A PRELIMINARY STUDY OF PLAGUE AT A HILL STATION IN THE NILGIRIS, SOUTH INDIA

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THE Nilgiris district has long been recognized as a potential plague zone. Potato farming is extensive in the whole district and in recent years it has become increasingly popular even as a cottage industry near the towns of Ootacamund and Coonoor. That field rats abound in potato farms is common knowledge. The health-conscious public of these towns have been, of late, much concerned with this problem of potato cultivation *vis-à-vis* plague, and attempted to discourage potato farming around residential areas by municipal legislation. The matter thus came to the notice of Government who ordered an enquiry into this matter to be made. The enquiry was accordingly carried out during the period May to July 1939, facilities for work being provided at the Pasteur Institute, Coonoor. The scientific aspects of this enquiry are included in this report. Field studies on plague undertaken in recent years at the instance of the Government and the Indian Research Fund Association in this province have all been connected with factors prevailing in the plains. The present enquiry has therefore contributed certain preliminary data pertaining to the epidemiology of plague in a hill station.

The Nilgiris is a plateau in South India, the smallest in extent and population of all districts in Madras province. It is roughly 1,000 square miles in extent upheaved at the junction of the Eastern and Western Ghats, and has a population of about 170,000. The plateau has an average altitude of 6,500 feet though some of its peaks are over 8,000 feet high. The attached map shows the topography, and main routes of communication of the district. Over half the area is either forest or downs, a third is cultivated, and the rest is sparsely populated. The fertile areas in the district are chiefly composed of a rich black loam of a peaty nature. A brown soil comes next in value while other soils of inferior quality are chiefly used as grazing grounds. Of the lands utilized for agricultural purposes, less than half is cultivated with cereal crops, such as rice, wheat, *ragi, samœ,* and barley, and over half with coffee, tea, cinchona, potato, etc. No portion of the district is irrigated. The grain grown in the district is hardly sufficient for 4 months' consumption in the year, and therefore much of these are imported either from Mysore and Malabar, *via* Gudalur, or from Coimbatore *via* the ghat road and the rack railway. Potato farming is very extensive, even as a cottage industry within the towns.

Climate.—The Nilgiris, owing to its high altitude, has one of the most temperate and equable of climates. Thus, for Ootacamund the average minimum temperature for the warmest month (April) is only about 9° higher than that for the coolest month (January) and the maxima for the same months vary only about 7°. Chart 1 shows the average monthly meteorological record for Ootacamund and chart 2 shows the average monthly plague death rate per mille of estimated population for the district for 35 years ending 1939. The annual rainfall averages about 67 inches, though it varies widely within the district from nearly 162 inches at Devala to about 56 inches in Ootacamund, depending on the effects of the south-west monsoon in each place. The humidity is low during the first 5 months of the year, and comparatively high during the remaining months. It has not been possible to procure necessary data for calculating average figures for saturation deficiency.

Plague in the Nilgiris

Plague first occurred in this district in Gudalur taluk about January 1903, and in Ootacamund in June of the same year. The disease then spread widely and rapidly all over the district and has been endemic ever since. The incidence of the disease has, however, been steadily coming down from the peak reached in the earlier years, though even with this decline a rough 3 to 4-year periodicity is evident, *vide* chart 3.

A special feature of the general incidence of plague in this district is, as stated in the geographical survey of plague in the Madras Presidency by Colonel Russell, that 'the usual difference between summer and winter months is not so clearly marked as in other districts' (*vide* chart 2). This point is discussed later.

(Continued from previous page)

sulphanilamide. Figures 5 and 6 show radiographs taken before and ten days after treatment.

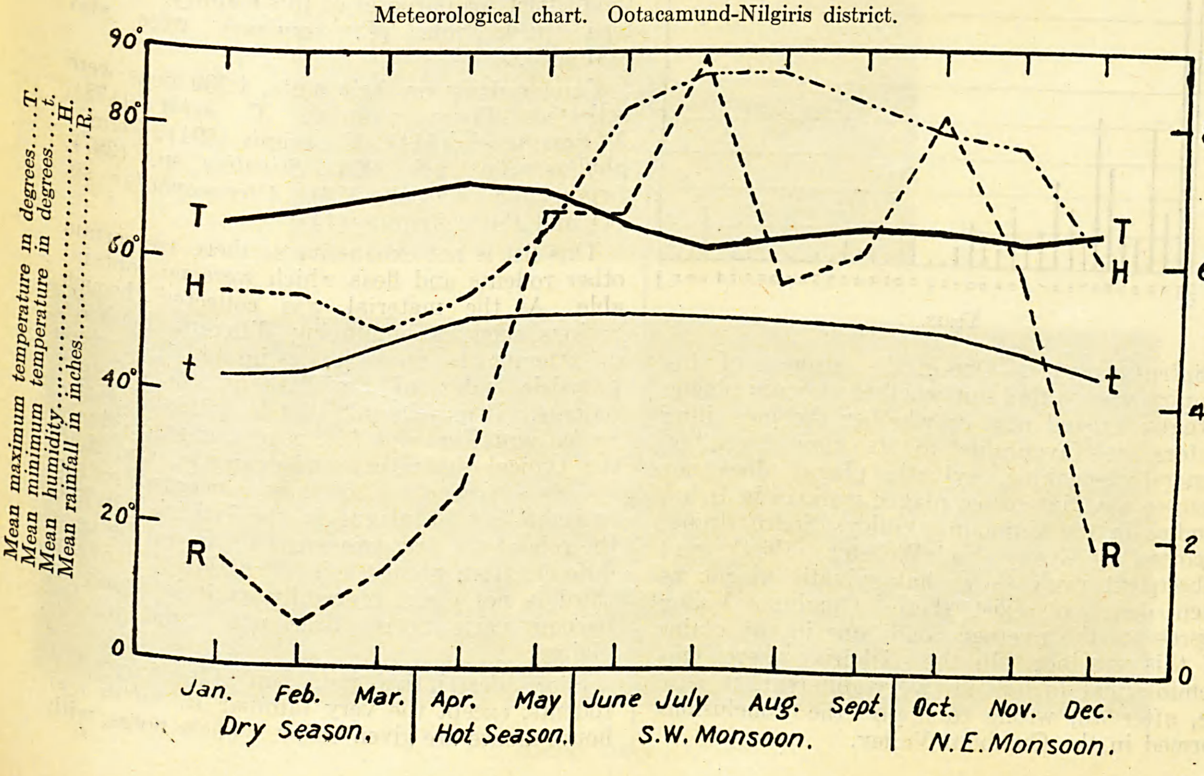
REFERENCES

ALLEN, W. H. (1936). *Ann. Intern. Med.,* **10,** 441.
AMBERSON, J. B. (1937). *Internat. Clin.,* **3,** 126.
BLAKE, F. G., and CECIL, R. L. (1920). *J. Exper. Med.,* **31,** 403, 445.
FRIED, B. M. (1933) .. *Ibid.,* **57,** 111.
GILL, A. M. (1938) .. *Brit. Med. J., i,* 504.
IKEDA, K. (1937) .. *Arch. Path.,* **23,** 470.
JEANNERET, R., and FAME, F. (1933). *Rev. Tuberc.,* **1,** 1013.
MAXWELL, J. (1938) .. *Lancet, ii,* 239.
RAMSAY, H., and SCADDING, J. G. (1939). *Quart. J. Med.,* **8,** 79.
SHARPE, E. A., and BLAKE, F. G. (1930). *J. Exper. Med.,* **52,** 501.
TERRELL, E. E., ROBERTSON, O. H., and COGGESHALL, L. T. (1933). *J. Clin. Investigation,* **12,** 393.
VISWANATHAN, R. (1939). *Tubercle,* **20,** 268.

Another feature is that, unlike what now occurs generally in other districts, the urban areas of Ootacamund and Coonoor, comprising only about a fiftieth of the total area of the

CHART 1

Meteorological chart. Ootacamund-Nilgiris district.



district and a quarter of its population, have been responsible for over 50 per cent of its total plague incidence.

Pneumonic plague.—Cases of pneumonic plague have occurred in the district at irregular intervals. Colonel Hutchinson, quoted by Wu Lien Teh (1926), reviewing the 10-year period 1913 to 1922, has recorded four limited pneumonic outbreaks in the Nilgiris, stating that 24 out of the 94 cases recorded in the whole province occurred in this district.

The chief lines of study undertaken during this enquiry were :—

(1) Study of rodents and fleas prevailing in this district with special reference to wild rodents in relation to plague.

(2) Transmission experiments with *Stivalius* and *Ceratophyllus* fleas.

The material for the enquiry was collected from various parts of the district through the co-operation of the planters and the officers of

CHART 2

Average monthly plague death rates, 1905–1939. The Nilgiris district.

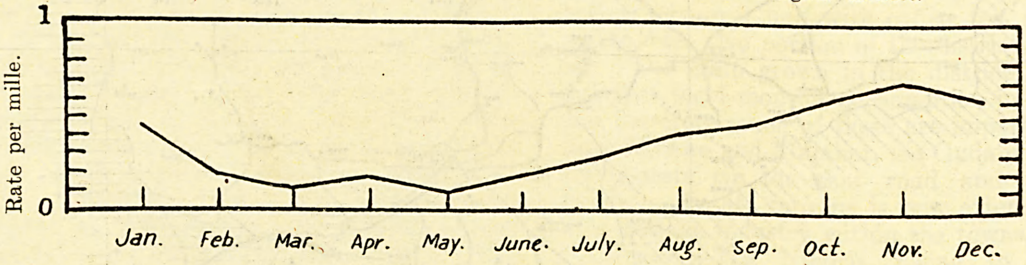
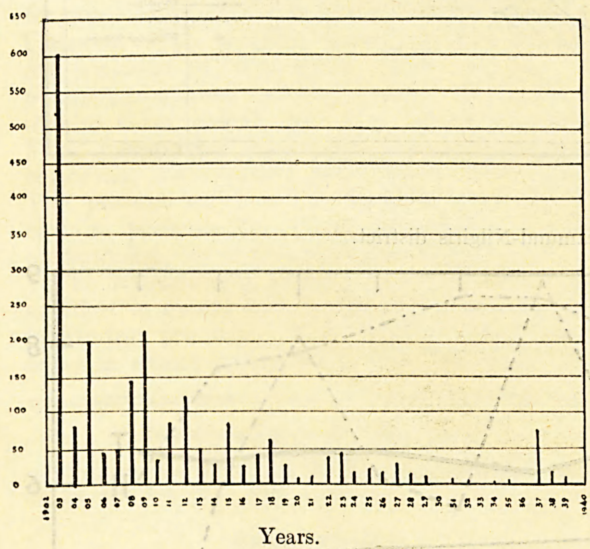


CHART 3

Deaths from plague in Nilgiris district during the years 1903–1939.



Sylvatic plague.—One of the purposes of this enquiry was to find out whether sylvatic plague actually existed now or whether the prevailing factors are favourable to its onset hereafter. Generally speaking, sylvatic plague does not seem to have interested plague workers in India. Studies in the Cumbum Valley, South India, reported by George and Webster (1934), and subsequent work show that sylvatic plague as such does not exist there. Cumbum Valley represents the average conditions in the plains of this province. In the Nilgiris where epidemiological factors are very different, it may be, after all, wrong to apply the conclusions formed in the Cumbum Valley.

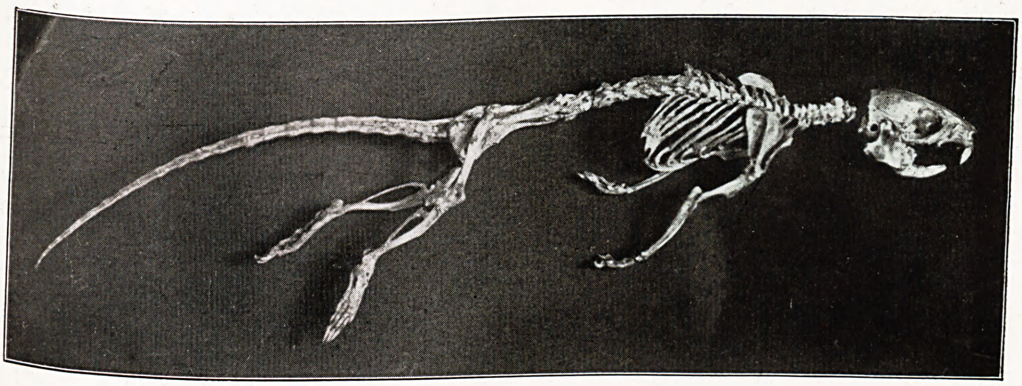
the public health department of the district and by ourselves. The technique for field studies was mainly that adopted in the Cumbum Valley.

(1) *Rodents and fleas examined.*—One thousand and nineteen rodents comprising 556 house rats (*R. rattus*), 30 bandicoots (*B. malabarica*), 136 mole rats (*Gunomys kok*), 271 house mice (*Mus musculus*), 13 field mice (*Leggada booduga*), and 13 bush rats (*Golunda ellioti*), were obtained from various parts of the district for purposes of this enquiry. Seventeen musk rats (*P. ceruleus*) were also examined.

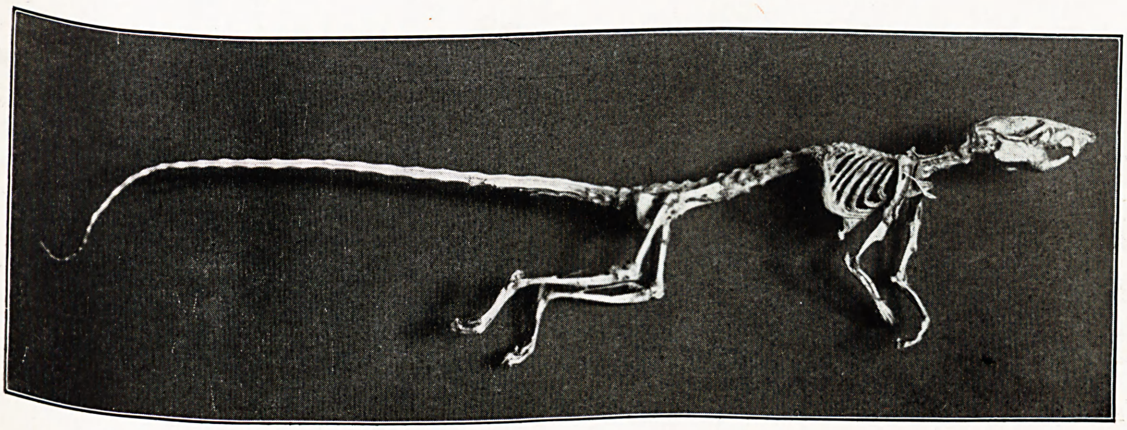
From rodents or their nests, 1,939 fleas were collected. These comprise *X. astia* (178), *X. brasiliensis* (514), *X. cheopis* (591), *Ceratophyllus nilgiriensis* (238), *Stivalius* sp. (387), *Leptopsylla musculi* (16), *Ctenocephalus* sp. (1) and *Pulex irritans* (14).

This list is not exhaustive as there are certain other rodents and fleas which were not obtainable. As the material was collected through various agencies, employing different methods, no attempt is made to estimate the species parasitic index of the fleas on the different rodents. It may be said that *R. rattus*, *B. malabarica* and *Gunomys kok* represent respectively the typical domestic, semi-domestic, and field species of rodents essentially concerned in the epidemiology of plague in the Nilgiris. While the rôle of the first two species may not be very different from what it is in the plains, that of the third is not clear, especially as it is found to harbour varieties of fleas not found in the plains.

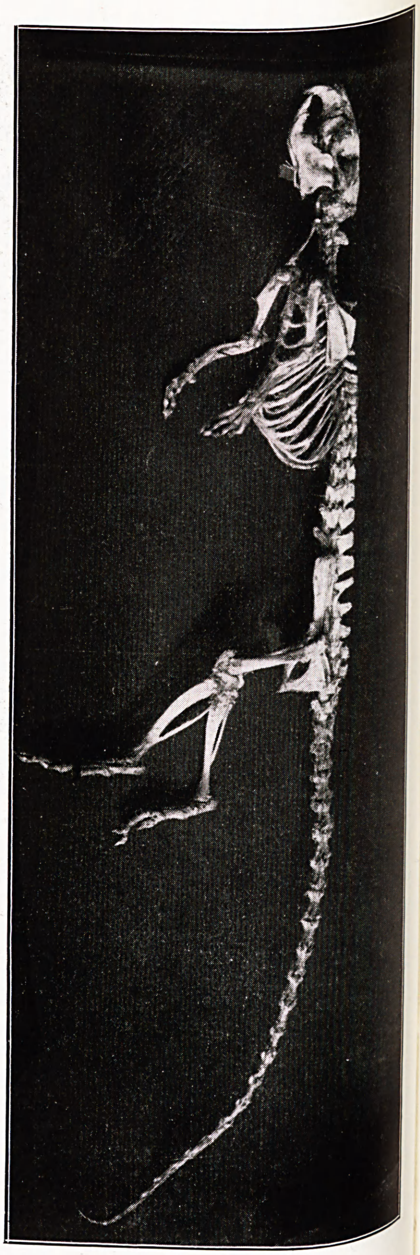
Short descriptive notes on the important rodents, except the very familiar *R. rattus* and house mouse are given below. These notes, with



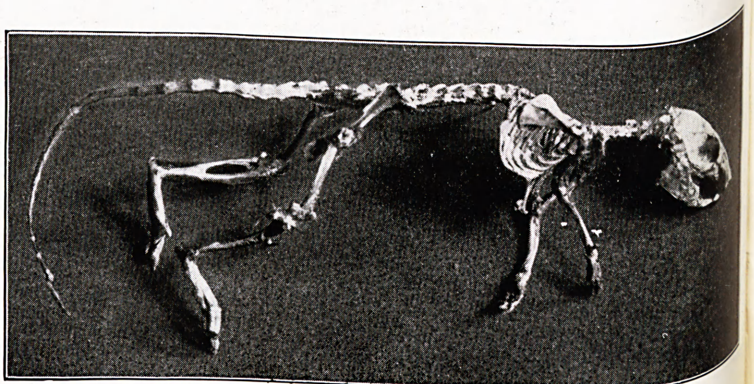
Gunomys kok.



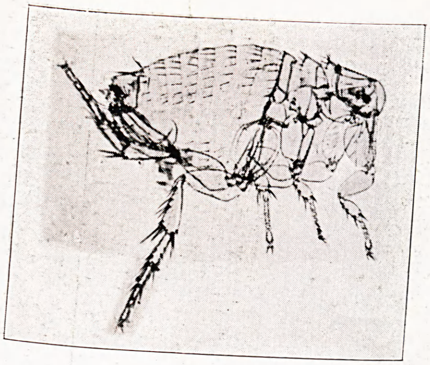
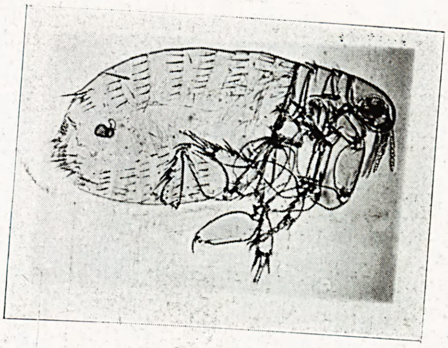
Rattus rattus.



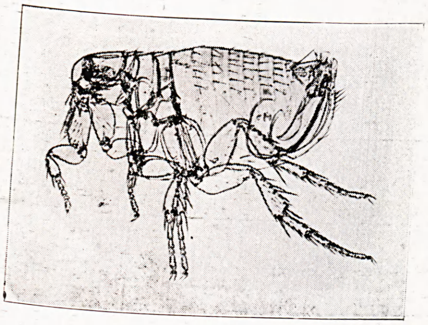
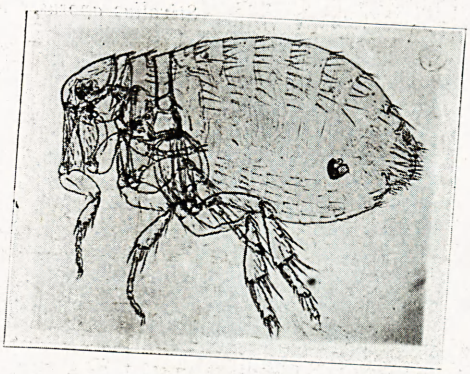
Bandicota malabarica.



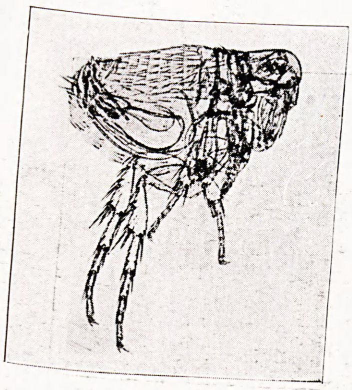
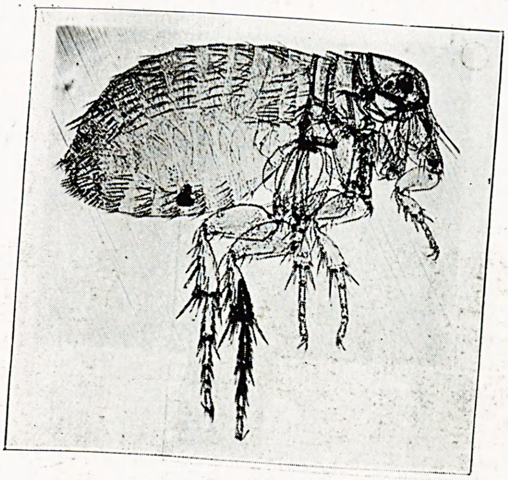
Golunda ellioti.

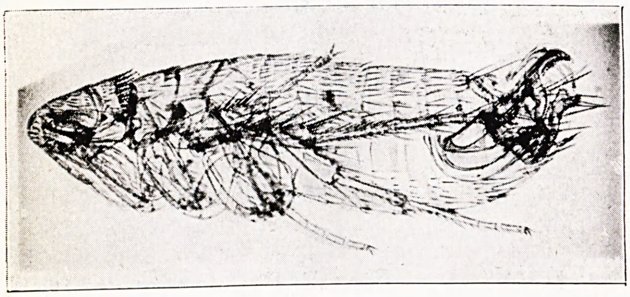
♂ *Xenopsylla brasiliensis.* ♀

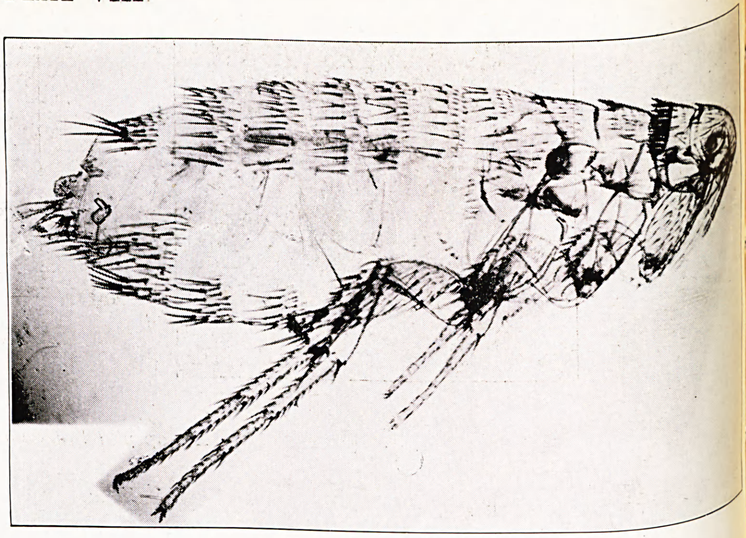



♂ *Xenopsylla cheopis.* ♀

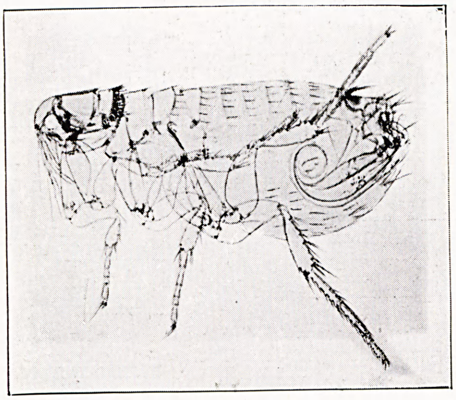



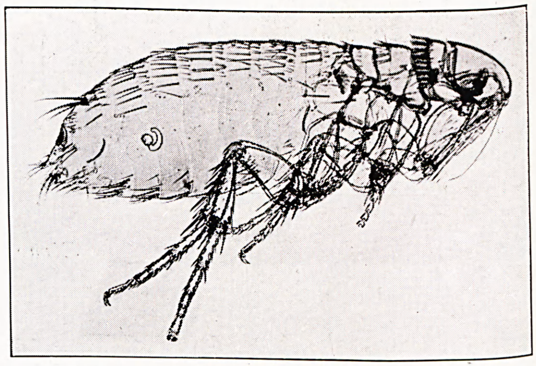
♂ *Xenopsylla astia.* ♀



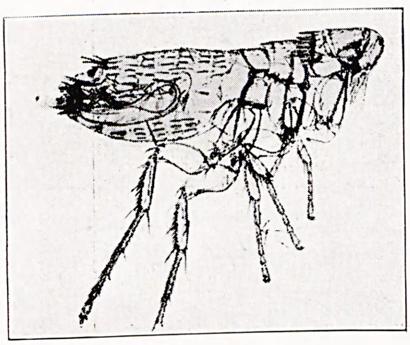


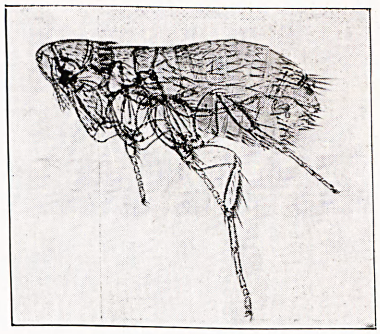
♂ *Stivalius aporus.* ♀





♂ *Ceratophyllus nilgiriensis.* ♀





♂ *Leptopsylla musculi.* ♀

the accompanying photographs of the rodents and their skeletons, may be of interest to field workers on plague, *vide* plates V and VI.

Plates VII and VIII show the important features of the fleas referred to in the text, as seen through a hand lens.

Mole rats (*Gunomys kok* Gray).—The rodent which abounds largely in the cultivated fields both within and outside the municipal areas of the Nilgiris is the mole rat. One of its favourite habitats in this district is the potato farm, but it also prevails in uncultivated lawns, tea and coffee plantations, fruit gardens, etc. It is easily distinguished from other prevailing species by its big size, only excelled by the bandicoot, broad head, more or less bull-dog-like face due to unduly prominent masseter muscles, coarse dark-brown dorsal coat, short tapering tail with ill-defined annular rings and no tuft of hair at the tip, and, above all, by its characteristic grunt and ferocity. It burrows more deeply and extensively than many other rodents. While in the plains it lives mostly on the bunds of paddy fields and other damp environments, in this hill station it is found all over, even around human habitations. It actually seeks shelter in houses during rainy months, or when food is scarce outside. The burrows of mole rats are extensive with numerous intricate branches most of which are temporarily plugged with earth for protection against enemies. Fumigation of burrows with cyanide products, unless accompanied with necessary exploratory diggings to unplug them, has therefore only a limited success with mole rats, contrary to experience with most other known plague rodents of South India. The nests of these mole rats usually contain, along with various bedding materials, large quantities of stored food. In the plains, often 4 to 6 lbs. of paddy or other grains are found in each system of burrows during the harvest season. In the nests in potato farms of the Nilgiris a number of potatoes are usually found.

One hundred and thirty-six mole rats and several of their nests were examined for fleas. It is interesting to note that 120 fleas collected from 5 mole rats and their nests at Nanjanad (7,400 feet altitude) were all *Ceratophyllus nilgiriensis*, while out of 230 fleas collected from 60 mole rats from the Pomological gardens in Coonoor (5,730 feet) 199 were *Stivalius* sp., 19 *Ceratophyllus nilgiriensis*, 11 *X. brasiliensis* and 1 *X. cheopis*. A rat flea survey by one of us (P. V. G.) of Ootacamund in 1929 revealed that while *X. cheopis* formed about 50 per cent of the fleas on *R. rattus*, they formed only about 8 per cent of the fleas on *Gunomys kok* within the town. At Coonoor, during the present enquiry, it was found that *X. cheopis* formed only 0.4 per cent of the fleas on mole rats. In the plains, observations in the Cumbum Valley show that mole rats harbour *X. astia* almost to the exclusion of *X. cheopis*. Mole rats have been found quite susceptible to plague, and their rôle in the epidemiology of plague should therefore depend on the vector efficiency of the sort of fleas which parasitize them in the different areas.

Bandicoots (*B. malabarica*).—The bandicoot prevails largely in the immediate vicinity of habitations, either in or around house drains, rubbish heaps, cowsheds, etc. It is much bigger than the mole rat or any other South Indian plague rodent. Its head is narrow, contrasting with that of the mole rat. The tail is thick and blunt with well-marked annular rings and in length is only about a tenth shorter than that of the head and body together. Its coat is uniformly harsh with long spinous hair. In its wandering and scavenging habits, no other Indian plague rodent can compare with it except perhaps *Rattus norvegicus* of the seaport towns. Plague epizootics in certain areas are heralded by deaths among bandicoots, followed by rat and mouse falls. From its semi-domestic habitat it may be rightly said to form the intermediary in the extension of plague from house rats to wild rodents. It is also as susceptible to plague as *R. rattus*. In proportion to its size, it harbours large numbers of fleas. At Coonoor, it was found infested with *X. astia*, *X. cheopis*, *X. brasiliensis* and *Ceratophyllus* fleas, the specific flea indices decreasing in the same order. Its cheopis index was 1.2 during this enquiry.

Bush rats (*Golunda species*).—More than one species of Golunda are said to prevail in the Nilgiris, but all the specimens we got, except one not yet identified, were *Golunda ellioti*. In this hill station, the bush rat is found to harbour very few fleas. When present, these are either *Ceratophyllus* or *Stivalius*. On the other hand, in the Cumbum Valley these rodents are found to harbour only *X. astia* and no *X. cheopis*. The bush rat is easily identified by its flat ears, longitudinally grooved incisor teeth and the characteristic yellowish brown coat. It is a poor burrower, the nest, generally composed of coarse grass, leaves and small twigs, being usually found in shallow pits or in discarded burrows of other rodents. Its favourite habitat is under cover of thick hedge growths on the edges of cultivated fields where its characteristic runs can easily be recognized. As it usually confines itself to its own trodden path, it is easily led into traps laid along the runs. Though it is susceptible to plague, it may be said to possess only a negligible rôle as a reservoir of plague as it harbours few fleas and seldom *X. cheopis*.

Field mice (*Leggada booduga* Gray).—The field mouse prevails largely in cultivated fields and lawns. It is easily recognized from the house mouse by its smaller size and yellowish brown dorsal and white ventral coat. Although it is quite susceptible to plague, its rôle in the spread of plague is negligible since it carries very few fleas.

Flea counts.—The following table (I) gives the percentages of various fleas found on *R. rattus*, *B. malabarica* and *Gunomys kok* during the present enquiry as compared with those from a survey carried out by one of us (P. V. G.) in 1929.

TABLE I

Place	Rodents	Number of Rodents	Number of Fleas	X. a.	X. b.	X. c.	C. n.	Stiv.	L. m.
Coonoor (1939)	*R. rattus*	243	1,038	8.7	37.9	40.5	3.5	0.2	1.2
	B. malabarica	12	81	74.1	7.4	14.8	2.5	..	..
	Gunomys kok	81	269	1.5	5.6	0.4	9.2	84.4	..
Ootacamund (1929)	*R. rattus*	77	276	9.7	14.5	49.0	22.6	..	3.7
	Gunomys kok	8	24	..	8.3	8.3	83.3	..	..

X. a. = *Xenopsylla astia*.
X. b. = „ *brasiliensis*.
X. c. = „ *cheopis*.
C. n. = *Ceratophyllus nilgiriensis*.
Stiv. = *Stivalius* sp.
L. m. = *Leptopsylla musculi*.

The above table clearly shows that the predominating flea on Gunomys in Coonoor is *Stivalius* and in Ootacamund, *Ceratophyllus*. The flea which predominates on the bandicoot is *X. astia*, though *X. cheopis* also are largely present. On *R. rattus*, which is primarily concerned with epidemic plague, the flea which predominates in both towns is *X. cheopis* and next in order *Ceratophyllus* in Ootacamund and *X. brasiliensis* in Coonoor. Expressed more scientifically, the cheopis index of *R. rattus* (average number of cheopis per rat) for Coonoor (1939) was 1.73 and for Ootacamund (1929) it was 1.75. This evidence of parasitology may alone explain the endemicity of plague in the Nilgiris district. Thus, Hirst (1927) states that a cheopis index of one associated with moderate density of rat population would indicate potential danger of plague epizootics.

Examination of rodents and fleas.—All rodents obtained were carefully autopsied and those with suspicious signs were studied by cultural methods, animal inoculation, smear examination, etc. Three carcasses of *R. rattus* examined from Iduhatty village proved positive to plague. One hundred and twenty live fleas were collected from these specimens and plague infection proved in them. About half the number of these infected fleas were examined alive in capillary tubes. One of those (*X. brasiliensis*) which suggested infection from the blocked condition of its proventriculus was fed on a white mouse. The mouse contracted infection from this bite and succumbed on the 8th day with signs of acute plague, later confirmed by animal passage. No definite positive signs of plague were noted in any of the other rodents or fleas examined. It may be noted that they were mostly collected from areas where there has been no recent infection.

(2) *Plague transmission experiment with Stivalius and Ceratophyllus fleas.*—*Stivalius* fleas are plentiful in the Nilgiris, especially in and around Coonoor. They appear to become fewer as the altitude increases beyond Coonoor. Three sub-species of this flea, *Stivalius ahalæ*, *Stivalius aporus* and *Stivalius ferinus*, have been described by Jordan and Rothschild from the Nilgiris. The similarity between these sub-species is rather close, and while the sorting of killed, cleared, and mounted specimens is not difficult, the sorting of live ones requires considerable experience. Ordinarily for biological transmission experiments one should work with each sub-species separately. In the present work, however, for want of sufficient time in rearing individual species of fleas in artificial nurseries, *Stivalius* fleas collected off *Gunomys kok*, presumably a natural mixture of all the prevailing sub-species, were employed for the transmission experiments. While the results obtained may be deemed to fall short of strict biological accuracy regarding each of the sub-species, they must be true with respect to one or other of all of them, and therefore should satisfy all the requirements for practical application.

Five transmission experiments were carried out—*vide* table II for details. Special transmission cages of the type employed by the Plague Research Commission in India, obtained on loan from the Haffkine Institute, Bombay, were employed. White mice were used as the animal hosts, as these are said to have a uniform susceptibility to plague, and are, further, easy to handle. Every technical precaution was adopted to eliminate the chances of extraneous rats or fleas having access to the transmission cages, or the escape therefrom of infected animals or fleas. For each experiment a white mouse was artificially inoculated by the cutaneous

TABLE II

Protocol of transmission experiments

Number	White mouse infected	Flea species with number employed	Introduction of fleas on to infected mouse	Death of infected mouse	Introduction of test mouse	Death of test mouse	Result of examination of: Mouse — Post-mortem signs of plague	Mouse — Smears	Mouse — Culture	Surviving fleas — Smears	Surviving fleas — Culture
1	12-6-39	*Stivalius* species (14) ..	17-6-39	22-6-39	22-6-39	25-6-39	+	+	Not done.	Not done.	Not done.
2	1-7-39	Do. (20) ..	2-7-39	4-7-39	7-7-39	* 17-7-39	+	+	–	+	–
3	1-7-39	Do. (20) ..	3-7-39	4-7-39	7-7-39	* 17-7-39	+	+	–	+	+
4	1-7-39	*Ceratophyllus nilgiriensis* (20).	2-7-39	3-7-39	3-7-39	† 6-7-39	–	–	–	Not done	Not done.
5	1-7-39	*Ceratophyllus nilgiriensis* (20).	3-7-39	4-7-39	7-7-39	12-7-39	–	–	–	+	+

* Test mouse killed. † Test mouse died of other causes.

route with a 48-hour broth culture of a recently isolated local strain of plague bacillus. Fleas purposely starved for a few days were introduced when the mouse showed signs of septicæmia preceding its fatal termination. To test the infectivity of these fed fleas, healthy mice were introduced after definite intervals. These test mice and the surviving fleas were tested for evidence of infection, either at the time of death of the mice or when the mice were killed about the time when the enquiry had to be wound up.

In the first experiment, where the fed fleas were put on the test mouse the same day, the latter died of acute plague on the third day. In the second and the third experiments, where the fed fleas were starved for 3 days, before being put on the test mice, the latter when killed showed certain post-mortem signs suggestive of plague and smears from their viscera showed plague bacilli. Pooled emulsion of the surviving fleas in the first experiment was injected into a guinea-pig which on being killed on the 14th day showed certain lesions of resolving plague. Crushed smears of fleas which survived the second and third experiments showed plague bacilli.

Employing similar technique, two experiments were carried out with *Ceratophyllus nilgiriensis*. One experiment had to be discounted as the test mouse died prematurely owing to other causes. In the second experiment, where fed fleas starved for 3 days were put on a test mouse the latter on being killed showed no evident post-mortem signs of plague. Two out of the 3 surviving fleas however showed numerous plague bacilli in their stomachs a week after they were fed on the infective mouse. Cultures from their stomach contents were also positive to plague.

It is clear from these experiments that *Stivalius* fleas can transmit plague at least up to 3 days after feeding on an infected host. If time had permitted the maximum period for which these fleas are capable of retaining infectivity could have been worked out and would have helped comparison. The flea which is infective for the longest period is really the most efficient vector, but such longevity experiments have been carried out only for very few of the known fleas. *X. cheopis* has been shown to remain infective for about a month under semi-natural conditions (George and Webster, *loc. cit.*).

It may also be reasonably concluded that *Ceratophyllus nilgiriensis* is at least a weak vector of plague among rodents inasmuch as they retained live plague bacilli in their stomachs for over a week. Another important point to be considered, in deciding the vector efficiency of these fleas, is whether they readily bite man. As there was plague in the district at the time, we did not experiment with the fleas collected from rats to ascertain this fact. Certain species of *Ceratophyllus* are already known to bite man readily, but we have not come across any authentic record about *Stivalius*. Local enquiry has not helped us in getting any information on this point, but if these fleas, which are unusually big in size, were really vicious human biters, like *Pulex irritans*, such information would have been readily forthcoming.

It is perhaps appropriate here to mention that another flea which prevails here and which is absent on rats in the plains is *Leptopsylla musculi*. No transmission experiments were done with this flea during this enquiry, but it is already known from Chinese workers that it is a weak vector of plague and that it only reluctantly bites man. The other fleas, *X. astia*, *X. brasiliensis*, *X. cheopis*, *Pulex irritans* and *Ctenocephalus*, most of which have been found to infest the field rodents as well as the domestic rodents of the Nilgiris, require to be discussed in this connection. The first three *Xenopsylla* fleas are all known to be good vectors of plague, the last (*cheopis*) being, of course, the most efficient of all known fleas. *Pulex irritans*, or the human flea, is largely prevalent all over the district to the extent of being a regular scourge. These fleas have been supposed by various workers to be capable of spreading plague, though convincing experimental proof is lacking. The need for their control is therefore to be emphasized, especially during plague epidemics. *Ctenocephalus* fleas are not good vectors of plague among the rodents, as they feed only very reluctantly on hosts other than their specific hosts, dogs, cats, cattle, etc.

Discussion.—As pointed out in the earlier part of this report, the usual seasonal variations in the incidence of plague are not evident in the Nilgiris district. The explanation may perhaps be found in a review of the ecology and vector efficiency of the indigenous plague fleas of the district. *X. cheopis*—the tropical plague flea—transmits plague best between 68° and 78°F., and when the saturation deficiency is below 0.3 inch of Hg. It is also known that certain fleas, such as *Ceratophyllus fasciatus*, of temperate climates transmit plague best at temperatures about 10 to 15° lower than the optimum for *X. cheopis*. Therefore, in areas where the biological factors concerned in the spread of plague, both of warm and cold climates, co-exist, it is possible that the infection may be carried over in relays from season to season. Thus the observation of Colonel Russell, *i.e.*, that seasonal variations in the incidence of plague in the Nilgiris is not very evident, may be explained as due to the co-existence and interplay of more than one efficient plague flea.

As examination of wild rodents and their fleas on an adequate scale could not be carried out during the limited period of this enquiry, no definite proof could be adduced either for or against the existence of sylvatic plague in the district. The examination of the small number of specimens collected did not yield any positive results. We are in agreement with K. F. Meyer (1939) that only animal inoculation tests with pooled emulsions of wild rodent fleas on an extensive scale could clinch the accuracy of the diagnosis of sylvatic plague. The crucial evidence of infection in wild rodents is difficult to obtain as their casualties occur either in their subterranean nests, or, if in the open, they fall a prey to carnivorous animals and birds. The report of Jellison (1939) on predatory and scavenger birds and their nests, offers the possible reason why it should be difficult for workers to detect plague infection in wild rodents during sylvatic plague surveys.

In the Nilgiris, the peculiar configuration of the land, the prevailing climatic conditions, the abundance of a variety of wild rodents and fleas (all complementary hosts and vectors of plague), the common occurrence of human and rodent plague sporadically in areas apparently independent of traffic and the occurrence of pneumonic plague more frequently than in the plains, are features which are in line with those in countries where sylvatic plague has actually been proved to exist. It is, therefore, suggested that sylvatic plague either actually exists now, or the factors are such as may contribute towards its onset at any time.

Summary

1. A review of the incidence of human plague in the Nilgiris district from 1903 to 1939 is given. Factors relating to sylvatic plague are also discussed.

2. A limited rodent and flea survey of the district with reference to plague has been carried out. One thousand and nineteen rodents and 1,939 fleas collected, formed the basis of this survey. All the specimens of rodents and fleas except those utilized for special experiments were examined for evidence of plague infection and the results are recorded. Plague infection was noted only in 3 rodents and 120 fleas, but these were collected from an infected area.

3. Transmission experiments with *Stivalius* and *Ceratophyllus* sp. were carried out and their vector-efficiency is discussed. *Stivalius* fleas transmitted plague to a white mouse 3 days after separation from an infected host. *Ceratophyllus nilgiriensis* were found to harbour plague bacilli in their alimentary tract up to 7 days after having fed on an infected host.

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REFERENCES

George, P. V., and Webster, W. J. (1934). *Indian J. Med. Res.*, **22**, 77.
Hirst, L. F. (1927). *Ceylon J. Sci.*, **1**, 277.
Jellison, W. L. (1939). *Pub. Health Rep.*, **54**, 792.
Meyer, K. F. (1939). *Amer. J. Pub. Health*, **29**, 1225.
Wu Lien Teh (1926). *A Treatise on Pneumonic Plague*. League of Nations, Geneva.

ON A PLASMODIUM SP. OF THE MALAY CHESTNUT-BELLIED MUNIA [*MUNIA ATRICAPILLA ATRICAPILLA* (VIEILL.)]

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Introduction.—During the examination of blood films from over 300 birds comprising fowls, a duck, a pigeon and a variety of sparrows and munias, parasitic infections due to a plasmodium were observed in three out of sixty-one specimens of the Malay chestnut-bellied munia [*Munia atricapilla atricapilla* (Vieill.)] examined. The infected birds had been imported and were obtained from dealers. Scott (1927) recorded a parasite of the order *Hæmosporidia* in the same host from a bird which had died in the Zoological Society's Gardens in London, but the infection was too scanty to enable him (and Wenyon) to determine whether it was *Plasmodium præcox* or a hæmoproteus.

Method of study.—In the present series of observations the strain was maintained by blood inoculation in the natural host and in the white-throated munia [*Uroloncha malabarica* (Linn.)] when the former was not available in the market. Both are small birds and 1/20 c.cm. of citrated blood was considered a suitable quantity for inoculation, either into the wing vein or intramuscularly into the leg.

Combined Leishman-Giemsa stain was used: prolonged staining was necessary to bring out the characteristic sex differences of the gametocytes.

Morphology (stained parasites).—The youngest form is a tiny rounded body consisting chiefly of chromatinic substance (figure 1). Soon a vacuole forms, the cytoplasmic content increases, and the parasite assumes the shape of a stout ring (figure 2). The ring stage, however, appears to be very transient, in that it is scarcely found even in blood showing heavy infections. As growth proceeds, pigment appears in the form of brown-black granules, and the cytoplasm looks spongy (figures 3 and 4). The growing parasite displaces the nucleus of the host cell to one side or more commonly