# Epidemiology of Lobar Pneumonia*

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IN a preliminary study one of us [1] determined the prevalence of various types of pneumococci in the nasopharynges of persons who had been in intimate contact with cases of lobar pneumonia. Nasopharyngeal cultures of over 1,000 persons (contacts and controls) indicated that Types I and II pneumococci were much more prevalent in the nasopharynges of immediate family contacts of cases of lobar pneumonia due to the homologous organisms than in the population at large. This suggested the advisability of further study in an attempt to determine the significance of this finding. Does the case of lobar pneumonia due to Type I or II pneumococcus infect his immediate contacts; or do these types invade the nasopharynges of a family, establish themselves and ultimately produce pneumonia in one unfortunate member? An answer to at least a part of this question might be reached by first taking cultures of the family contacts of an individual who had developed lobar pneumonia. One would then remove that person to a new uninfected environment, thus exposing a new, presumably susceptible and uninfected group of contacts, and make a study of this new group. Our approach to the problem was to restrict ourselves to a study of the contacts of cases of lobar pneumonia which were due to Type I or II pneumococcus and that were taken to the wards of general hospitals early in the course of the disease. We compared the nasopharyngeal content of the home contacts of each case with the nasopharyngeal content of hospital contacts of the same case.

The hospitals of Metropolitan Boston coöperated in the study and informed us immediately by telephone whenever a case of lobar pneumonia due to either Type I or Type II pneumococcus was admitted to their wards. Our procedure was to culture immediately the new environment of the patient; namely, the hospital patients adjoining the new case (if the case was in a large ward), or all the contacts, if the new case was placed in a small 4- or 5-bed ward. This enabled us to establish the nasopharyngeal flora present in the new environment at the time of the introduction of a source of Type I or II pneumococcus. These contacts were then re-cultured at intervals as long as the contact remained unbroken, and as long as the pneumonia patient continued to exhibit Type I or II pneumococci in his sputum.

The environment from which the patient had come was studied concurrently. The family from which the case had been removed was visited, and nasopharyngeal cultures were taken from as many of the immediate family contacts as possible.

As a further index of the extent to which Type I or II pneumococcus

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TABLE I

NASOPHARYNGEAL CULTURES ON HOSPITAL PATIENT AND FAMILY CONTACTS OF CASES OF LOBAR PNEUMONIA DUE TO TYPE I PNEUMOCOCCI

| | *Cases* | *Contacts* | *Contact Days* | *Negative* | *Positive and not Homologous* | *Positive and Homologous* | *Per Cent Positive and Homologous* |
|---|---|---|---|---|---|---|---|
| Hospital Contacts | 20 | 61 | 426 | 38 | 50 | 1 | 1.6 |
| Family Contacts | 17 | 62 | 153 | 13 | 34 | 15 | 24.2 |

strains are transmitted from acute cases to their contacts, house officers, nurses, and orderlies working on the wards in which lobar pneumonia caused by these types of pneumococcus were being treated were cultured. These cultures were taken before exposure to the case, during exposure, and at intervals after the exposure had ended.

Several families in which the incidence of homologous carriers was high were cultured at regular intervals to discover the length of time a "healthy" carrier was likely to carry a Type I or II pneumococcus.

Various factors of the environment which might influence the transfer of pneumococci from patient to contact, such as overcrowding, low economic or social status, were noted. Similarly, variations in the individual contacts, such as age, the existence of respiratory disease, or the occurrence of acute respiratory infection, chilling of the body by exposure, etc., received attention.

The pneumococci were identified by standard mouse passage and tube agglutination technic as recommended by Cooper [2] whose specific sera from I to XXXII, inclusive, were employed. Our Type XX serum cross-agglutinated with so many types of pneumococci that it was used only occasionally, which probably accounts for our finding this type but once. The virulence to a mouse of each strain of pneumococcus that was isolated from a contact was determined. The technic and personnel for both this study and the one previously reported by Smillie [1] were the same, so that the results of the two are comparable.

The general study was continued through a 9 months period, November to July, inclusive.

## FAMILY, PATIENT, AND HOSPITAL STAFF CONTACTS OF LOBAR PNEUMONIA DUE TO TYPE I OR II PNEUMOCOCCUS

The contacts of 64 cases were studied. Of these 64 cases, Type I was the infecting organism 42 times, and Type II, 22 times.

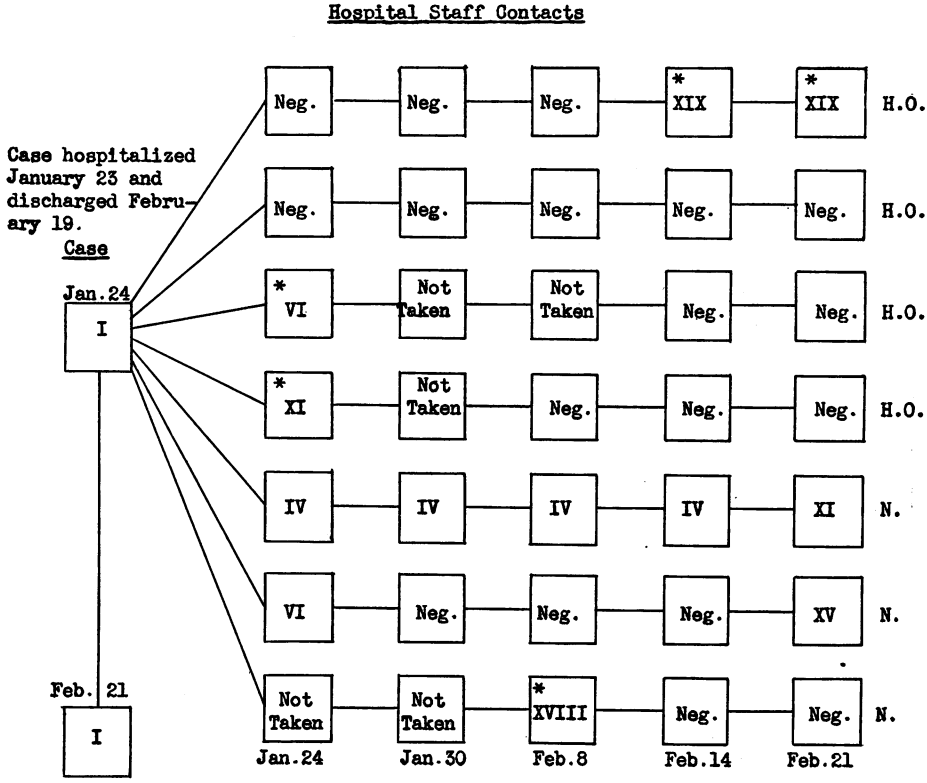
TABLE II

NASOPHARYNGEAL CULTURES ON HOSPITAL PATIENT AND FAMILY CONTACTS OF CASES OF LOBAR PNEUMONIA DUE TO TYPE II PNEUMOCOCCI

| | *Cases* | *Contacts* | *Contact Days* | *Negative* | *Positive and not Homologous* | *Positive and Homologous* | *Per Cent Positive and Homologous* |
|---|---|---|---|---|---|---|---|
| Hospital Contacts | 11 | 33 | 281 | 25 | 25 | 1 | 3.0 |
| Family Contacts | 10 | 37 | 134 | 9 | 22 | 6 | 16.2 |

DIAGRAM 1

PNEUMOCOCCI ISOLATED FROM THE NASOPHARYNGES OF FOUR HOUSE OFFICERS AND THREE NURSES IN CHARGE OF A WARD IN WHICH A CASE OF TYPE I LOBAR PNEUMONIA WAS TREATED




*Indicates the presence of a cold at the time the culture was taken.
H.O. indicates House Officer
N. indicates Nurse.

Family contacts were considered only when they had been in contact with the patient within 7 days; and hospital patients were cultured only if they occupied contiguous beds in a large ward or were in a small 4- or 5-bed ward with the case. Thus, all contacts could be called intimate from the point of view of ease of exchange of nasopharyngeal flora by droplets.

The distribution of cases and contacts was: 61 patient contacts of 20 Type I cases; 62 family contacts of 17 Type I cases; 33 patient contacts of 11 Type II cases; 37 family contacts of 10 Type II cases; and 71 hospital staff contacts of 5 Type I and 1 Type II cases.

A summary of the results of the study of these 5 groups is shown in Tables I, II, and III. Diagram I illustrates the details of a typical study on hospital staff contacts.

The striking thing about the tables is the high percentage of homologous carriers among the family contacts, as compared to the low percentage among hospital staff or patient contacts. This difference is further emphasized when we compare the number of contact days for family contacts with the number of

TABLE III

NASOPHARYNGEAL CULTURES ON HOSPITAL PATIENTS, HOSPITAL STAFF AND FAMILY CONTACTS OF CASES OF LOBAR PNEUMONIA DUE TO TYPE I OR II PNEUMOCOCCI

| | *Cases* | *Contacts* | *Contact Days* | *Negative* | *Positive and not Homologous* | *Positive and Homologous* | *Per Cent Positive and Homologous* |
|---|---|---|---|---|---|---|---|
| Hospital Patient Contacts | 31 | 94 | 707 | 63 | 75 | 2 | 2.1 |
| Hospital Staff Contacts | 6 | 71 | 610 | 42 | 27 | 2 | 2.8 |
| Family Contacts | 27 | 99 | 287 | 22 | 56 | 21 | 21.2 |

contact days for hospital staff and patient contacts. Sixty-two family contacts of 17 Type I cases were exposed for 153 days and yielded 15, or 24.2 per cent, homologous carriers, whereas 61 hospital patient contacts of 20 Type I cases were exposed for 426 days and yielded only 1, or 1.6 per cent, homologous carriers. A similar relationship exists for contacts of Type II cases. Thirty-seven family contacts of 10 Type II cases yielded 6, or 16.2 per cent, homologous carriers for 134 days exposure, whereas 33 hospital patient contacts of 11 Type II cases yielded only 1, or 3.0 per cent, homologous carriers after 281 contact days. Similarly, 71 hospital staff contacts of 5 Type I and 1 Type II cases yielded only 2, or 2.8 per cent, homologous carriers after 610 days of exposure.

Another striking thing in relation to family contacts should be emphasized, namely, that one is just as likely to find homologous carriers among the family contacts of cases of Type I or II lobar pneumonia on the first day of exposure as after a week of exposure. That is, the number of contact days following the onset of the lobar pneumonia does not appear to affect the carrier rate in the home. This, coupled with the low rate of spread in hospitals, suggests that there must be some additional factor which determines whether or not a Type I or II pneumococcus becomes established in the nasopharynx of persons that are exposed to cases of lobar pneumonia due to these particular strains.

In order to study this phenomenon further, we determined to introduce a known healthy carrier of Type I pneumococcus into a group of normal persons that were free from pneumococci of this particular type, and then to measure the spread of the organism in the new, uninfected environment, incident with the culturing of a group of controls in the Wrentham State School for Mental Defectives, we discovered that an inmate, E. H., age 28, harbored a strain of virulent Type I pneumococcus in her nasopharynx. E. H. gave no history of previous pneumonia, nor of contact with a case. E. H. was in Building F, housing a group of slightly mentally retarded females, averaging about 25 years of age, so that the group was fairly similar to one of normal adults. On the campus was another building—B—with a comparable group of women at a slightly higher age level, averaging about 30 years of age. Each building was a unit, with little contact from building to building, or with the outside.

The plan followed was to culture first the occupants of Building F, in

which E. H. had been a patient for several years. We also cultured the occupants of Building B in order to establish the normal nasopharyngeal flora of the persons in the two buildings. We then transferred E. H. to Building B and cultured, at frequent intervals, her new contacts in this new environment.

Building F contained 116 girls. They were about equally divided between 3 wards in which the beds were arranged as elsewhere in the institution; the head of one touching the foot of the next one, and the rows separated by a narrow aisle just wide enough to allow a person to walk between the rows. The night time contact, therefore, could be consdered closer than would be found either in the home or in a general hospital. Building B housed 97 girls under exactly the same living conditions, so that the degree of contact in the two buildings was comparable.

The two buildings gave a total of 213 persons. Of these 103 (48.3 per cent) harbored pneumococci of various types, and 110 (51.7 per cent) did not. These percentages are compatible with the figures obtained by other workers for the normal population. Gundel,[3] in 1,114 cultures of school children, found 734 strains of pneumococci, and Smillie,[1] in 458 cultures of a cross-section of the normal population, found 212 strains. In our series of cultures from Building B and F, all of the 32 Cooper types except II, XXII, XXIII, XXVI, XXVII, XXIX, XXXI, and XXXII were recovered. Types III,

TABLE IV

TYPES OF PNEUMOCOCCI PRESENT IN THE NASOPHARYNGES OF CONTACTS WITH A TYPE I PNEUMOCOCCUS HEALTHY CARRIER BEFORE AND AFTER THE INTRODUCTION OF THE INFECTED PERSON INTO THE DORMITORY

| | | *Type of Pneumococcus* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | July | | | | | | | |
| | Case No. | 11 | 17 | 18 | 19 | 21 | 24 | 27 | 28 |
| Type I Carrier | – | – | – | – | * | I | I | I | I |
| Contacts in contiguous beds and at same dining table | 1 | – | Neg. | – | * | VI | Neg. | VI | Neg. |
| | 2 | – | Neg. | – | * | Neg. | VI | VI | VI |
| | 3 | III | – | – | * | III | Neg. | IV | Neg. |
| | 4 | – | – | VI | * | VI | XXVI | VI | VI |
| | 5 | VIII | – | – | * | VIII | VIII | VIII | VIII |
| | 6 | – | – | Neg. | * | III | VI | VI | VI |
| Contacts at same dining table, but not in contiguous beds | 7 | Neg. | – | – | * | – | Neg. | – | VII |
| | 8 | Neg. | – | – | * | – | II | – | II |
| | 9 | VII | – | – | * | – | VIII | VIII | VIII |
| | 10 | VII | – | – | * | – | XI, XVI | – | XI, XVI |
| Contacts in contiguous beds, but not at same dining table | 11 | – | – | Neg. | * | III | – | Neg. | Neg. |

* Type I carrier introduced on this date

VII, X, and XVIII were found most frequently, but no single type predominated. Type I was not found in Building B. In Building F, where the carrier was an inmate, 2 other girls yielded Type I pneumococcus on one occasion. It was impossible to obtain this organism from these 2 inmates on repeat cultures. Only E. H. was continually positive for the virulent Type I pneumococcus.

The culturing of the two buildings was started on June 28, and was completed on July 19, on which date E. H. was transferred from Building F to Building B, and her new contacts were then cultured at intervals. Our procedure by days follows:

July 21—Contacts in contiguous beds—Building B
July 21—Previous contacts in contagious beds—Building F
July 24—Contacts at same dining table—Building B
July 26—Contacts in same ward, but not in contiguous beds—Building B
July 26—Contacts in same building, but not in same ward—Building B
July 26—Previous contacts not in same ward—Building F
July 27—Contacts in same building, but not in same ward—Building B
July 27—Contacts in contiguous beds—Building B
July 28—Contacts at same dining table—Building B
July 28—Contacts in contiguous beds—Building B

It will be noted that we concentrated our efforts on contacts occupying beds contiguous to E. H. and to contacts eating at the same dining table. Many of the people in the contiguous beds also used the same dining table, so that some had more contact than others. As a check, cultures were also taken from time to time in the other wards in Building B and in Building F from which E. H. had come. None of these control cultures were positive for Type I pneumococcus.

The results of one group of serial cultures of intimate contacts of E. H. in her new environment are shown in Table IV. It is obvious from this table that E. H. did not infect her new contacts with Type I pneumococcus, though she continued to carry this strain throughout her stay in Building B.

Analysis of all the data, consisting of approximately 125 nasopharyngeal cultures of immediate contacts, reveals that the introduction of an individual harboring Type I pneumococci in the nasopharynx into a group of people having continued close contact with the carrier was without effect. This statement, however, is modified by the length of contact, which was fairly short, July 19–28; and by the time of the year, July—a month during which the incidence of pneumococci in the population is low, and in which little lobar pneumonia occurs. Additional important data would be secured if one repeated the Wrentham experiment during the winter months, or during an outbreak of upper respiratory disease, such as the common cold.

We have some evidence that Type I pneumococci, under certain conditions, may be transmitted through contact in the hospital. In one instance of close contact of a hospital staff member with an infected person, it would appear that a strain of Type I pneumococcus was transmitted from patient to contact and that lobar pneumonia due to Type I pneumococcus had resulted.

On March 9, a girl 2½ years old, suffering from lobar pneumonia, complicated by an empyema, was hospitalized, and Type I pneumococci were isolated from the nasopharynx, and from the pleural fluid. We made serial nasopharyngeal cultures on 7 doctors and 3 nurses who came in contact with this child. On March 20, Dr. A., who was in charge of aspirating pus from the pleural cavity, developed lobar pneumonia due to Type I pneumococcus.

Dr. B. assumed care of the child, and on March 25 a nasopharyngeal culture of his throat revealed Type I pneumococcus, but he did not develop pneumonia. The remaining 5 doctors and 3 nurses were cultured repeatedly until April 11, on which date the case ceased to exhibit Type I organisms. None of them became positive for Type I pneumococcus.

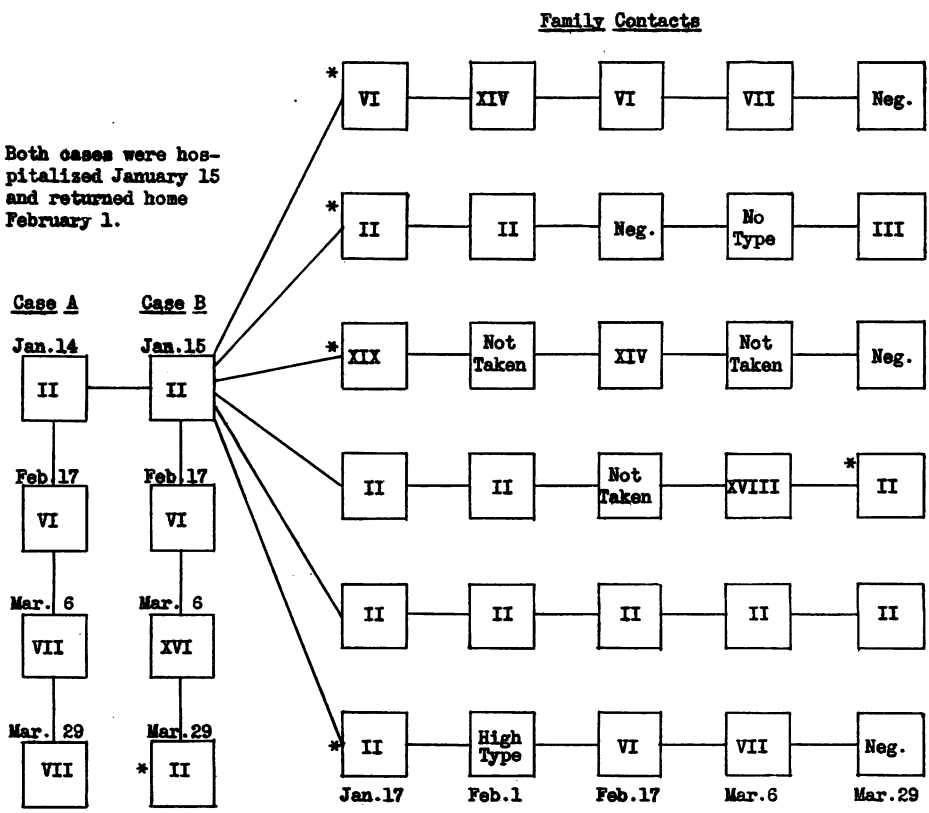
Since this child was the only known source of Type I pneumococcus in the hospital, it would seem reasonable to assume that this patient was responsible for the spread of the infection to the 2 doctors, the spread probably being influenced by the intimate contact associated with the aspiration of the pleural cavity of a small child.

Several families in which there occurred a high percentage of contacts that carried Type I or II pneumococci were studied with special care.

*Family A*—The mother of Family A became ill on January 14 with lobar pneumonia. The infecting organism was Type II pneumococcus. On the following day a small daughter developed lobar pneumonia, also caused by a Type II pneumococcus. Both patients were removed to a local hospital on January 15. On January 17, the 6 remaining members of the family, 1 man, 2 boys, and 3 girls, were cul-

DIAGRAM 2

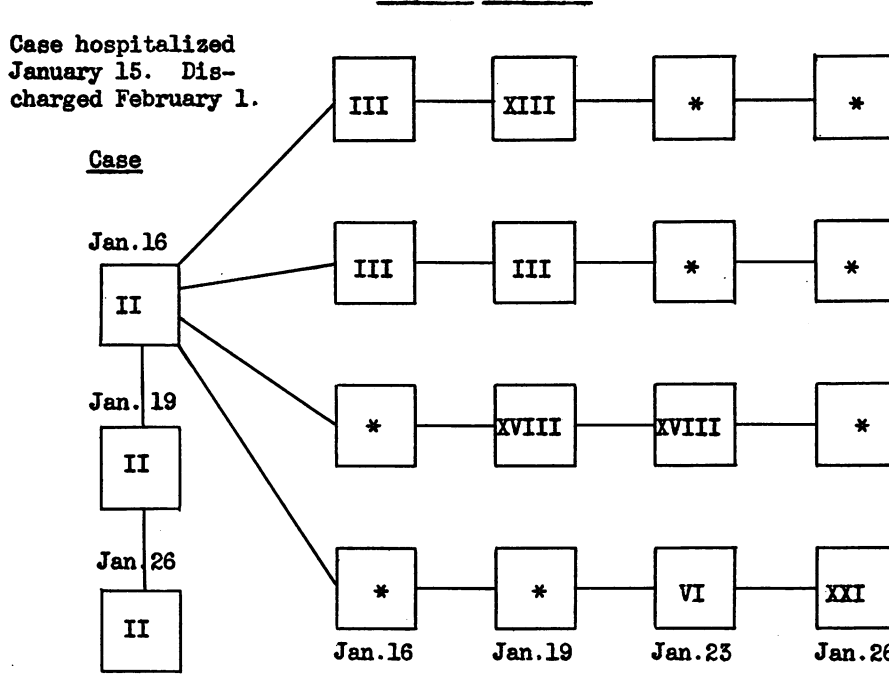
PNEUMOCOCCI ISOLATED FROM THE NASOPHARYNGES OF SIX MEMBERS OF A FAMILY IN WHICH TWO CASES OF TYPE II LOBAR PNEUMONIA OCCURRED




*Indicates the presence of a cold at the time the culture was taken.

DIAGRAM 3

PNEUMOCOCCI ISOLATED FROM THE NASOPHARYNGES OF FOUR PATIENTS OCCUPYING THE SAME FIVE-BED WARD AS A CASE OF TYPE II LOBAR PNEUMONIA




*Indicates that no culture was obtained.

tured. Type II pneumococci were recovered from the nasopharynges of 4 of these contacts. Two that carried Type II pneumococci had bad colds at the time the cultures were taken, and 2 had not had bad colds for more than a month.

These 6 contacts were recultured at about 2-week intervals until 5 serial cultures had been obtained (Diagram II). It will be noted from the diagram that 1 continued positive for Type II pneumococcus throughout; 1 yielded Type II pneumococcus only on the first culture; 1 yielded Type II on the second culture, became negative to Type II, and finally exhibited a Type III; and 1 yielded a Type II on the second and last cultures, having been negative for Type II in the meantime.

The 2 patients who had been in the hospital with pneumonia returned home on February 1, free from Type II pneumococcus. The mother remained consistently negative, but her daughter became positive for Type II pneumococcus again, after being negative for this strain on two previous cultures. It is interesting to note that during the 2½ months that the family was studied it was never free from a source of Type II pneumococcus, and that the 2 persons who became negative to Type II pneumococcus and later positive both

gave a history of an acute cold at the time the Type II pneumococcus was recovered.

The mother of Family A was hospitalized in a 5-bed ward and serial cultures were taken on the 4 patients in her new environment. These having on the average at least 4 days close contact with her, each failed to yield a Type II pneumococcus (Diagram 3).

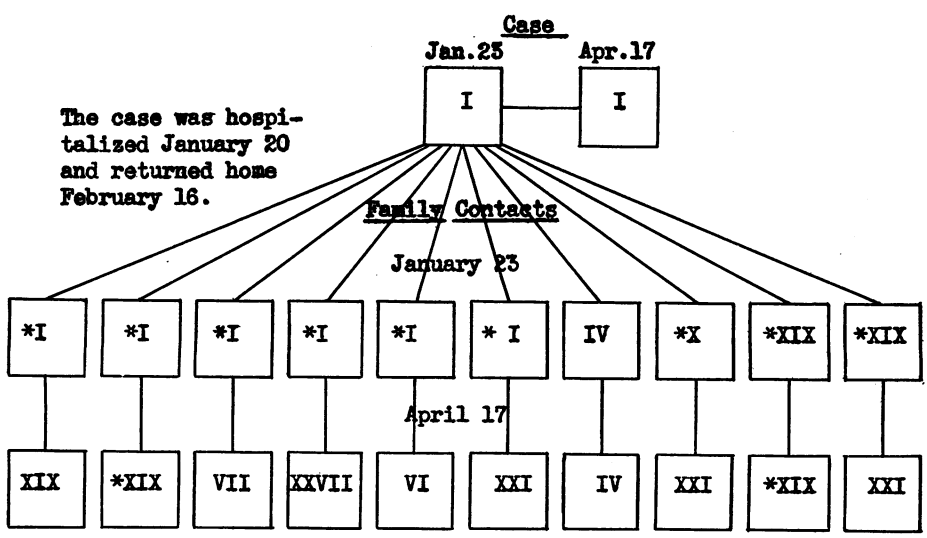
*Family B*—On January 23, the mother of Family B developed lobar pneumonia due to Type I pneumococcus. On January 27, 4 days after the patient had been removed to a hospital, nasopharyngeal cultures were taken on 10 home contacts, 6 of whom were found to be carrying Type I pneumococci. In this particular family, 9 of the 10 contacts, which included all 6 of the homologous carriers, had severe colds at the time the cultures were taken (Diagram 4). This family was not followed at short intervals, but when recultured April 17, nearly 3 months later, none of the contacts yielded Type I pneumococci. The original case, however, who had recovered and returned home February 16, was still positive for Type I pneumococcus on April 17.

The mother of Family B was hospitalized in a 5-bed ward and serial cultures were taken on the 4 patients in her new environment. As with Family A, the 4 patients, having at least 4 days close contact with her, each failed to yield a Type I pneumococcus.

*Family C*—In April, 1932, a 13 year old boy in Family C developed lobar pneumonia due to Type II pneumococcus. Five family contacts that were cultured at the time yielded 4 type II carriers. This family was not followed at frequent intervals, but the hospital records show that the child developed a chronic empyema, from which Type II pneumococci were recovered, and which

DIAGRAM 4

PNEUMOCOCCI ISOLATED FROM THE NASOPHARYNGES OF TEN MEMBERS OF A FAMILY IN WHICH ONE CASE OF TYPE I LOBAR PNEUMONIA OCCURRED




*Indicates the presence of a cold at the time the culture was taken.

continued to discharge for several months after the child returned home. The family was recultured in April, 1933, nearly a year later, and Type II pneumococci were recovered from the nasopharynges of the original case and 3 of the 4 original carriers.

### THE RELATIONSHIP OF ACUTE RESPIRATORY DISEASE IN CONTACTS OF TYPE I OR II LOBAR PNEUMONIA TO PREVALENCE OF PNEUMOCOCCI IN THE NASOPHARYNX

It has been suggested that a person with a cold is more likely to harbor pneumococci than one without a cold. Our data indicate, however, that pneumococci were not significantly more prevalent in contacts suffering from colds than in those free from colds. A different picture was presented when we considered only the group of contacts of Type I or II cases which harbored the homologous organism. Of our group of 25 homologous carriers, 19, or 76 per cent, had colds at the time they were cultured. The numbers are small, but the figures are significant, and suggest further study in this direction.

Our data indicate that overcrowded living conditions in the home, and also low economic status were not factors in the establishment of carriers of Type I and Type II pneumococci.

### SUMMARY AND CONCLUSIONS

1. Nasopharyngeal cultures from 264 contacts of 64 cases of lobar pneumonia due to Type I and Type II pneumococcus have been studied. The results indicate that 20± per cent of the immediate family contacts of these patients harbored the homologous strain in their nasopharynges. The hospital contacts of the same patients, however, were seldom infected (about 2 per cent). These results suggest that it is quite justifiable to treat cases of lobar pneumonia due to Type I and Type II pneumococci in the open wards of our general hospitals.

2. One experiment indicates that a healthy carrier of Type I pneumococcus does not transmit this organism to immediate contacts, even though the individuals are living under overcrowded conditions.

3. Our evidence suggests that there is some additional factor other than simple contact which determines the transfer of Type I or II pneumococci from a patient with lobar pneumonia to contacts. Nineteen of the 25 family contacts of cases of lobar pneumonia due to Type I or Type II pneumococci that became homologous carriers were suffering from acute colds at the time the cultures were taken. Positive cultures were found as frequently on the first day of exposure as after a week. This evidence suggests that family epidemics of colds may be a factor which determines the transfer and establishment of Type I and Type II pneumococci from the infected to the uninfected.

4. Carriers of Type I and Type II pneumococci, when once established, may continue as carriers of these strains for a considerable period of time without giving rise to lobar pneumonia in the carrier or his contacts and without producing a second group of carriers.

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3. Gundel, M. *Ztschr. f. Hyg. u. Infektionskr.*, V, 114:659–677, 1933.