

XVII. EXPERIMENTS IN PLAGUE HOUSES IN BOMBAY.

(Second Communication.)

In a paper published in the first report (vol. VI. p. 467) we detailed a number of observations which were carried out in plague houses in Bombay and which went to prove that in a plague-infected house the infection is due to the presence therein of infected rat fleas, which were capable of transmitting the disease to animals.

During the epidemic of 1907 we have confirmed and amplified these previous observations.

I. OBSERVATIONS IN CONFIRMATION OF THOSE MADE LAST PLAGUE SEASON.

The houses which were used for these observations were selected with a certain amount of discretion, our object being to ensure that they were really plague infected. In the majority of instances before using the houses for experimental purposes we satisfied ourselves (*a*) that there had been two or more cases of plague in the house, or (*b*) that there had been a single case of plague with a history of dead rats, or (*c*) that a dead rat had been found, but no plague case had occurred. In some instances at the beginning of the observations we were satisfied if a dead rat, which had been proved plague infected at the laboratory, had been found alongside the building in which a plague case had occurred, the presumption being that the rat had been thrown out from the house. It was soon found, however, that such houses seldom or never yielded successful results. They were, therefore, omitted in the later experiments.

The experiments, following the classification made in the first paper, may be conveniently divided into two groups.

GROUP I.

Experiments with Guinea-pigs running free in plague houses.

In the similar experiments of last year already detailed, out of 42 experiments twelve houses (29 %) proved infective for guinea-pigs which had been placed therein, the animals dying of plague within a few days after they had been removed from the house. In practically all these guinea-pigs the situation of the primary bubo was in the cervical region.

In the present series of experiments as a general rule only one guinea-pig was put into each house. It was left in for 18 hours. In all 100 houses were tested in this way. The guinea-pig died of plague in 19 instances, that is to say, 19 % of the houses yielded successful results. The details of the successful experiments are given in Table I. It is to be noted that the distribution of the primary bubo in these animals was as follows:—no bubo, 1: buboes in neck only, 15: buboes in neck and groin, 3: that is to say, in every case which had a bubo the neck glands were affected. The significance of this distribution of the primary bubo has already been dealt with in another paper (p. 382).

The question of the number of fleas taken in these houses will be discussed later on.

Summary and Conclusions.

In 19 out of 100 experiments guinea-pigs allowed to run free in houses which were deemed to be plague infected developed the disease and died.

GROUP II.

In this group of observations, which is made up of two series, fleas obtained in plague houses were fed on guinea-pigs in flea-proof cages in the laboratory. The two series only differ from one another in the manner in which the fleas were obtained.

SERIES I.

Experiments with fleas caught on plague-infected rats found in houses.

In the series of experiments of this nature, which have been already reported, on three occasions, namely, on every occasion on which the experiment was made, fleas transferred from plague-infected rats found

TABLE I.
Experiments with Guinea-pigs running free in houses.

Serial No.	Date	Address	No. of guinea-pigs put in	No. of guinea-pigs caught	No. of guinea-pigs which died of plague	Position of primary bubo	Remarks
1	30. 1. 07	13 Girgaum Road	1	40	1	Double submaxillary, double cervical	2 plague cases : a sick rat had been killed.
2	7. 2. 07	385 Girgaum Road	1	10	1	Left cervical and submaxillary, left inguinal	3 plague cases in house : 1 dead rat in this room : 4 fleas had <i>B. pestis</i> in stomach.
3	7. 2. 07	385 Girgaum Road (Kitchen)	1	38	1	Double submaxillary, double cervical, right inguinal	3 plague cases in house : 3 dead rats were found in this kitchen.
4	21. 2. 07	New Sewri Road	1	18	1	Double cervical	A dead rat had been found in this house.
5	16. 2. 07	B. Sakharani's Shop, Esau Buildings	3	12	1	Double cervical and submaxillary	2 plague cases had occurred amongst the staff.
6	27. 2. 07	5 Victoria Road	1	13	1	Left submaxillary, left cervical	2 plague-infected rats had been found in this room—a godown.
7	27. 2. 07	5 Victoria Road	1	17	1	Double submaxillary and cervical	1 dead rat, proved plague infected, had been found in this room.
8	1. 3. 07	43 Moreland Road	1	55	1	Double submaxillary, left cervical	1 plague case : 2 dead rats had been found in the room.
9	7. 3. 07	5 Victoria Road	1	1	1	Right cervical	1 plague case : a dead rat had been found in the room.
10	11. 3. 07	199 Clerk Road	1	17	1	Right submaxillary, right cervical	1 dead rat had been found in this room.
11	14. 3. 07	65 Sonapur Street	1	66	1	Double cervical, right inguinal	2 plague cases : no dead rats had been found.
12	19. 3. 07	236 Doctor Street	1	20	1	Double submaxillary and cervical	2 plague cases : 2 dead rats found at door of room on 5. 3. 07 : of 20 fleas dissected the stomach contents of one contained plague bacilli.
13	14. 3. 07	104 Sonapur Street	1	137	1	Double submaxillary and cervical	3 plague cases. History of dead rats.
14	25. 3. 07	Superintendent's Bungalow Colaba Asylum	2	3	1	Left cervical	2 dead putrid rats found : fleas dissected and 2 found infected.
15	24. 3. 07	Godown, Jubilee Mills, Sewri	2	6	1	Right cervical	Several dead rats found. 5 plague cases from this godown.
16	1. 4. 07	Colaba Asylum, Clerk's House	1	55	1	Left cervical	1 dead rat found, not examined.
17	25. 3. 07	Colaba Asylum, Superintendent's Bungalow	1	35	1	Nil	1 rat proved plague infected on 24. 3. 07. 1 dead rat (not examined) on 25. 3. 07.
18	1. 4. 07	Colaba Asylum, room in Clerk's House	1	20	1	Double submaxillary and cervical	2 putrid rats found in room on 1. 4. 07.
19	1. 4. 07	Dadysett Agriary	1	14	1	Double submaxillary	1 plague case.

in houses in Bombay were able to transmit the disease to healthy animals in flea-proof cages in the laboratory.

In the present series of experiments, also three in number, an exactly similar result was obtained, that is to say, all the guinea-pigs, to which the fleas were transferred, died of plague. The details of these three experiments are given in Table II. In the first two experiments the rats were sent dead to the laboratory. There the fleas were removed and at once transferred to a guinea-pig, which in each instance died of plague in a few days. The history of the third experiment is instructive. In a commercial office in the Fort two dead rats were found in the corner of a large room. One of these rats was proved to be plague infected at the laboratory. That same evening a guinea-pig was allowed to run free in this corner, being shut off from the rest of the office by means of a low barricade. On visiting the office

TABLE II.

Experiments with fleas caught on plague-infected rats found in houses.

Serial No.	Date	Address	No. of fleas	Animal on which fleas were fed	Result	Position of primary bubo	Remarks
1	20. 2. 07	84, 1st Lane Kamathipura	13	Guinea-pig	Died of plague	Double submaxillary and cervical	Rat was found dead in the house.
2	21. 2. 07	5 Victoria Road	12	Guinea-pig	Died of plague	Left inguinal	Rat was found dead in stable.
3	19. 3. 07	29 Hummum St.	6	Guinea-pig	Died of plague	Double cervical, left sub-maxillary	Rat was found dead in an office at above address.

next morning we found a fresh dead rat lying on the floor outside the barricade underneath the desk of a clerk. On this rat, which was proved to be plague infected at the laboratory, six fleas were taken. These fleas were transferred to a fresh guinea-pig in the laboratory, which animal died of plague. Over the spot on which the rat was found a guinea-pig was allowed to run backwards and forwards for about one minute. It was then chloroformed and searched for fleas, 82 being captured on it. A second guinea-pig was allowed to run over this place for a few minutes: 32 fleas were caught on this second animal. Of these 114 fleas 29 were dissected: in the stomach contents of 17 abundant plague bacilli were found on microscopical examination. The remainder of the fleas were transferred to a fresh guinea-pig in the laboratory, which guinea-pig died of plague in four days. Neither of the guinea-pigs which had been used as traps to catch the fleas developed plague.

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Summary.

On three occasions, namely, on every occasion on which the experiment was made, fleas transferred from plague-infected rats found in houses in Bombay were able to transmit the disease to healthy animals in flea-proof cages in the laboratory.

SERIES 2.

Experiments with fleas caught on guinea-pigs which had been left for some hours in plague houses.

In this series of experiments the fleas caught on guinea-pigs, which had been left in plague houses running about free for about 18 hours, were transferred to fresh guinea-pigs in flea-proof cages in the laboratory.

In the series of experiments of this nature, which was made last year and which has been already reported (vol. VI. p. 475), in 8 out of 40 instances (20%) the animals to which the fleas were transferred died of plague. The situation of the primary bubo in these animals was in the great majority of cases in the cervical region.

In the present series of experiments, fleas captured in the manner mentioned were transferred on 31 occasions to fresh guinea-pigs in the laboratory. 11 of these animals died of plague, namely, 35% of successful transmissions. The details of these cases are given in Table III, from which it is seen that the distribution of the primary bubo was as follows:—neck alone 4 cases, groin alone 2 cases, neck and groin 4 cases, neck and axilla 1 case. Thus the neck glands were affected in 8 out of 11 instances.

Summary.

Rat fleas captured in plague houses are capable of giving plague to fresh guinea-pigs in the laboratory.

II. OBSERVATIONS ON THE NUMBER OF RAT FLEAS CAUGHT IN PLAGUE AND NON-PLAGUE HOUSES IN BOMBAY DURING THE PLAGUE SEASON.

In the course of the observations made last year a count was made of the fleas caught on the guinea-pigs which had been allowed to run free in plague houses (vol. VI. p. 482). In one group of these houses disinfection with perchloride of mercury solution or with the fumes of

TABLE III.

Experiments with fleas caught on Guinea-pigs which had been left for some hours in plague houses.

Serial No.	Date	Address	No. of fleas	Animal on which fleas were fed	Result	Position of primary bubo	Remarks
1	30. 1. 07	13 Girgaum Road	30	Guinea-pig	Died of plague	Right submaxillary and cervical	2 plague cases: a sick rat had been killed.
2	7. 2. 07	385 Girgaum Road	38	"	"	Double submaxillary and cervical, right axillary and cervical	3 plague cases in house, 3 dead rats had been found in the room from which the fleas were got.
3	31. 1. 07	B. Bacteriological Laboratory	20	"	"	Right submaxillary and cervical	A dead plague-infected rat had been found in this room.
4	27. 2. 07	5 Victoria Road	13	"	"	Double submaxillary and cervical	2 dead rats proved plague infected had been found in this room.
5	27. 2. 07	5 Victoria Road	17	"	"	Right submaxillary and cervical, left inguinal	1 dead rat proved plague infected had been found in this room.
6	1. 3. 07	43 Moreland Road	55	"	"	Double inguinal	1 plague case: 2 dead rats had been found in the room.
7	12. 3. 07	29 Hummum Street	29	"	"	Double submaxillary and cervical, double inguinal	2 dead rats had been found in the corner of this office where the guinea-pig was allowed to run free.
8	13. 3. 07	29 Hummum Street	82	"	"	Double inguinal	1 dead rat had been found and the fleas were got from 2 guinea-pigs which were left in this spot for a few minutes.
9	25. 3. 07	Superintendent's Bungalow, Colaba Asylum	35	"	"	Double submaxillary and cervical	1 dead rat proved plague infected and 1 not examined found in room.
10	1. 4. 07	Colaba Asylum (2nd room), Clerk's House	20	"	"	Double submaxillary and right inguinal	2 putrid rats found in this room on 1. 4. 07.
11	1. 4. 07	Colaba Asylum, Clerk's House	55	"	"	Right cervical and left inguinal	1 dead rat found on 1. 4. 07.

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SO₂ had been carried out just before the guinea-pigs were put in. In the case of each of these two groups we can divide the houses into two classes, namely, (a) a class in which the houses were definitely proved by us to be plague infected, either because plague-infected rats had been found in the house or because one or both of the guinea-pigs developed the disease, and (b) a class, made up of the remainder, in which the houses were only presumably plague infected, inasmuch as one or more plague cases had occurred in them. The data concerning the flea census in these two classes of houses are summarised in Table IV. From this table it is seen that the average number of fleas in the houses, which were definitely proved to be plague infected, was about three times greater than in the houses which were only presumably plague infected. The average number of fleas was much larger in the disinfected than in the non-disinfected houses. This was probably due to a few very large counts, rather than to an increase distributed equally over the majority of the counts.

TABLE IV.

Showing data referring to flea census in plague houses in the epidemic of 1906.

	Houses not previously disinfected			Houses previously disinfected		
	No. of houses examined	Total no. of fleas caught	Average no. of fleas per house	No. of houses examined	Total no. of fleas caught	Average no. of fleas per house
Houses definitely proved } plague infected	13	445	34	10	731	73
Houses only presumably } plague infected	29	388	13	21	488	23

During the plague season of 1907 we have obtained further data which show that the average number of fleas in houses which can be definitely proved to be plague infected is greater than in houses which are only presumably infected, and greater in the latter than in houses in which neither plague cases had occurred nor dead rats been found.

The method which was adopted to obtain these data was as follows:—

On being advised of a plague-infected house, which on examination proved satisfactory, a guinea-pig was allowed to run free in it. At the same time a house, in which no plague case had occurred nor dead rats been found, was selected in the same building or in a building of the same type in the immediate neighbourhood. In this house another guinea-pig was set free.

As many houses as obtainable were treated each evening in this way. Next morning the guinea-pigs were chloroformed and searched for fleas. They were then brought back to the laboratory and segregated. The fleas which were caught were in some instances dissected, the contents of the stomach being examined as to the presence or absence of plague bacilli, and in other instances transferred to a fresh guinea-pig in a flea-proof cage. If the number of fleas was large some were dissected and the remainder transferred.

The houses operated on were classified into groups as before.

Group A. Houses deemed plague infected for one or more of the following reasons:—1. A dead plague-infected rat or rats had been found in the house. 2. The guinea-pig which was allowed to run free in the house developed plague and died. 3. Some of the fleas caught on the guinea-pig which was allowed to run free in the house were found on dissection to be plague infected. 4. Fleas caught on the guinea-pig which was allowed to run free in the house gave plague to a healthy guinea-pig, to which they were subsequently transferred.

Group B. Houses presumably plague infected (1) either, because a plague case or cases had occurred in the house, (2) or, because dead rats, which had not been sent for examination, were found in the house.

Group C. Control houses of same type and situated in same neighbourhood.

The results of the flea census in these three groups of houses are set forth in Table V.

TABLE V.

Showing data referring to the flea census in houses classified according as to whether they were plague infected or not.

	Total no. of houses	Total no. of fleas taken	Average no. of fleas taken per house
Group A—namely, houses proved to be plague infected }	27	784	29
Group B—namely, houses not proved to be, but presumably, plague infected }	73	755	10·3
Group C—namely, houses which were not plague infected }	68	169	2·5

Houses which were definitely proved to be plague infected contained on an average nearly three times the number of rat fleas contained in houses which were only presumably plague infected and 12 times the number contained in houses which were free from suspicion. The details

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TABLE VI.

Details of experiments made in houses which were proved plague infected.

Serial No.	Address	No. of fleas taken	Reasons for classifying as plague infected
1	13 Girgaum Road	40	Running free guinea-pig died of plague. Guinea-pig to which fleas were transferred died of plague.
2	385 Girgaum Road (Bedroom)	10	Running free guinea-pig died of plague. 6 fleas dissected, 4 found plague infected.
3	385 Girgaum Road (Kitchen)	38	Running free guinea-pig died of plague. Guinea-pig to which fleas were transferred died of plague.
4	Office in Bombay Bact. Laboratory	20	Dead plague-infected rat found. Guinea-pig to which fleas were transferred died of plague.
5	82—84, 14th Lane, Kama-thipura	18	Dead plague-infected rat found. 16 fleas dissected, 9 found plague infected.
6	159 Queen's Road	11	11 fleas dissected, 2 found plague infected.
7	New Sewri Road	18	Running about guinea-pig died of plague.
8	Shop in Esuf building	12	Running about guinea-pig died of plague.
9	Godown, 5 Victoria Road	13	Dead plague-infected rat found. Running about guinea-pig died of plague. Guinea-pig to which fleas were transferred died of plague.
10	Godown, 5 Victoria Road	17	Dead plague-infected rat found. Running about guinea-pig died of plague. Guinea-pig to which fleas were transferred died of plague.
11	43 Morland Road	55	Running about guinea-pig died of plague. Guinea-pig to which fleas were transferred died of plague.
12	9 Military Square	8	8 fleas dissected, 1 found plague infected.
13	5 Victoria Road	1	Running about guinea-pig died of plague.
14	199 Clerk Road	17	Running about guinea-pig died of plague.
15	29 Hummum Street	29	Dead plague-infected rat found. Guinea-pig to which fleas were transferred died of plague.
16	29 Hummum Street	114	Dead plague-infected rat found. Guinea-pig to which fleas were transferred died of plague. 29 fleas dissected, 17 found plague infected.
17	65 Sonapur Street	66	Running about guinea-pig died of plague.
18	87 Fanaswadi	5	4 fleas dissected, 3 found plague infected.
19	236 Doctor Street	20	Running about guinea-pig died of plague. 20 fleas dissected, 1 found plague infected.
20	104 Sonapur Street	137	Running about guinea-pig died of plague.
21	Asylum, Colaba, Superintendent's Bungalow	3	Running about guinea-pig died of plague. 3 fleas dissected, 2 found plague infected.
22	Asylum, Colaba, Superintendent's Bungalow	35	Dead plague-infected rat found. Running about guinea-pig died of plague. Guinea-pig to which fleas were transferred died of plague.
23	Godown, Jubilee Mills, Sewri	6	Running about guinea-pig died of plague.
24	1 Dadysett Agiary	14	14 fleas dissected, 1 found with abundant <i>B. pestis</i> in stomach contents. Running about guinea-pig died of plague.
25	Havildar's House, Lunatic Asylum, Colaba	2	One dead rat proved plague infected found in room.
26	Clerk's House, Lunatic Asylum, Colaba	55	Running about guinea-pig died of plague. Guinea-pig to which fleas were transferred died of plague.
27	Lunatic Asylum, Colaba Clerk's House (2nd room)	20	Running about guinea-pig died of plague. Guinea-pig to which fleas were transferred died of plague.

of the experiments in the 27 houses which were proved to be plague infected are set forth in Table VI.

A further point of interest in these observations is the proportion of fleas with plague bacilli in their stomach contents. In all 130 fleas were dissected and of these 41, or 32 %, contained in their stomachs bacilli microscopically indistinguishable from *B. pestis*. It is also worthy of mention that in all the 27 houses which were proved to be plague infected, with the exception of three, namely Nos. 8, 17 and 24, dead rats had been found shortly before the experiments were made.

Summary.

During the plague epidemic season of 1907 in Bombay a census of rat fleas in houses classified as follows has been made:—*A*, houses definitely proved to be plague infected: *B*, houses which were presumably, but not proved to be, plague infected: *C*, control houses.

In the case of group *A* the average number of fleas taken was three times greater than in the case of group *B* and 12 times greater than in the case of group *C*.

General Summary and Conclusions.

1. In 19 out of 100 experiments guinea-pigs allowed to run free in houses which were presumably plague infected developed the disease and died.

2. On three occasions, namely, on every occasion on which the experiment was made, fleas transferred from plague-infected rats found in houses infected fresh guinea-pigs in the laboratory.

3. Rat fleas, caught on guinea-pigs in plague houses and transferred to fresh guinea-pigs, transmitted the disease in 35 % of the cases.

4. A census of rat fleas in houses in Bombay, which were proved plague infected, indicated that rat fleas were 12 times as numerous as in control houses; and that in presumably infected houses rat fleas were four times as numerous as in control houses.

5. In 41 out of 130 fleas taken on guinea-pigs in plague-infected houses, bacilli microscopically indistinguishable from plague were found in the stomach.

6. In the case of 24 of the 27 houses definitely proved to be plague infected, dead rats had been found shortly before the experiments were made.