests within the states. The fourth section will consider the desirability of licensing or approving, for the performance of serodiagnostic tests for syphilis, laboratories within the states by the respective state departments of health.

A separate committee will draft recommendations for each of the four sections for presentation to the assembly. The respective chairmen of these 4 section meetings will be Drs. Walter M. Simpson, Dayton, Ohio, Arthur H. Sanford, Rochester, Minn., F. E. Senear, Chicago, Ill., and H. H. Hazen, Washington, D. C.

Out of the meeting should come a crystallization of opinion with regard to the important problems which will be considered. Those interested in obtaining further information should write to the Surgeon General, U. S. Public Health Service, Washington, D. C.