

LXXX. OBSERVATIONS ON THE LENGTH OF TIME THAT FLEAS (*CERATOPHYLLUS FASCIATUS*) CARRYING *BACILLUS PESTIS* IN THEIR ALIMENTARY CANALS ARE ABLE TO SURVIVE IN THE ABSENCE OF A HOST AND RETAIN THE POWER TO RE-INFECT WITH PLAGUE.

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VERJBITZKI (1904) records the period for which he found fleas able to carry the bacilli and re-infect as three days.

The Commission for the Investigation of Plague in India (1906) found that in their experimental godowns, infection conveyed by fleas might take place 21 days after the flea population had had any opportunity of imbibing infected blood.

Bacot and Martin (1914) found that infected fleas which were regularly fed might live for 50 days at 10° C. to 15° C. and 23 days at 27° C. and remain infected at death.

*Methods employed in the following Experiment.*

Cages similar to those used in the Indian investigation (see Report, 1906, *Journal of Hygiene*, Vol. VI. p. 435) and also by Bacot and Martin (Report LXVII, p. 429, Plate XXIV, fig. 2, Plague Supplement, *Journal of Hygiene*, 1914), after sterilization, were prepared for the reception of mice and then stocked with 100 to 300 fleas (*Ceratophyllus fasciatus*) which had been infected by allowing them, when hungry, to feed on pest-infected mice that were in the comatose condition that immediately precedes death<sup>1</sup>. By delaying the fleas' opportunity to feed until this

<sup>1</sup> Three attempts were made to infect fleas (*Ceratophyllus fasciatus* and *Xenopsylla cheopis*), which had not fed previously, on mice that had already died of pest. In two of the three cases the fleas were placed with the mouse within an hour after its death. Subsequent dissection and the examination of stomach smears revealed neither blood nor lymph, nor was there any trace of bacilli, although in each instance the heart blood of the mouse showed a heavy septicaemia. Bugs (*Cimex lectularius*), which were tried at the same time, also gave a negative result as regards the presence of bacteria, but it is not possible to state definitely that they did not obtain any fluid at all from the bodies, owing to the fact that the gut of bugs which have been starved for considerable periods generally contains some remnants of a previous meal.

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acute stage of the disease it was found possible to infect a much higher percentage than was otherwise possible. Samples of each batch were dissected and smears made from their stomachs showed on microscopic examination that from 65 % to 80 % of the sample fleas carried *B. pestis*.

After stocking the cages they were tested by placing two or three healthy mice in each. In all but two of the cases (Nos. 1 and 8) these mice died of typical pest. In the great majority of cases one or both of the glands on the groin were infected, less frequently one or both of the axillary glands were also involved, and, in very few cases, the axillary glands only were infected.

The spleen was in every case infected, usually heavily, and blood from the heart always showed some bacilli, the degree of septicaemia being generally marked.

As regards cages Nos. 1 and 8, no infection occurred within the usual period of three to five days, and the mice were removed and killed under ether. After the animals (dead or living) had been removed, the cages were covered with waxed cloth in order to check drying as far as possible, and then stored in a cool situation—the temperature varying from 35° F. to 60° F. with a mean of about 45° F. or 47° F.

When the desired period had elapsed the waxed cloth cover was removed and two healthy mice added to each cage.

The following table shows that cages Nos. 2, 3 and 8 remained infective for 29, 34 and 47 days respectively.

No. of Cage	Result of Preliminary Test	Period for which the Cages were stored without any host for the Fleas	Result
1	Mice not infected	18 days	—
2	4 mice died of pest	29 "	2 mice died of pest, 1 within 4 and 1 within 5 days
3	3 " "	34 "	1 mouse died of pest within 3 days
4	3 " "	35 "	—
5	3 " "	39 "	—
6	3 " "	45 "	—
7	3 " "	45 "	—
8	Mice not infected	47 "	1 mouse died of pest within 24 days
9	3 mice died of pest	59 "	—
10	1 mouse died of pest	68 "	—
11	1 rat and 1 mouse died of pest	73 "	—

In cages Nos. 2 and 3 it will be noted that the fleas had an opportunity of ingesting infected blood after the initial meal which infected them, but in cage No. 8 the only chance of feeding afforded them after the infecting meal was on healthy mice, which showed no signs of infection up to the time of their removal from the cage. The infection of the mice in cages 2 and 3 must have taken place within a few hours, at most, of the animals being placed in the cages after a lapse of 29 and 34 days respectively. In cage No. 8, however, there must have been an interval of about 20 days before the mouse was infected by the fleas in the cage. The records of the preliminary tests of the cages used in these experiments show that the period between the ingestion of bacilli by the fleas and the infection of a new host may be as short as three days—more usually it is longer, seven, nine or 12 days. It is of some interest to note in this connection that a period of latency in the development of plague among rats on shipping has been noticed by Dr C. Oswald Stallybrass, who, in writing me commenting on the subject, supplies the following instances: "Two cases have been brought to my notice within a month. One, a vessel from River Plate on which a small number of recently dead rats were found about five weeks after it had left the River Plate. In the second, the ship had probably been infected not later than the 29th November, while five rats dead of plague were found in one limited portion of the ship on the 15th January—nearly seven weeks later. Two of the rats were recently dead and the other three less than ten days previously. Apart from two rats apparently killed by the dock labourers, no other dead or sick rats were found on the vessel, though 70 were destroyed by fumigation; these on examination proved to be healthy."

#### *Conclusions.*

1. Fleas (*Ceratophyllus fasciatus*) are able to carry *Bacillus pestis* for periods up to 47 days in the absence of any host and subsequently to infect a mouse.
2. That infected fleas, starved for 47 days and then placed upon a mouse, may not infect it for a further period of about 20 days.
3. There is no reason to suppose that the positive results obtained in these few experiments represent the limit of time after which infection may take place, but indicate that plague infection may persist in fleas for one or two months in cool weather and, subsequently, give rise to an epizootic.

REFERENCES.

- BACOT AND MARTIN (1914), Observations on the Mechanism of the Transmission of Plague by Fleas. Plague Supplement III, January 14, 1914, p. 429 and Plate XXIV, fig. 2.
- REPORTS ON PLAGUE INVESTIGATIONS IN INDIA (1906), *Journal of Hygiene*, Vol. VI. p. 435.
- VERJBITZKI (1904), The Part played by Insects in the Epidemiology of Plague. Thesis for M.D., St Petersburg. Republished in *Journal of Hygiene* (1908), Vol. VIII. p. 162.