

THE TRANSMISSION OF THE TYPHUS FEVER
OF MEXICO (TABARDILLO) BY MEANS
OF THE LOUSE (PEDICULUS
VESTAMENTI)*

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In a previous article¹ we referred to Nicolle's experiment, in which he apparently succeeded in transmitting the typhus fever of Tunis from the chimpanzee to the macacus monkey, through the bite of the louse. Nicolle used twenty-nine lice in his experiment; after feeding on the chimpanzee they were allowed to feed on the monkey for several successive days. Also, Anderson and Goldberger² report two attempts to transmit the typhus fever of Mexico City to the macacus by means of the louse. Their first experiment seemed to be without result, and although the second showed a slight rise in temperature, their inability to give an immunity test to the animal makes it impossible to interpret the result. This test is essential, as will be manifest from considerations which follow.

Since January 1 we have performed a series of experiments bearing on the relation of *Pediculus vestimenti* to the typhus of Mexico, some of which may be recorded at this time.

Certain conditions pertaining to the experiments should be detailed before the protocols are given.

The first relates to the susceptibility of the monkey to typhus, and the positiveness with which the disease may be recognized in this animal.

As shown by the experiments of Anderson and Goldberger, and by our own, the injection of virulent blood from man, under suitable conditions, gives rise to a well-marked course of fever, following an incubation period from five to twelve days. A further constant factor is the absence of micro-organisms, which are susceptible to cultivation by ordinary methods, from the blood of the animal during his course of fever. This sequence of events has now resulted a sufficient number of times without any failures, so that it may be expected constantly when the established technic is observed. In the course of our experiments so far six monkeys have received virulent blood from man in doses of from 1 to 7, c.c.; two have received virulent unfiltered serum in doses of 7.5 and 8.5 c.c.; and one received 5 c.c. of defibrinated blood from another monkey as an experiment in passage. All of these animals exhibited an incubation period followed by a distinct course of fever, accompanied by signs of severe illness, and with negative attempts to obtain cultures from the blood. Anderson and Goldberger obtained similar results in the four animals inoculated by them. It would seem, therefore, that even in the absence of an eruption resembling that of typhus (and indeed, no such eruption has appeared), the consistency of the phenomena mentioned is a satisfactory index of the transmissibility of the disease to the monkey. Constantly the temperatures of seven or eight normal monkeys were taken twice daily as a means of detecting possible adventitious infections which might be contagious in character; but none was observed.

A second, and, as it seems, a conclusive method of determining whether a course of fever was really due to an infection with typhus, consists of an immunity

test, i. e., a second injection of virulent blood, after the subsidence of the fever. The immunity test must, of course, be accompanied by the injection of a similar quantity of the same blood into a normal monkey, as a control to the virulence of the material. Thus, six monkeys (Nos. 3, 7, 9, 11, 24, and 25) which exhibited a distinct course of fever following their first inoculation, and all of which were seriously ill, showed no febrile response, or other signs of illness, when the second inoculations, or the immunity tests, were given. They received their immunity tests in three groups at different times, and in all five normal controls were used for each group. Five cc. of human virus were injected into each member of one of the groups, and 4 c.c. into each of the other two. The controls in each case developed a course of fever similar to that already described.¹

The degree of susceptibility of the monkey is another important consideration, and, if it is low, experiments on insect transmission might be rendered difficult or impossible. It will be recalled that Nicolle failed entirely in his attempts to infect the macacus with the Old-World typhus by the direct injection of human blood; he succeeded only by first infecting the chimpanzee and then transferring blood from the latter to the macacus. After the macacus was once infected, he attempted to maintain the disease in this species by passage, but the virus apparently underwent a rapid loss in virulence, and the infection "died out" after two or three passages.

It seems also that Anderson and Goldberger had a similar experience in trying to maintain Mexican typhus in the macacus.

We, also, have made two attempts to keep the disease alive by passage. In one instance, the second monkey (No. 11) became infected, whereas the third (No. 22) showed no fever. In the second instance the second animal (No. 9) exhibited only an indefinite fever, and further passage was not attempted.

There was, therefore, sufficient reason to suspect that the macacus might not be sufficiently susceptible for satisfactory work on insect transmission. Information of at least suggestive value regarding this question might be obtained by determining the minimum infective dose of human blood for the monkey. Although it appeared inadvisable on account of the cost, to investigate this point extensively, one experiment was performed in which one animal (No. 25) received 1 c.c. of virulent human blood, and another 0.2 c.c. of the same material. After the lapse of an incubation period of ten days, the former developed a severe course of fever of ten days' duration, and showed no reaction to a second injection which was given a month later. The animal which received 0.2 c.c. had no fever and showed no signs of illness. Although the immunity test of the latter remains to be given, it is probable that the minimum infected dose in this instance lay between 0.2 c.c. and 1 c.c.

The question arises, however, as to whether the monkey may undergo a mild type of infection, which might be accompanied by little or no fever, and which would be recognizable only from the fact that the mild or "abortive" attack had established immunity to a subsequent injection of virulent blood.

The possibility of such an occurrence is well known. We have observed it a number of times in experiments with spotted fever on the guinea-pig. We have, furthermore, one instance of a very mild and scarcely percep-

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1. THE JOURNAL A. M. A., Feb. 5, 1910, p. 463.
2. Anderson and Goldberger: Pub. Health. Rep., Feb. 18, 1910.

tible infection with typhus in the second attempt at passage referred to above.

Monkey 4, which was infected with virulent human serum, and whose history was given in a previous paper,¹ was bled from heart on its second day of fever and 5 c.c. of the blood were injected intraperitoneally into No. 9, which showed on successive days the temperature given in Table 1:

TABLE 1.—TEMPERATURE OF MONKEY 9 AFTER INTRA-PERITONEAL INJECTION OF INFECTED BLOOD

	A. M.		P. M.	
	F.	C.	F.	C.
January 19	103.6	39.8	102.6	39.2
January 20	102.5	39.2	103.4	39.6
January 21	101.8	38.8	103.1	39.5
January 22	103.2	39.5	103.9	39.9
January 23	102.3	39.1	102.8	39.3
January 24	102.0	38.9	102.5	39.2
January 25	101.6	38.6	102.6	39.2
January 26	102.0	38.9	103.6	39.8
January 27	102.0	38.9	103.2	39.5
January 28	101.0	38.3	102.4	39.1
January 29	102.7	39.3	104.3	40.2
January 30	102.9	39.4	102.0	38.9
January 31	101.8	38.8	103.1	39.5
February 1	102.9	39.4	103.4	39.7
February 2	102.7	39.3	103.2	39.5
February 3	104.0	40.0	104.8	40.4
February 4	104.0	40.0	104.4	40.2
February 5	103.9	39.9	103.9	39.9
February 6	103.1	39.5	103.6	39.8
February 7	101.8	38.8	103.3	39.6
February 8	.....	.....	103.0	39.4
February 9	101.0	38.3	102.8	39.3

Below 103 for two weeks thereafter.

Not until the sixteenth day after inoculation did the temperature rise above a possible normal (for this individual), remaining somewhat elevated for only three or four days. A positive diagnosis of infection with typhus could not be made under these conditions; yet, when an immunity test was given (February 18) the temperature did not rise higher than 103 during the twenty-six days it was under observation. The control (No. 18) exhibited, on the other hand, a severe course of fever.

Hence, as a consequence of this experiment, and from the experience with spotted fever, it seemed not unreasonable to anticipate that the monkey might suffer from mild infections with typhus, not manifested by marked elevation of the temperature or by distinct signs of illness, but the occurrence of which might be determined later by means of immunity tests. This we believe, is what happened in our attempts to transmit the disease by means of the louse, as will appear below.

The point may also be raised as to whether some of our monkeys may have acquired typhus by contagion, or by means of their own lice from other monkeys which had been infected deliberately, thus vitiating later experiments. Although the evidence is entirely against typhus being contagious, we protected our experiments, (by first killing the lice on the monkeys by means of insect powder, petroleum and scrubbing with green soap; and furthermore, by the practice of keeping a healthy monkey in the same cage with an infected animal in order to test the question of contagiousness. Two monkeys which were thus exposed (Nos. 18 and 20) proved susceptible to later inoculation, the result tending to disprove contagiousness.

Comparatively large numbers of lice were used in each experiment, because of the supposed low susceptibility of the monkey. This condition lays the experiments open to the objection that the transmission might be purely mechanical, and may not, on this account, reproduce the natural conditions. The natural method, however, is still unknown, and may indeed be of a mechanical nature rather than the so-called "biologic." If sixty lice are able to infect a monkey mechanically, a smaller number may infect man, provided the latter is more susceptible. Protocols follow.

TRANSMISSION OF TYPHUS FROM MAN TO THE MONKEY BY MEANS OF PEDICULUS VESTAMENTI

Group 3, *Pediculus vestamenti*, was infected as follows: January 5, they fed for thirty minutes on E. S., on the tenth or eleventh day of his sickness; January 6, on J. V., tenth day of sickness; January 7, on C. A., ninth day of sickness; January 8, on the same patient.

On January 9, 45 lice were alive and 40 fed on Monkey 1 for about an hour; January 10, 334 were alive and 23 fed on the monkey; January 11, they were not fed; January 12, 19 fed; January 13, 13 fed; January 14, 11 fed; January 15, 9 fed. The feedings were not carried further.

The temperature of the monkey on successive days was as shown in Table 2:

TABLE 2.—TEMPERATURE OF MONKEY 1 AFTER BEING BITTEN BY INFECTED LICE

	A. M.		P. M.	
	F.	C.	F.	C.
January 9	100.4	38.0	.....	.....
January 11	102.8	39.3	104.6	40.3
January 12	98.6	37.0	101.2	38.4
January 13	99.2	37.3	102.9	39.4
January 14	99.4	37.4	99.9	37.7
January 15	101.2	38.4	101.7	38.7
January 16	100.8	38.2	100.2	37.9
January 17	99.0	37.2	103.6	39.8
January 18	100.6	38.1	102.9	39.4
January 19	100.6	38.1	102.0	38.9
January 20	99.1	37.3	103.2	39.5
January 21	98.9	37.2	103.2	39.5
January 22	101.2	38.4	103.2	39.5
January 23	99.7	37.6	102.6	39.2
January 24	100.9	38.3	102.1	39.0
January 25	99.4	37.4	102.6	39.2
January 26	98.5	37.5	103.3	39.6

Did not rise above 102.4 F. thereafter.

It will be noted that in the afternoons of January 17, 20, 21 and 22, the temperature lay between 103.2 and 103.6, the first rise being eight days after the lice began to feed, or having the 20th in mind, the interval was ten days. Inasmuch as the animal's temperature was constantly below 102.5 for a period of thirty-one days later, it is not improbable that the slight elevation referred to represented a mild infection, although no other signs were apparent.

The belief that the animal had suffered from typhus was corroborated by an immunity test consisting of 7 c.c. of defibrinated blood from Patient 27, given February 8. For nineteen days thereafter, the morning temperature lay between 99.0 and 102.0, and in the afternoon between 101.5 and 102.8. This immunity test was controlled by inoculations of 4 c.c. of the same blood² into No. 3, and 1 c.c. into No. 25.

No. 3, after an incubation period of seven days, and No. 25 of nine days, developed fever, which in both animals lasted for ten days, going as high as 106 in the former, and 106.8 in the latter.

The immunity of No. 1 was again tested a month later, March 11, with the same result, whereas Control 20, after an incubation period of five or six days, passed through the usual course of high fever. The first immunity test, however, is the one which indicates, and it would seem conclusively, that No. 1 was infected by the lice.

TRANSMISSION FROM MONKEY TO MONKEY BY MEANS OF THE LOUSE

Monkey 7 was infected by the injection of blood from man, as described in our first paper.¹

Group 5, *Pediculus vestamenti*, was infected by three feedings on Monkey 7, on the sixth, seventh and eighth days of its fever. Thereafter, the lice were fed for eight successive days on Monkey 12, their number gradually decreasing from eighty-one on the first day to nine on the last day of feeding.

The temperature of No. 12 was irregular and rather high prior to the experiment, although the animal was active and well nourished.

Its temperature continued as in Table 3:

3. No. 3 had been injected previously with filtered serum, without becoming infected; hence this injection constitutes an immunity test for No. 3.

TABLE 3.—TEMPERATURE OF MONKEY 12 AFTER BEING BITTEN BY INFECTED LICE

	—A. M.—		—P. M.—	
	F.	C.	F.	C.
January 23	.....	.....	103.2	39.5
January 24	.....	.....	103.6	39.8
January 25	103.4	39.7	103.4	39.7
January 26	103.6	39.8	103.9	39.9
January 27	102.7	39.3	104.3	40.2
January 28	102.6	39.2	103.2	39.5
January 29	102.9	39.4	101.9	38.8
January 30	104.2	40.1	103.0	39.4
January 31	103.3	39.6	104.2	40.1
February 1	103.0	39.4	104.0	40.0
February 2	102.7	39.3	103.6	39.8
February 3	103.7	39.8	103.4	39.7
February 4	103.7	39.8	103.3	39.6
February 5	103.6	39.8	104.0	40.0
February 6	103.4	39.7	103.5	39.7
February 7	102.1	38.9	103.7	39.8
February 8	.....	.....	103.7	39.8

A definite course of fever cannot be made out positively. If present, it would appear to lie between January 30 and February 5 or 6, a period of seven or eight days, and the incubation period would be seven or eight days. On February 2, the animal was manifestly ill, in contrast to its former active condition, and this condition continued for four or five days. On February 9, however, it was again active and appeared well. At this time an immunity test was given; the temperature is given in Table 4:

TABLE 4.—TEMPERATURE OF MONKEY 12 AFTER IMMUNITY TEST

	—A. M.—		—P. M.—	
	F.	C.	F.	C.
February 9	103.9	39.9	103.9	39.9
February 10	102.5	39.2	103.9	39.9
February 11	103.3	39.6	103.9	39.9
February 12	103.1	39.5	103.7	39.8
February 13	102.9	39.4	103.4	39.7
February 13	102.9	39.4	103.4	39.7
February 15	102.7	39.3	104.3	40.2
February 16	102.3	39.1	104.4	40.2
February 17	102.9	39.4	103.5	39.7
February 18	103.2	39.5	103.5	39.7
February 19	103.2	39.5	104.1	40.1
February 20	101.9	38.8	103.7	39.7
February 21	102.9	39.4	103.6	39.7
February 22	102.6	39.2	102.8	39.3
February 23	102.4	39.1	102.9	39.4
February 24	101.1	38.3	103.2	39.5
February 25	102.9	39.3	102.4	39.1
February 26	102.4	39.1	103.7	39.7
February 27	102.4	39.1	102.6	39.2

Continued similarly for twelve days more.

The controls were Nos. 3, 24 and 25, already cited. A second immunity test resulted in the same way. No. 20 (see above) being the control. During neither of the immunity tests did the animal show any sign of illness.

No. 25 is a particularly good control for No. 12, since, like the latter, its temperature was naturally high and irregular. The course of fever was as shown in Table 5:

TABLE 5.—TEMPERATURE OF MONKEY 25, CONTROL OF NO. 12

	—A. M.—		—P. M.—	
	F.	C.	F.	C.
February 9	103.9	40.	104.4	40.2
February 10	104.0	40.	104.0	40.0
February 11	103.3	39.6	104.1	40.1
February 12	103.9	40.	103.2	39.6
February 13	103.5	39.7	103.6	39.8
February 14	102.5	39.2	103.3	39.6
February 15	100.9	38.3	103.9	40.0
February 16	103.4	39.7	103.9	40.0
February 17	102.3	39.1	103.2	39.6
February 18	102.5	39.2	105.2	40.7
February 19	104.6	40.3	105.5	40.8
February 20	103.7	39.8	104.4	40.2
February 21	104.4	40.2	104.4	40.2
February 22	104.2	40.1	104.7	40.4
February 23	106.3	41.3	106.8	41.5
February 24	106.2	41.2	105.8	41.0
February 25	104.6	40.3	104.5	40.3
February 26	105.8	41.0	104.2	40.1
February 27	103.6	39.8	103.2	39.5
February 28	101.6	38.7	102.9	39.4

Continuing as before the fever appeared.

In our opinion, the result justifies the conclusion that No. 12 was infected by the lice of Group 5.

INFECTION OF THE MONKEY BY INTRODUCING INTESTINAL CONTENTS OF LICE INTO SCARIFICATIONS

A first experiment, which consisted of the subcutaneous injection of the intestinal contents of infected lice, resulted in death in less than twenty-four hours, from septicemia.

A second experiment was performed as follows: As the lice of Group 5 were feeding on Monkey 12, a small quantity of feces was collected from a number of the lice as it was extruded, and placed in a sterile test-glass. To this material the abdominal contents of three lice were added and the mass was triturated in sterile salt solution. This was done three days after the last feeding of the lice on the infected Monkey 7.

Twelve small incisions, each less than one-eighth inch in length, and extending through the entire depth of the skin, were made in the abdominal skin on Monkey 13. The emulsion of feces and abdominal contents was then instilled into these incisions, which thereafter were massaged by means of a sterile probe. The incisions healed promptly and without suppuration. The temperature of No. 13 was as shown in Table 6:

TABLE 6.—TEMPERATURE OF MONKEY 13 AFTER INFECTION WITH ABDOMINAL CONTENTS OF INFECTED LICE

	—A. M.—		—P. M.—	
	F.	C.	F.	C.
January 26	102.7	39.3	103.4	39.6
January 27	102.4	39.1	103.6	39.7
January 28	100.3	38.0	102.1	39.0
January 29	102.2	39.0	101.9	38.8
January 30	102.8	39.3	104.0	40.0
January 31	103.3	39.6	103.9	40.0
February 1	103.0	39.4	103.8	39.8
February 2	102.2	39.0	103.8	39.8
February 3	104.4	40.2	102.4	39.1
February 4	103.7	39.8	103.0	39.4
February 5	102.4	39.1	103.1	39.5
February 6	101.8	38.7	102.1	39.0
February 7	102.0	38.8	103.0	39.4

As appears in the table, the temperature rose on the fifth day after inoculation and remained above the normal for this animal for five or six days. During this period the animal became passive and was not inclined to run about, although it was not seriously ill at any time.

As a consequence of an immunity test given on February 9, the animal showed no febrile reaction whatever and appeared perfectly well, whereas the controls (Nos. 3, 24 and 25) reacted with severe fever, as stated above. A second immunity test, given a month later, gave the same results, the control in this instance being No. 20 (see above).

In our judgment, this experiment proves the existence of the virus of typhus fever in the abdominal contents of the louse for at least three days after feeding on infected blood.

SUMMARY AND CONCLUSIONS

1. It seems that *Macacus rhesus* can be infected with tabardillo invariably by the injection of virulent blood from man taken on the eighth to tenth day of fever. The blood should be diluted with salt solution, as stated previously.

2. Attempts to maintain typhus in the monkey by passage through other monkeys were not successful.

3. The monkey may pass through an attack of typhus so mild that it cannot be recognized clinically. Vaccination results.

4. The immunity test is a reliable proof of the previous occurrence or non-occurrence of typhus at least within a period of one month.

5. Typhus was transmitted to the monkey by the bite of the louse in two experiments, the lice in one instance deriving their infection from man and in another from the monkey.

6. Another monkey was infected by typhus through the introduction of the feces and abdominal contents of infected lice into small incisions.

Other experiments, in which the immunity tests have not yet been given, corroborate the carrying power of the louse.

As to whether these experiments on transmission are to be considered merely as substantiating that of Nicolle, or whether they should be regarded as new observations, will depend on the identity or non-identity of tabardillo with the Old World typhus. If *Macacus rhesus* is susceptible to the direct injection of blood from patients suffering from tabardillo, and not to the injection of the blood of the Old-World typhus, the two diseases in our judgment cannot be regarded as identical, although they may be closely related. As stated in a previous paper, Nicolle was unable to infect the macacus directly with human blood, but succeeded first in infecting the chimpanzee and then the macacus by the injection of blood from the chimpanzee. Nicolle's result, if it is to be regarded as final, when compared with ours and with those of Anderson and Goldberger, seem to indicate non-identity of the disease in the two localities.

It would seem that Nicolle's work, at least in this regard, demands repetition. Possibly, also, the point may be elucidated further by determining whether an attack of Old-World typhus confers immunity to tabardillo.

We are greatly indebted to Director Gaviño of the Bacteriologic Institute, to his assistant, Dr. Girard, to their superiors of the Department of Public Instruction, to the authorities of the General Hospital of the City of Mexico in particular to Dr. Escalona, for their numerous courtesies and cooperation.

A PRELIMINARY REPORT OF THE PEDIATRIC
DEPARTMENT OF AN OUTDOOR
MATERNITY CLINIC

ALSO A PLAN BY WHICH INFANT MORTALITY MAY BE
REDUCED IN LARGE CITIES *

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The outdoor maternity service mentioned in the title of this paper is one conducted by Dr. I. L. Hill in New York City for the past nine years. By means of graduates and undergraduates who desire experience in obstetrics, six to seven hundred women are treated during childbirth in their tenement homes in the course of a year. In November, 1908, I organized a pediatric department to this outdoor maternity service, a novelty in this country.

As soon as the mother applies for aid a social worker calls at her home and obtains on a special card exact data concerning the age, nationalities of parents, previous pregnancies, premature deliveries, miscarriages, causes of death of these children, parents' occupation, total earnings of family, rent paid per month, housing conditions, number of people per room, boarders, cleanliness, amount of food, knowledge of infant hygiene, general intelligence, willingness to cooperate, mother's general condition, etc. Should these notes show that the woman required medical care, this is obtained for her. If other conditions are present, she is referred to the various charities, so as to put her in the best possible condition for the child birth.

As soon as the child is born a trained nurse is sent to the house and instructs the mother in the principles of infant hygiene. The child is seen every day until it is taking the breast properly. The nurses are impressed with this, for it is our aim to supply that link in the chain which is missing in other institutions that we know of, namely, to get the care of the child before its birth and from its birth, to be sure that it is nursing well or to find the reason why it is not.

The first day the child is taken into the street it is brought to the clinic, and this clinic visit is repeated once a month until the child is a year old. We realize that this time limit is rather short, but we also know that the first half-year is the most important and needs absolute follow-up work. Every child is seen once a month somewhere, either on the street, in its home, or at the clinic. In order to do this the children are indexed as to names in a book where the months of the year are ruled off in perpendicular parallel columns. Each time a child is seen a mark is made opposite its name. At the end of the month every child must have had its present mark in evidence, or the parents are written to or called on. The only way we lose track of our cases in this great city is by being unable, in spite of all possible detective work, to find out the new address. Thus we have taken care of 784 children; 100 we have lost track of, and 38 have died. The average attendance at the clinic was 14; largest number, 40; attendance during the year, 2,042. During July, August and September, 1,872 house visits were made. The cost of this work, including rent, salaries of three nurses and one social worker, gas, telephone, etc., was \$350 per month, or about \$4,000 per year. Much interesting data as to infant mortality and sociologic conditions have been gathered during the progress of the work, which will be published elsewhere *in extenso*.

One of the main objects of this work is the propaganda of breast feeding, which, to our minds, is the most important element in the reduction of infant mortality. The changes in the sociologic conditions, which must not be underestimated, are but a means to this end. Statistics of breast feeding, both as to the number of children on the breast and the duration of this manner of feeding, are entirely lacking in America. There are many methods by which this information has been obtained more or less completely—by questioning physicians, midwives, at public vaccinations, in clinics, and in the census taking. The most reliable method is to follow each child individually and, as it becomes a bottle baby, put it in that class. The following is a table which we have been able to compile, showing the number and length of time our babies have been breast babies:

Number of Infants.	Time Observed Months.	Number on the Breast.	Percentage.
641	1	616	96
532	2	486	91.3
472	3	423	89.6
387	4	331	85.5
309	5	250	80.9
258	6	196	75.9
181	7	123	67.9
138	8	95	68.9
92	9	60	65

From this it will be seen that of our babies observed for five months 80 per cent. were on the breast, which is up to the critical period of their lives. One might here sound a warning to all charitable institutions, hospitals and dispensaries, that have to do with the distribution of

* Abstract of an address before the Section on Hygiene and Public Health of the Academy of Medicine, New York City, Dec. 14, 1909.