

means of the bite of the body louse from man to monkey and from monkey to monkey. They also reported the successful transmission of typhus virus to the monkey by introducing into scarification of the skin the abdominal contents of some infected lice. They note the interesting observation that, as a rule, in their louse experiments the monkeys had no very significant temperature reaction and the proof of infection was dependent upon immunity tests with virulent blood.

In July, 1911, Wilder<sup>1</sup> reported additional experiments on infection of monkeys with body lice by biting and intradermal inoculation.

In January, 1911, Nicolle and Conseil,<sup>2</sup> continuing their work of September, 1909, report further successful experiments on the transmission of typhus fever to the bonnet monkey by means of the bite of infected body lice.

#### EXPERIMENTAL.

##### Body lice (*Pediculus vestimentis*).

The first experiments we wish to report were made with body lice. *Experiment No. 1.*—A number of body lice were collected from the clothes of healthy persons and on the afternoon of October 18, 1911, were applied to the belly of rhesus No. 158. They were again allowed to feed on No. 158 in the morning and afternoon of October 19, and again in the morning of October 20. In the afternoon of October 21 and thereafter twice daily up to and including October 22 they were fed on rhesus No. 157. Rhesus No. 157 and No. 158 were both sick at this time with typhus fever (New York virus—Brill's disease). After having fed in diminishing numbers on 5 successive days on sick monkeys the lice were applied to a fresh monkey, rhesus No. 127, in the morning and afternoon of October 23 and twice daily thereafter up to and including October 29, when feeding was discontinued. At the time 22 of the lice were still alive and were used in experiment No. 2. During the experiment the lice were kept at a temperature of 15° to 18° C.

Rhesus No. 127 was kept under observation for 37 days after the last feeding, when the animal was given an immunity test by inoculation with virulent blood. After 9 days incubation rhesus No. 127 developed typhus fever, indicating that the animal had not been infected by the previous biting of the lice.

*Experiment No. 2.*—The lice used in experiment No. 1 were killed with chloroform vapor on October 30, the day after their last feed on rhesus No. 127. They were then ground in a mortar with salt solution and injected subcutaneously into rhesus No. 137. Forty-three days later, having in the meantime given no evidence of infection with typhus fever, this monkey was given an immunity test consisting of an injection of virulent blood (New York virus). To this it responded after 9 days incubation with a typical attack of typhus fever, showing that the injection of crushed lice killed with chloroform vapor had infected rhesus No. 137 with typhus.

*Experiment No. 3.*—On October 27 about 150 body lice were obtained from the clothes of healthy persons and applied to the

belly of rhesus No. 139 in the afternoon of the same day. Twice daily thereafter up to and including the morning of October 31, they were allowed to feed on rhesus No. 139. In the afternoon of October 31 and in the morning and afternoon of November 1 they fed on rhesus No. 95. Rhesus Nos. 139 and 95 were at this time both sick with typhus, induced by blood inoculation with the New York virus (Brill's disease). From November 2 up to and including November 9 they were fed twice daily on rhesus No. 165, a fresh monkey. When the feedings were discontinued on November 9 only 9 lice remained alive. Throughout this experiment the lice were kept at 15° to 18° C. Chart No. 1 shows the temperature curve of rhesus No. 165 from the first feeding by infected lice on November 2 up to the time of the animal's death. Eleven days after the first and 4 days after the last feeding by infected lice the temperature of rhesus No. 165 began to rise and remained elevated 4 days, when it fell below its normal range. Ten days later the animal apparently had a relapse lasting 3 days. From this time on the animal progressively failed, and death occurred on December 8. At the autopsy no macroscopical changes were noted in any of the organs. An attempt at passage on the first day of what we interpret as typhus fever, with the blood of this animal, using washed corpses, failed.

In spite of the failure at passage (compare experiment No. 7 below), we believe it is permissible to conclude that the rise in temperature of rhesus No. 165, beginning on November 13, was due to infection with typhus (Brill's disease), following the bite of infected lice from 4 to 11 days previously.

*Experiment No. 4.*—On November 2, 6 days after their first and 1 after their last infecting feed, 10 of the lice used in experiment No. 3 were killed with chloroform vapor, ground in a mortar with salt solution, and injected subcutaneously into rhesus No. 145. Having given no evidence of a constitutional reaction, the immunity of this animal was tested 40 days after the injection of the crushed lice by an injection of virulent typhus blood (New York virus). The monkey developed fever after 8 days' incubation, indicating that infection with typhus had not resulted from the subcutaneous injection of crushed lice killed with chloroform vapor.

*Experiment No. 5.*—About 9.30 a. m. on December 3, 83 body lice were mixed, crushed in a mortar, and ground up in saline solution. Of this suspension 3.5 c. c., representing about 35 body lice, was subcutaneously injected into rhesus No. 308 and 1.5 c. c., representing about 15 lice, into rhesus No. 309.

Body lice of group No. 7-M had been allowed to feed daily during the 6 days immediately prior to the date of the experiment on various cases of typhus fever in the Hospital General, Mexico City. They were last applied to case No. 16-M, in the eleventh day of illness, at 10.50 to 11.20 a. m. December 2.

Body lice of group No. 8-M were insects that had been allowed to feed daily during the 5 days immediately preceding the date of the experiment on various cases of typhus fever. They were last applied to case No. 16-M, in the eleventh day of illness, at 10.20 to 10.50 a. m.

<sup>1</sup> Wilder, Russell M.: The problem of the transmission of typhus fever. *Jourm. Invec. Dis.*, vol. 4, 1911, p. 9-10.

<sup>2</sup> Nicolle, Charles, and Conseil, C.: *Etiologie du typhus exanthématique*. Ann. de l'Inst. Pasteur, 25, p. 68-78.



sharp febrile reactions, testifying to the virulence of at least one of the specimens used for their inoculation.

We conclude, therefore, that the febrile reaction beginning November 21 suffered by rhesus No. 306 was due to infection with the typhus virus in the bodies of the head lice with which it was inoculated. Although the typhus virus may retain its virulence in the body of the head louse for at least 20 to 24 hours, as shown in the foregoing experiment, it does not necessarily follow, though strongly suggested, that this louse is capable of transmitting the disease in the normal way, namely, by biting. The following experiments with head lice were made, therefore, to test this point:

*Experiment No. 8.*—On November 16, 1911, at 12 m., 25 head lice of group No. 3 were applied to the shaved belly of rhesus No. 302 and 15 of them fed. At 4:30 p. m. this group of lice was reapplied and again 15 fed. After this the lice were applied to rhesus No. 302 twice daily in rapidly diminishing numbers till November 19, in the afternoon of which date a solitary survivor was given its last feed.

The lice of group No. 3-M were head lice collected from the heads of 3 typhus patients (cases 6-M, 7-M, and 8-M) in the afternoon of November 15, at the time of their admission to the typhus ward of the Hospital General, Mexico City. From the time they were collected these insects were kept at room temperature (about 14° to 22° C.).

In addition to the foregoing rhesus No. 302 was subjected to the bites of two lice constituting group No. 4-M in the forenoon and afternoon of November 18. Thereafter, twice daily, a single survivor of this group was applied until the morning of November 22, when this insect obtained its final feed. The two lice constituting group No. 4-M were obtained from the hair of the head of case No. 9-M at about 3 p. m. of November 17 on admission to the typhus ward. Two hours later they were reapplied to this patient and he fed. Following this they were kept at room temperature (about 14° to 22° C.).

During a period of observation of 30 days subsequent to the inoculation by the bite of the survivor of lice group No. 4-M rhesus No. 302 gave no appreciable reaction. On December 22, or 32 days after being last bitten, this monkey was subjected to an immunity test by receiving an intraperitoneal injection of 4.5 c. c. of defibrinated blood of case No. 26-M, diluted with an equal volume of normal saline solution. At the same time and with some of the same blood monkeys Nos. 314, 315, and 316 were similarly inoculated. Nos. 314 and 316 each receiving 4.5 c. c. and No. 315, 5 c. c., likewise diluted with equal volumes of saline solution. Of these 4 animals No. 302 was much the smallest, No. 315 very much the largest, while Nos. 314 and 316 were intermediate in size between Nos. 302 and 315. It follows therefore, that although Nos. 314 and 316 received the same amount of blood as No. 302 and No. 315 about 0.5 c. c. more, rhesus No. 302 actually received a relatively larger dose. Nevertheless, rhesus No. 302 is the only one of the 4 animals that failed to give any evidence of a reaction (see charts Nos. 3, 4, 5, and 6). Rhesus No. 314 gave a prompt and well-marked reaction. This animal, it will be recalled, was previously used for the unsuccessful attempt at passage of typhus No. 306. Rhesus No. 315 presented a well-defined but feeble reaction, while No. 316 gave indications of a brief abortive reaction,

that was at its height (40° C.) on the tenth day after inoculation. Both these animals had been subjected to a previous inoculation with typhus fever blood, each having received an intravenous inoculation of 2.5 c. c. of defibrinated blood from a patient (case No. 16-M) on the eleventh day of a sharp attack and when the fever was already falling.

The foregoing test would indicate, therefore, that rhesus No. 302 had developed a resistance to infection with virulent typhus blood as the result of having been bitten by head lice of groups Nos. 3-M and 4-M.

On account of the importance of the question involved it was thought desirable to give rhesus No. 302 a second immunity test. Accordingly on February 1, having been returned to the Hygienic Laboratory, he was given an intravenous injection of 2.5 c. c. of typhus blood (New York virus). At the same time rhesus Nos. 315 and 316 that had served as controls in the previous test were similarly inoculated. Following this inoculation none of these animals gave any appreciable evidence of reaction, although two other monkeys, Nos. 198 and 322, inoculated at the same time, reacted promptly and sharply, testifying to the virulence of the blood used for the test. The result of this test is in harmony with and confirms the result of the previous one and therefore strengthens the conclusion that the resistance of rhesus No. 302 to the immunity test was due to the bites of the head lice to which he was previously subjected.

*Experiment No. 9.*—Shortly after the lice-feedings on rhesus No. 302 had terminated, a series of feedings with lice of group No. 5-M and group No. 6-M were begun on rhesus No. 304. The lice constituting these groups were obtained from the hair clipped from the scalp of case No. 11-M and of case No. 12-M November 20, 1911, on admission to the typhus ward. One portion of these lice (group No. 5-M) was applied about 24 hours later to rhesus No. 304, 54 of the insects feeding. Thereafter they were applied daily in rapidly diminishing numbers until the morning of November 26, when a single survivor was given its last feed.

Another portion, 18 in all, of the head lice from cases No. 11-M and No. 12-M (group No. 6-M) were reapplied to case No. 11-M on November 21, or about 24 hours after they were isolated. On the succeeding day they were applied to the monkey and thereafter were applied twice daily in diminishing numbers until the afternoon of November 26, when a single survivor of the group obtained its last feed. Throughout the experiment the lice were kept at room temperature (about 14° to 24° C.). During a period of observation of 32 days following the last exposure to the bites of groups Nos. 5-M and 6-M this animal gave no indication of a reaction. On December 29, or 33 days after the last exposure, this animal was given an intraperitoneal injection of 6 c. c. of defibrinated blood of case No. 35-M diluted with an equal volume of saline solution. Three days later rhesus No. 304 received an additional intraperitoneal injection of 4 c. c. of defibrinated blood from Case No. 39-M, also diluted with an equal volume of saline solution. Following this inoculation the animal very promptly developed a sharp reaction of 10 to 11 days' duration. The result of this immunity test indicates that the repeated bites of the head lice of groups Nos. 5-M and 6-M failed to confer any resistance to a subsequent inoculation with virulent typhus blood.



(b) Two attempts to transmit typhus fever (New York virus) to monkey by means of subcutaneous injections of suspensions of chloroformized and crushed lice resulted negatively.

(c) In one of two attempts to transmit typhus fever (Mexican virus) from man to monkey by means of subcutaneous injection of saline suspension of crushed body lice, the monkey so inoculated resisted two subsequent inoculations with virulent typhus blood (New York virus).

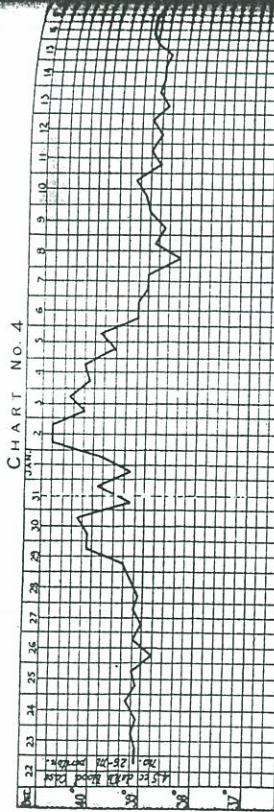


CHART No. 4.—Temperature curve of rhesus No. 314 following immunity test; control on rhesus No. 314.

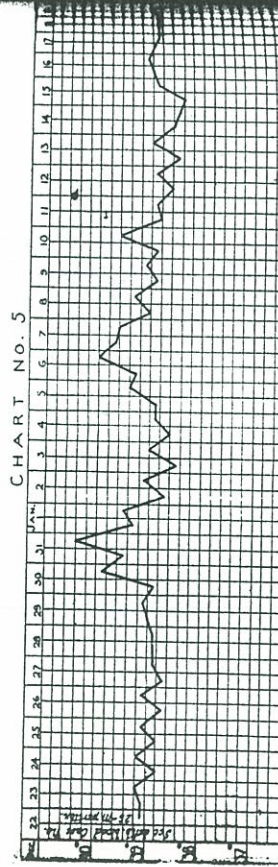


CHART No. 5.—Temperature curve of rhesus No. 315 following immunity test; control on rhesus No. 315.

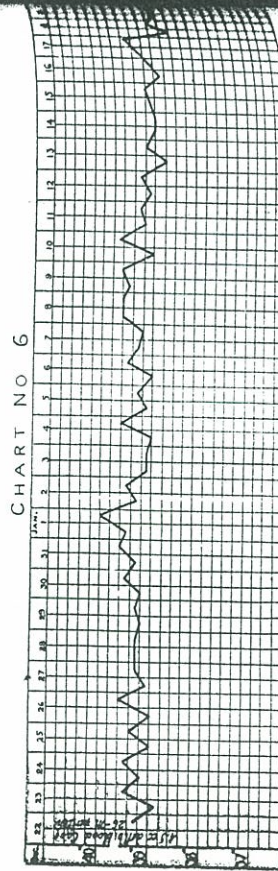


CHART No. 6.—Temperature curve of rhesus No. 316 following immunity test; control on rhesus No. 316.

The foregoing results are in harmony with and confirm those reported by previous workers.

II.

In this paper we present the first evidence incriminating an insect other than the body louse as an intermediary in the transmission of typhus fever:

(a) In an attempt to transmit typhus fever (Mexican virus) from man to monkey by subcutaneous injection of a saline suspension

crushed head lice (*Pediculus capitis*), the monkey developed a febrile reaction with subsequent resistance to an inoculation of virulent typhus (Mexican) blood.

(b) In one of three experiments to transmit typhus fever (Mexican) from man to monkey by means of the bite of the head louse (*Pediculus capitis*), the animal bitten by the presumably infected head louse proved resistant to two successive immunity tests with virulent typhus blood.

CONCLUSIONS.

1. The body louse (*Pediculus vestimentis*) may become infected with typhus. The virus is contained in the body of the infected louse and is transmissible by subcutaneous injection of the crushed insect or by its bite.

2. The head louse (*Pediculus capitis*) may become infected with typhus. The virus is contained in the body of the infected louse and may be transmitted by subcutaneous injection of the crushed insect and, we believe, also by its bite.

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SCHOOL CLOSURE IN THE CONTROL OF EPIDEMICS OF MEASLES.

The control of outbreaks of measles has usually been found difficult. This has been so to such an extent that in many cities no attempt at control is made. Under these circumstances the disease very probably subsides only after it has attacked a considerable proportion of the susceptible children and remains in a state of relative inactivity until a sufficient number of other children reach an age when their relation to the community life makes them available material for a new epidemic.

Studies of outbreaks of measles and of the effect of measures aimed at their control are of special interest to municipal health authorities. Dr. Raffle, school medical officer of South Shields, England, reported in the *Lancet* (London) of February 3, 1912, an outbreak of measles in which the closing of the schools seemed to have a decided limiting effect on the spread of the infection. The following is the report:

SCHOOL CLOSURE IN MEASLES.

To those working on the preventive side of medicine school closure as a means of controlling epidemics is always an interesting question. Opinions differ as to its efficacy even amongst medical men, and the present article is an account of how it