THE FLEAS COMMON ON RATS IN DIFFERENT PARTS OF THE WORLD AND THE READINESS WITH WHICH THEY BITE MAN.

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(With Plate II.)

The appetite for mankind of the fleas which infest rats in different parts of the world has become a question of epidemiological importance in view of the conclusion now generally accepted, that in the present pandemic these parasites play the principal part in the transmission of plague from rat to rat and from rat to man.

Whether rat fleas bite man has been much controverted, ever since Ogata (1896) and Simond (1898) put forth the theory that bubonic plague was conveyed by infected fleas. The difference of opinion is to some extent due to want of recognition of the fact that rats in different parts of the world, and also when living under varying conditions in the same part of the world, may harbour fleas belonging to different species. After making due allowance for this source of error, however, the fact remains that two observers experimenting with the same species of fleas have, not infrequently, come to opposite conclusions. It is therefore clear that the number of observations recorded and the precise conditions under which the experiments were made must be taken into account.

It is not necessary to enumerate all the species of flea which have, on occasion, been captured off rats, because this has already been done by Tiraboschi (1904), Shipley (1908) and quite recently by Rothschild (1910). From the point of view of epidemiology, it is only important to know, what fleas infest rats in different parts of the world and whether these fleas bite man with any readiness.

Fleas commonly infesting rats.

Knowledge on this point is incomplete. It is only recently that a large number of rats has been examined with this object and so far comparatively few localities have been studied. The occurrence of plague in a locality has alone provided a sufficient excuse for taking a census of the fleas infesting the rats.

As far as at present known the fleas commonly infesting both *Mus rattus* and *Mus decumanus* are:

1. *Xenopsylla cheopis* (Rothschild).
   Synon. *Pulex cheopis* Rothschild, 1903.
   Pulex pallidus Tidswell, 1903.
   Pulex brasiliensis Baker, 1904.
   Pulex murinus Tiraboschi, 1904.
   Pulex philippinensis Herzog, 1904.
   Loemopsylla cheopis (Rothsch.) Rothschild 1908.
2. *Ceratophyllus fasciatus* (Bosc.).
3. *Ceratophyllus anisus* Rothschild, 1907.
4. *Ctenopsylla musculi* (Dugès).
5. *Ctenophthalmus agyrtes* (Heller).

The dog flea (*Ctenocephalus canis*), the cat flea (*Ctenocephalus felis*), the fowl flea (*Echidnophaga gallinacea*) and the human flea (*Pulex irritans*) are also sometimes found upon rats, but they appear to be only occasional visitors. In certain localities, however, they have formed quite a considerable proportion of the fleas captured. Tiraboschi (1904, p. 259) states that in several regions of Italy as many as 25 % to 30 % of the fleas on rats were dog and cat fleas, and Verjbitski (1908, p. 165) found *Ct. felis* or *canis* on 12 % of rats (300) in Cronstadt. In Dar-es-Salam (German East Africa) *Echidnophaga gallinacea* accounted for 22 % of fleas taken off rats (Schuberg and Manteufel, 1910). As may be seen from Table I, *P. irritans* has seldom been found except in San Francisco, where it was present to the extent of 9 % of the total fleas taken.

Distribution of rat fleas.

The particular fleas found in greatest numbers upon rats seem to be determined by geographical position, including climate, and the habitat of the rats examined. The influence of species, whether *Mus decumanus* or *Mus rattus*, upon the parasite carried appears to be indirect and

brought about by a general difference in the mode of life and distribution of the two species.

In Table I below we have collected all the available quantitative data upon the subject which are based upon the examination of a sufficient number of fleas to permit the facts to speak for themselves. The results are, therefore, independent of the impressions of the individual observers. For the reason mentioned above (p. 123) such data are only forthcoming from comparatively few places, but they are sufficient to draw certain broad conclusions, as to the distribution of some of the commonest parasites infesting rats.

As an instance of the effect of geographical position independent of climatic conditions, the replacement of *Ceratophyllus fasciatus* by *Ceratophyllus anisus* in Japan (Kitasato, 1909) may be mentioned, and the occurrence of *Xenopsylla scopulifer* Rothschild only in Africa. The influence of temperature will be discussed when dealing with the distribution of *Xenopsylla cheopis*.

By habitat, we mean differences in conditions and mode of life depending upon whether the rats live in the fields, sewers, docks, barns, stores, granaries or poultry houses, &c. These varying surroundings will bring the rats into association with other animals and some amount of exchange of parasites may take place. Provided these parasites can flourish upon a diet of rat-blood, they may establish themselves locally on these rodents. An instance is the prevalence of *Ctenopsylla musculi*, the common mouse-flea, upon rats living under conditions in which rats and mice come together, such as in barns, provision stores and on some ships; the presence of fowl-fleas and dog-fleas in considerable numbers upon rats inhabiting poultry farms and stables is to be explained in the same manner. The large proportion, 52 %, of *Ctenophthalmus agyrtes* found by Martin and Rowland (1911) upon *Mus decumanus* living in the open in this country is another striking illustration of the case in point, the usual host of this flea being, according to Rothschild, the field vole.

(1) *Xenopsylla cheopis* (Rothschild). This flea was described by Rothschild (1903 and 1906) after examination of specimens taken from several small rodents in Egypt and the Soudan. It is now known to be the common rat flea in the tropical and sub-tropical parts of the world, occurring in some regions to the almost entire exclusion of other species. In India[1], where rat fleas were very extensively examined in four places,

[1] The authorities for this and the following statements are given in the last column of Table I.

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it formed nearly 100% of all the rat fleas found in three instances (Table I); in the fourth (Punjab) the same was true in the warmer months, 2% of *Ceratophyllus fasciatus* appeared in the cooler weather. In Manila, where, however, comparatively few fleas (42) were examined, all were identified as *Xenopsylla cheopis*.

In the warmer parts of the temperate regions, *e.g.* Mediterranean, Southern Japan, San Francisco and Australia as far south as Sydney, it occurs in varying proportion according to the time of year.

Xenopsylla cheopis is also stated to be common on rats in South Africa and Central and South America (Jordan and Rothschild, 1908).

One specimen has been found at Plymouth by Giles (1906) and this is the only recorded instance of its appearance in this country. We have no doubt, however, that it would be frequently found if, during September, a sufficiently extensive examination were made of rats from ships in English ports[1].

The extensive census of rat fleas in various parts of India made throughout the year by the Plague Commission (1908, p. 266, 1910, pp. 460 and 524) shows a striking maximum for flea prevalence (*X. cheopis*) during some portion of the year, the mean number infesting rats increasing three to ten fold.

In those temperate climates (Japan, Sydney, Marseilles) where observations have been directed to the point, a seasonal prevalence of these fleas has also been observed, the numbers increasing greatly both actually and relatively towards the end of summer and declining with the onset of cold weather (Kitasato, 1909; Tidswell, 1910, p. 20; Gauthier and Raybaud, 1910, II.).

(2) *Ceratophyllus fasciatus* (Bosc.). This species is, according to Rothschild (1906, p. 483) and Tiraboschi (1907, p. 595), the common flea upon *Mus decumanus* and *Mus rattus* in this country and in the northern and central parts of Europe. Galli Valerio (1900, I.), however, found it rarely in Lausanne. He believes that *Ctenopsylla musculi* is the usual flea on rats in this city and states that it is commonly present in Holland and at Halle and that he himself found it at Milan.

Recently Martin and Rowland (1911) found it to constitute about one half (48%) of 1057 fleas taken from *Mus decumanus* in Suffolk and Elstree (Herts.).

[1] Since this paper was written Dr Boycott has taken two specimens of *X. cheopis* off *Mus decumanus* captured at Guy's Hospital, London, S.E. The specimens were identified by Mr Rothschild.

TABLE I.

Locality	Source	Species	No. of rat fleas examined	Percentage of *Xenopsylla cheopis*	Percentage of *Xenopsylla astopulifer*
India: Bombay ...	Houses, gullies outbuildings	*M. rattus* and *M. decumanus*	216,000	100	—
Poona	Houses, outbuildings	*M. rattus*	240,000	100	4 only
Belgaum ...	Houses	,,	380,600	100	—
Punjab... ...	Houses	,,	54,000	98	—
Australia: Brisbane ...	—	*M. rattus* and *M. decumanus*	103	76·7	—
Sydney ...	—	,, ,,	100	81·0	—
,, ...	—	—	1926	61·8	—
San Francisco ...	—	*M. rattus* and *M. decumanus*	10,972	21·4	—
,,	—	,, ,,	15,554†	32·1	—
,, (Oakland)...	—	*M. decumanus*	4140	23·2	—
Manila	—	*M. rattus* and *M. decumanus*	42	100	—
Africa: Dar-es-Salam ...	—	,, ,,	258	66·6	10·9
Japan: Yokohama, Tokio, and other large towns (winter)	—	—	2713	6·1	—
Yokohama ...	Ships	*M. rattus*	—	100	—
Awaji Island near Kobe (autumn)	—	—	835	45·5	—
,, ,, (winter)	—	—	4617	20·2	—
Marseilles	Ships	*M. rattus*	250	25·6	—
,, ...	Town	*M. decumanus*	52	5·8	—
,, ...	Ships	*M. rattus*	2276	92·7	—
,, ...	Quays	*M. decumanus*	2424	33·0	—
,, ...	Town	,,	4377	50·4	—
Tunis	—	*M. rattus* and *M. decumanus*	1242	83·6	—
Algeria: Algiers ...	—	,, ,,	2410	59·7	—
Constantine and Oran	—	,, ,,	428	35·9	—
Great Britain: Suffolk ...	Rats in the open	*M. decumanus*	584	—	—
,, ...	Rats' nests	,,	215	—	—
Herts. ...	,,	,,	258	—	—

* In some cases the fleas are not described by these authorities in accordance with the latest nomenclature; there is, however, seldom any doubt as to the species intended.

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TABLE I (*continued*).

total fleas belonging to the various species*						
Ceratophyllus fasciatus	*Ctenopsylla musculi*	*Ctenophthalmus agyrtes*	*Ctenocephalus felis* and *Ct. canis*	*Echidnophaga gallinacea*	*Pulex irritans*	Observer
—	—	—	—	—	—	*Commission for Investigation of Plague in India Report*, 1907, p. 412; 1908, p. 297.
—	—	—	2 only	—	—	*Ibid.* 1910, p. 524.
—	—	—	—	—	—	*Ibid.* 1910, p. 461.
2 (winter only)	—	—	—	—	—	*Ibid.* 1907, p. 914.
—	17·5	—	5·8	—	—	Tidswell, 1903, p. 71.
10	8·0	—	1·0	—	—	,, ,,
10·9	26·7	—	0·5	—	0·05	,, 1910, p. 20.
68·1	4·5	—	0·5	—	5·6	Surgeon Rupert Blue, private communication, 1908.
52·0	4·6	—	1·8	—	9·4	Carroll Fox, 1910.
44·8	31·6	—	0·2	—	0·2	,, ,,
—	—	—	—	—	—	Herzog, 1905.
—	—	—	—	22·5	—	Schuberg and Manteufel, 1910.
66·5‡	27·4	—	0·3	—	—	Kitasato, 1909.
—	—	—	—	—	—	,, ,,
58·6‡	25·5	—	3·9	—	—	,, ,,
28·1‡	20·7	—	0·03	—	0·1	,, ,,
2·4	71·2	—	—	—	0·8	Gauthier and Raybaud, 1903.
86·5	3·8	—	3·8	—	—	,, ,, ,,
6·7	0·5	—	0·1	—	—	,, ,, 1910.
51·5	10·2	—	5·2	—	—	,, ,, ,,
35·1	7·9	—	6·4	—	—	,, ,, ,,
5·1	10·1	—	0·4	—	0·1	Conseil, 1909.
13·5	20·1	—	6·3	—	0·4	Raynaud, 1909.
22·9	36·9	—	4·3	—	—	Billet, 1908.
55·5	—	44·4	—	—	—	Martin and Rowland, 1911.
47·0	—	53·0	—	—	—	,, ,, ,,
33·3	—	66·7	—	—	—	,, ,, ,,

† It is possible that some of these fleas may be included among those previously reported upon by Surgeon Blue.

‡ These numbers refer to *Ceratophyllus anisus*.

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In warmer temperate regions *Ceratophyllus fasciatus* together with *Xenopsylla cheopis* forms the bulk of the rat-flea population, *e.g.* San Francisco, where out of a total of 10,972 rat fleas collected, 68 % were *Ceratophyllus fasciatus* and 21·4 % *Xenopsylla cheopis*. As a rule, in such climates, the proportion of the former increases relatively during the winter, and that of the latter during summer.

Ceratophyllus fasciatus has not been found in the warmer parts of India, but in the Punjab it appears during the cooler half of the year, November to March, and accounts for 2 % of the total.

In the Himalayas (Simla) this flea is common.

(3) *Ceratophyllus anisus* Rothschild. In Japan this flea appears to occupy the position assumed by *Ceratophyllus fasciatus* elsewhere (Kitasato, 1909), occurring to a relatively larger extent in the winter than in the summer, when *Xenopsylla cheopis* makes its appearance in some places in large proportion.

(4) *Ctenopsylla musculi* (Dugès). This is the flea which usually infests the house mouse, *Mus musculus*. Tiraboschi (1907, p. 60) found it on rats in all parts of Italy, but less frequently on *Mus decumanus* than on *Mus rattus*. According to Verjbitski (1904) it is the flea most common upon rats in Cronstadt.

As may be seen from Table I, this flea furnishes a considerable contribution to the total fleas harboured by rats in many widely separated parts of the world: North America, Europe, Japan, Australia. It was rarely found in India.

It is sometimes very prevalent upon *Mus rattus* from ships; on one occasion at Marseilles, among 250 fleas from this source Gauthier and Raybaud (1903) identified 178 as *Ctenopsylla musculi*.

(5) *Ctenophthalmus agyrtes* (Heller). According to Rothschild, this flea is common in England and Europe upon field mice and bank voles and occurs also on *Mus decumanus* when captured in the open. The recent observations of Martin and Rowland (1911) on the fleas from rats living on farms in Suffolk, Hertfordshire and Hampshire showed an unexpected proportion of this flea to be present (Table I). The rats examined were living in burrows in the fields or in corn stacks. It appears therefore that in these localities *Ctenophthalmus agyrtes* accounts for about half of the fleas infesting rats living under the conditions mentioned. Whether the same obtains in other rural parts of England is at present unknown.

Members of the above five species constitute the bulk of fleas, which up to the present have been shown to commonly occur upon rats.

One other flea, *Xenopsylla scopulifer* Rothschild, which, according to Schuberg and Manteufel (1910), replaces *Xenopsylla cheopis* to some extent in German East Africa, demands mention. It was described by Rothschild (1905) and obtained off *Saccostomus campestris* and *Mus auricomis* in Zululand. It is closely allied to *Xenopsylla cheopis.*

The readiness with which various rat fleas attack man.

1. *Xenopsylla cheopis.* That this flea readily feeds on man was observed by Tidswell (1903) and Gauthier and Raybaud (1903). This was confirmed by Liston (1904), who also collected many observations showing that, in the absence of its natural host the rat, *X. cheopis* is attracted to mankind. This fact was subsequently confirmed by the Commission for Investigation of Plague in India (*Report*, 1907, p. 472 and 1908, p. 249).

2. *Ceratophyllus fasciatus.* With regard to the readiness with which this flea attacks man considerable divergence of opinion has hitherto existed. According to Wagner (quoted by Tiraboschi 1904, p. 180), Tiraboschi (1904, p. 266) and Galli-Valerio (1907) this flea does not bite man. On the other hand, Gauthier and Raybaud (1903 and 1909) and McCoy and Mitzmain (1909) found that when hungry it fed on man with readiness.

We have made some hundreds of experiments on this question and are at a loss to understand the negative conclusion arrived at by Tiraboschi and Galli-Valerio.

The fleas used in our observations had been bred in the Institute and were kindly placed at our disposal by Professor E. A. Minchin. The fleas were caught in the breeding cages and placed separately in test tubes, which were kept in tins or jars in a dark cupboard covered with damp cloths to prevent undue drying of the atmosphere.

The fleas were starved for periods varying from 24 hours to 14 days before testing their inclination to feed on man. The tubes were inverted upon the naked skin of the arm of the subject and the flea carefully watched for a period of two minutes. If it did not bite during this time it was regarded as negative for our experiments. Frequently the flea attached itself instantly or within a few seconds and began to feed without delay; sometimes it took a little longer to get started, but usually if it were going to bite at all it did so before one minute had elapsed.

As soon as the flea attached itself the tube was removed and the behaviour of the insect was watched with a hand-lens. The position assumed was generally characteristic. After a preliminary investigation of the surface with the tip of the labium and the maxillary palps, the insect was seen to press its head firmly on to the skin and raise its abdomen steeply into the air. The mandibles and epipharynx, which constitute the "pricker" and enter the skin, are too small to be seen with a magnification of 10 to 20 diameters but the labium in which these parts are carried, can be clearly observed. As the "pricker" is pressed into the skin the slack of the bifurcated labium is either bent in the form of two bows or flexed as the fingers are in making a rest for a billiard cue. The insect is so much absorbed in the occupation of sucking, that it can be rotated 180 degrees around its pricker as axis without being detached. In a few cases in which, for some reason or other, notwithstanding the manifest efforts of the animal, no blood entered the stomach, this attachment of the insect was regarded as evidence of biting for statistical purposes. Usually, however, there was no difficulty in seeing the blood entering the stomach in rapid jets. A pink flush spreads over the anterior portion of the abdomen, which gradually reddens as the stomach becomes distended.

The fleas which did not bite usually wandered about during the two minutes they were under observation, and in some cases showed evident dislike, making efforts to crawl or jump back into the tube, away from the skin of the subject.

The results of 517 experiments with 364 fleas and 8 persons are given in Table II. The proportion of fleas which bit varied from 36 % to 77 %, giving a mean value for man of 59·6 %. The variation between different people is large enough to warrant the conclusion that the suggested idiosyncrasy is a reality.

In order to obtain a satisfactory control for these experiments, a similar set were undertaken, using the rabbit and the rat as subjects; the results are also given in Table II. The experiments were in all details similar to the above, except for the expedients adopted for keeping the animal quiet during the observations.

The rabbit was rolled up in a cloth, and remained motionless on a table in a sleepy condition. The fleas were each allowed to remain for 2 minutes on the inside of the ear. 32 fleas were tried of which 23 bit, a proportion of 72 %.

The rat was secured by a similar method. Two bandages were used, one for the neck and shoulders, and one for the thighs and legs, leaving a portion of the abdominal wall free. The area of skin upon which the

fleas were tried was shaved. The rat was laid on its back, the head comfortably supported with a pillow of cotton wool, and kept from rolling away by fastening the ends of the bandages to a board with drawing pins. The rat remained perfectly quiet and there was no difficulty in carrying out the observations. 101 fleas were tried, of which 59 bit.

Under the conditions of these experiments *Ceratophyllus fasciatus* fed upon man as readily as upon a rat.

TABLE II.

Ceratophyllus fasciatus.

Subject:—	C.J.M.	H.C.	A.M.	J.H.S.	H.Y.	G.F.P.	H.W.A.	S.R.	Summary	Rat	Rabbit
Total No. of Exps.	161	118	39	33	52	51	40	23	517	101	32
Positive... ...	106	65	30	12	36	25	19	15	308	59	23
Negative ...	55	53	9	21	16	26	21	8	209	42	9
% positive ...	65·8	55·1	76·9	36·4	69·2	49·0	47·5	65·2	59·6	58·4	71·9

Cage experiments with Ceratophyllus fasciatus.

The readiness with which *C. fasciatus*, if hungry, will attach itself to man was demonstrated in the following manner. The rat was removed from a flea breeding-cage, into which 100 fleas had been placed a few days previously. Four days later, the hand and arm of a number of persons were, at different times during the day, placed in the cage and allowed to remain there for two minutes. The results are given in Table III, where it is seen that in one case as many as 18 fleas jumped upon the arm, many of which could be felt at once to bite vigorously.

TABLE III.

Cage experiment 16. XI. 10.

Observer:—	C. J. M.			H. C.	A. M.		J. L. C.	H.Y.	G.F.P.	H.A.	H.B.
	1	2	3		1	2					
No. of fleas found upon arm after 2 mins.	7	3	7	18	3	3	3	6	0	6	14

Further observations to test this point were made by putting the arm into cages in which the fleas were bred. These cages consisted of two compartments, separated from one another by coarse-meshed wire netting. The rat inhabited one compartment, and the other served as breeding ground for the fleas which could freely pass from one to the other. When the hand was placed in the compartment containing the

rat the result was negative, but when inserted into the other, although within six inches of the rat, numbers of fleas (in one case 40) hopped on to the arm, and most of them fed immediately.

The details of these experiments are set out in Table IV below.

TABLE IV.

Cage experiment 26. XI. 10.

Observer	Cage No.	No. of fleas attaching themselves in 1 minute, outside rat compartment but within 6 inches of rat
C. J. M.	1	8
C. J. M.	2	40
G. K.	2	20

The bite of *Ceratophyllus fasciatus* was not, as a rule, followed by either irritation or swelling. In the case of one individual, however, the results were very distinct and lasted for several days. The photograph reproduced in Pl. II was taken 48 hours after 30 fleas of this species had been placed upon the arm. Every bite was followed by an inflamed papule surrounded by oedema. The irritation was considerable and lasted for some days.

3. *Ctenopsylla musculi.* According to Galli-Valerio (1900, *a* and *b*), Tidswell (1903) and Tiraboschi (1904, p. 282) this flea does not bite man. Verjbitski (1908, p. 164) came to the same conclusion. This observer made 40 experiments on himself, after starving the fleas for different periods, but in no case did they feed. On the other hand, McCoy and Mitzmain (1909), and Gauthier and Raybaud (1910) found that this flea would occasionally bite man.

McCoy and Mitzmain's observations were made with 15 fleas. Each flea was tested on successive days for five minutes until it either died or escaped. With these opportunities eight of them were induced to feed on at least one occasion.

In our own experiments the fleas were bred in the Institute in cages with mice. From a cage started in December 1910, enough fleas were obtained on January 14, 1911, for a satisfactory experiment, viz.: 71 fleas. On the day following their removal from the cage only 46 were still alive. This species would appear to be less robust than either *Ceratophyllus fasciatus* or *Ctenophthalmus agyrtes*, a fact also noted by McCoy and Mitzmain.

With these 46 fleas, starved for 24 hours, the 111 experiments set forth in Table V were made; 4 of the fleas bit and remained attached

for several minutes, in fact until removed. In only one of these was blood found at the subsequent examination. 11 fleas which had given negative results were placed upon the shaved abdomen of a mouse; 9 of them fed. The same conditions obtained as in the case of *Ceratophyllus fasciatus* and the fleas were allowed to remain on the skin for two minutes only.

TABLE V.

Experiments with Ctenopsylla musculi, 14. I. 11.

Subject	H. C.	C. J. M.	S. R.	Summary	Mouse
No. of Experiments	36	47	28	111	11
Positive ...	1	1	2	4	9
Negative ...	35	46	26	107	2
% positive ...	—	—	—	3·6	81·8

Our results are in agreement with those of McCoy and Mitzmain and Gauthier and Raybaud. This flea will occasionally bite man, but it evinces small inclination to do so.

4. *Ctenophthalmus agyrtes.* No observations to determine whether this species bites man have, as far as we know, been previously made.

The fleas for our experiments were obtained from rats and rats' nests examined during the investigation of plague among rats in Suffolk (November 1910 to January 1911) by Martin and Rowland (1911).

In all 98 experiments were made with 68 fleas and four persons (C. J. M., H. C., S. R. and A. M.); in every case the result was negative.

As control, some of the fleas, which would not feed upon man, were tested upon a rat. Unfortunately we omitted to do this until our supply was nearly exhausted and the number of fleas constituting the control was only 19. These 19 were placed upon the arm and allowed to remain for two minutes with negative result. Immediately afterwards they were placed upon the shaved skin of a rat (in the manner described above) under precisely similar circumstances as those in which they had failed to bite us. 11 fastened upon the rat and fed.

We have not yet succeeded in breeding a supply of *Ctenophthalmus agyrtes*, so that our experiments are not so numerous as with *Ceratophyllus fasciatus*, but they show that the former flea exhibits no inclination to feed upon man.

The following experiment described by Rowland and one of us (1911) illustrates the difference between *Ceratophyllus fasciatus* and *Ctenophthalmus agyrtes* as regards their appetite for man. A bottle containing 23 unidentified fleas, taken from wild rats three days previously,

was inverted upon the arm of one of the authors (S. R.). Eleven attached themselves and remained feeding; the remainder, 12, were shaken back into the bottle. The 11 which had fed were chloroformed and on examination were identified as *Ceratophyllus fasciatus*. The remaining 12 were placed upon C. J. M.; one fed and this also was identified as *Ceratophyllus fasciatus*. The 11, which had bitten neither observer, were found to consist of eight *Ctenophthalmus agyrtes* and three *Ceratophyllus fasciatus*.

Summary.

(1) *As far as is at present known*, the great majority of the fleas infesting *Mus rattus* and *Mus decumanus* in different parts of the world, belong to either the species *Xenopsylla cheopis*, *Ceratophyllus fasciatus*, *Ceratophyllus anisus*, *Ctenopsylla musculi* or *Ctenophthalmus agyrtes* or are comprised of some admixture of these five species.

(2) *Xenopsylla cheopis* is the most prevalent in the tropics and sub-tropical regions and often occurs there to the almost complete exclusion of other species. It is common during summer and autumn in some of the warmer parts of the temperate zone, more especially in ports which have maritime intercourse with the tropics.

(3) In the cooler regions *Ceratophyllus fasciatus* is the most universally distributed flea and is associated with more or less of *Ctenopsylla musculi* and *Ctenophthalmus agyrtes* according to the locality and the habitat of the particular rats.

(4) In Japan *Ceratophyllus fasciatus* is replaced by *Ceratophyllus anisus*, a closely allied species.

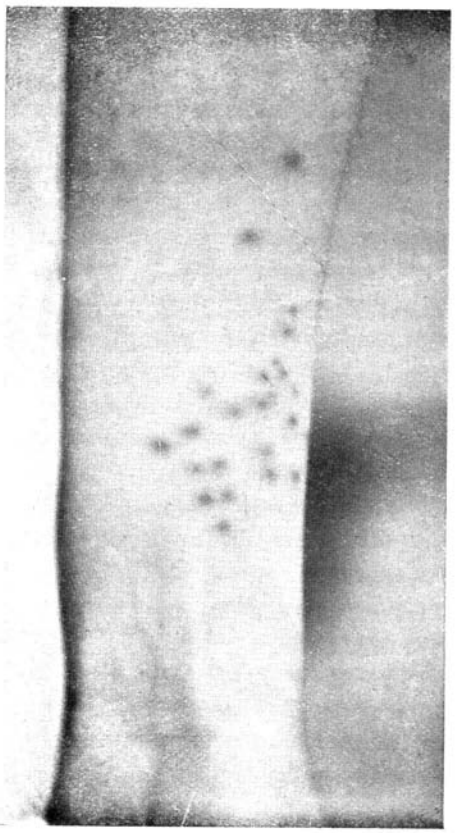
(5) The numerous other fleas which have been captured off rats are only occasional visitors.

(6) *Ceratophyllus fasciatus*, like *Xenopsylla cheopis*, readily bites man. Out of 517 experiments 308 fed, or 59 % were positive. In 101 experiments, under identical circumstances with a rat, 59, or 58·4 % of the fleas fed.

(7) The experiments with *Ceratophyllus fasciatus* were made upon eight persons and evidence was obtained of preference on the part of the insects for particular individuals.

(8) 111 experiments were made with 46 specimens of *Ctenopsylla musculi*; only 4 fed = 3·6 %, whereas 9 out of 11 fed on a mouse.

(9) 68 specimens of *Ctenophthalmus agyrtes* were tried, in some cases upon three persons. None fed, whereas 11 out of 19 of the same fleas fed on a rat under identical conditions.



Forearm of A. M. 48 hours after 30 "Ceratophyllus fasciatus" had been placed upon it, 24 of the fleas having fed.

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GENERAL CONCLUSION.

Xenopsylla cheopis and *Ceratophyllus fasciatus* are the species of rat fleas which, when hungry, readily bite man. There is no reason to suppose that, other things being equal, *Ceratophyllus fasciatus* would not be as efficient an agent in the transmission of plague from rat to man as *Xenopsylla cheopis* has been shown to be in India.

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