

A FURTHER NOTE ON NATURAL AND EXPERIMENTAL PLAGUE IN TARBAGANS¹.

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I. A SPONTANEOUS OUTBREAK OF PLAGUE AMONG TARBAGANS.

TOWARDS the end of May, 1923, we received information of two fatal cases of bubonic plague in man, one near Yakoshih (a village on the Chinese Eastern Railway, 168 miles east of Manchouli), and the other at Haranor (in Transbaikalia, 52 miles west of Manchouli); both victims were Russians who had hunted tarbagans and afterwards developed axillary buboes.

At the same time we obtained news of an epizootic among the tarbagans at Suktui, a village in Transbaikalia, 15 miles distant from the Trans-Siberian Railway and 30 miles from Manchouli, the frontier station of Manchuria.

The Russian authorities had established a post in the village with the purpose of investigating the natural occurrence of plague in tarbagans. They chose this site because periodic outbreaks of disease among these rodents are known to occur here, and, indeed, in the summer and autumn of 1921 they were able to obtain definite evidence of plague among the tarbagans.

Dr Pollitzer, Dr Kwan and myself journeyed from Harbin on June 2nd, arrived at Suktui on June 10th, and returned to Harbin on June 23rd. Dr Sukneff, the head of the Russian Plague Detachment, a keen, friendly and experienced investigator, kindly gave us an account of his findings and demonstrated his specimens to us, thereby convincing us that the mortality among the tarbagans in the district was due to plague. On June 10th Dr Sukneff gave us the opportunity of dissecting a tarbagan found on the previous day in the Barun Zasulan valley, 6½ miles south-east of Suktui. The post-mortem findings on this animal were as follows:

Autopsy on Tarbagan: Large superficial bubo on left side of neck; salivary glands oedematous and congested; cervical glands on left side much enlarged, showing caseous and

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purulent matter on section. Glands on right side of neck swollen but not purulent. Spleen enlarged and soft. Liver swollen and congested. Some clear liquid in pericardial sac. Both lungs showed congested areas, especially the right lung almost the whole lower lobe of which was affected. *B. pestis* present in smears of all organs. Cultures and inoculation experiments on guinea-pigs gave positive results for plague.

Summary of results of Histological Examination:

(a) *Cervical bubo*: A portion of the caseating area was cut. There was marked leucocytic infiltration adjoining the caseating region; *B. pestis* in isolated masses found in and around malpighian bodies; haemorrhages in lymph spaces; capsule of gland infiltrated. (b) *Sub-maxillary Salivary gland*: Intense infiltration; haemorrhages into and around acini; *B. pestis* in small numbers among lobules; epithelial cells of acini mostly show granular degeneration; lymph spaces invaded by red blood corpuscles. (c) *Lungs*: A portion of congested area of right lung was cut. It showed marked early pneumonia; most alveoli invaded by red corpuscles and leucocytes; some alveoli collapsed. Many *B. pestis* in alveoli and interalveolar spaces; proliferation of cells of infundibulae; intense reaction. (d) *Spleen*: Lymph nodules darkly stained; *B. pestis* in great numbers in and between malpighian bodies; capsule infiltrated; blood vessels dilated; lymph spaces invaded by red corpuscles.

Note. On June 23rd, after our departure, a decomposed tarbagan was found in the same valley. A guinea-pig inoculated with material from this tarbagan died of typical plague.

We brought back to Harbin four strains of *B. pestis* which had been isolated from three tarbagans by the Russian Commission. These strains conformed to the usual cultural tests for *B. pestis*, and killed guinea-pigs with typical signs of acute plague, when rubbed in the skin.

II. EXPERIMENTAL INFECTION OF HIBERNATING TARBAGANS.

Zabolotny and Tchurilina (1911) using tarbagans, and Dujardin-Beaumetz and Mosny (1912) using European marmots, found that when these animals were inoculated with plague while in the hibernating state, the infection ran an unusually prolonged course before death ensued.

During the winter 1922-1923 we exposed to infection six hibernating tarbagans, three by spraying, two by way of the nostrils, and one by the cutaneous method. The illness lasted from seven to eighty-six days, and all the animals died. Two showed the signs of acute plague; in two the appearances suggested those of "resolving plague"; and two showed no definite evidence of plague.

III. THE ECTO-PARASITES OF THE TARBAGAN.

In a recent paper Jettmar (1923) gives a detailed list of the ecto-parasites of the tarbagan; these include the tarbagan flea, *Ceratophyllus silantievi* Wagner (Wagner, 1898), lice (*Polyplax*) and ticks (*Rhipicephalus*).

(a) *The ability of the tarbagan flea to bite man.*

Petrie (1911) found that this flea is able to bite man. In a supplementary note (1912) he states that a description of it is given by Tiraboschi (1903-1904), who recognised its importance as a possible carrier of plague infection; and that Dudchenko (1909) noted that "in the fur of the tarbagan there are always numerous fleas with a long body and reddish-brown colour. . . . The fleas do not

Table I. *Winter Experiments* 1922-23.

No. of tarbagan	Date of infection	Mode of infection	Condition during experiment	Date of death	Days sick	Autopsy result
T. 197	9. xi.	Inhaled	Continuously feverish	16. xii.	37	Chronic plague
T. 223	27. xi. 14. xii.	„	Hibernating	25. ii.	59	Smears suspicious, but cultures sterile
T. 233	21. ii.	„	„	14. iii.	21	Acute plague
T. 238	21. ii.	„	„	3. iv.	41	Resolving plague (?)
T. 231	8. iii.	„	Feverish	13. iii.	5	Acute plague
T. 232	18. iii.	„	„	14. iii.	6	„ „
T. 224	19. ii.	Nostrils	Hibernating	26. ii.	7	„ „
T. 250	1. iii.	„	„	26. v.	86	Negative for plague
T. 241	30. i.	Cutan.	„	14. iv.	74	Resolving plague (?)
T. 236	12. iii.	Conj.	Slight local reaction, feverish	29. iii.	17	Subacute plague
T. 251	2. iii.	„	Sick, not hibernating	28. v.	157	No signs of plague
T. 213	11. xi.	Contact	Hibernating	12. i.	62	No signs of plague. Fed Corpse 197 16. xii.
T. 234	26. xi.-14. iii.	Contact from fed Corpse 232	Hibernating	19. iii.	113	Acute plague (intestine affected?)

live on man, but, if opportunity offers, they bite him. The bites produce red spots and sometimes swellings resembling urticaria.” Some months later, in 1911, the author (W. L. T.) proved in a number of experiments that *Ceratophyllus silantiewi*, when hungry, readily fed upon man. Dudchenko (1915) mentions an instance where, in the process of digging up a tarbagan burrow, one of his workmen was bitten by a flea, which proved to be the specific flea of the tarbagan. Jettmar (1923) also notes the ability of this flea to imbibe human blood.

(b) *Author's Experiments.*

The following record relates to recent experiments of ours with *C. silantiewi*:

23. v. 1923: Two fleas (a) and (b) which had been starved for four days were used. Flea (a) bit a man, remaining attached to his skin for 31 minutes; flea (b) refused to bite.

25. v. 23: Flea (a) again bit a man for ten minutes.

26. v. 23: Flea (a) bit a healthy guinea-pig for ten minutes.

31. v. 23: Flea (c) was allowed to bite a plague-infected guinea-pig for ten minutes. Next day it was fed on a healthy tarbagan and a healthy guinea-pig, but both animals remained well. This flea survived for 18 days, when, after its death, it was ground up in saline solution; the emulsion was injected intraperitoneally into a guinea-pig, but no plague resulted.

Later experiments showed the periods of attachment of tarbagan fleas to the skin of human beings to be 13, $4\frac{1}{2}$, 3, and 2 minutes respectively. We have seen only on one occasion a flea deposit its faeces on the skin, but never while biting.

We may add here that ticks (over 30) were repeatedly given the chance but refused to bite; a louse bit a man for 5 minutes.

(c) *Seasonal variations in the numbers of fleas infesting the tarbagan.*

The available data are as follows: (1) Petrie at the time of the Mukden Conference (April, 1911) reported that the numbers of fleas on twelve tarbagans (brought from Manchouli to Mukden, a distance of 925 miles) were 2, 2, 2, 3, 0, 2, 2, 5, 2, 0, 12, 3, respectively, an average of 3 fleas per tarbagan. (2) The author (W. L.-T.) examined a number of freshly caught tarbagans from August to September, 1911, in Mongolia, and found the flea-rate to vary within wide limits. On one animal 94 fleas were caught, and the number on each was seldom less than 5; the average was over 10. Occasional observations made by Russian medical men (Wassilewski and others) also suggest a high flea-rate in the autumn. (3) Our flea counts in May—June, 1923, were as follows:

At Manchouli. May 19th: 20, 2, 0, 1, 0, 1, 0, 0 fleas on 8 animals examined.

At Harbin. May 29th: 0 fleas on 14 animals freshly arrived from Manchouli (584 miles).

At Manchouli. June 6th. Two tarbagans arrived on the previous evening and were kept in a tin bucket. Next morning one was found dead; 4 fleas, 6 ticks and 4 lice were taken from it. The surviving animal had no fleas.

At Manchouli. June 6th: 0, 0, 1, 0, 0 fleas on 5 animals examined.

„ „ 7th: 0, 3, 1 „ „ 3 „ „

„ „ 9th: 0, 0, 0, 0, 0, 1, 0, 2 „ „ 8 „ „

The figures indicate that the flea-average in spring is small, when compared with that in autumn, and in this respect are significant because human plague is generally reported from Siberia towards the end of summer or in the autumn, that is, during the season for hunting the tarbagan and during the harvest, when human beings come into contact with this animal.

IV. THE MODE OF SPREAD OF TARBAGAN PLAGUE AND OF THE ASSOCIATED HUMAN INFECTION.

The mode of spread of plague-infection among tarbagans: Strong, the chief delegate of America to the International Plague Conference, read a paper in April, 1911, which showed that the tarbagan is susceptible to acute plague; and Zabolotny and Tehurilina two months later proved the existence of spontaneous plague infection in a tarbagan.

The Russian investigators have since obtained ample proof of epizootic plague in tarbagans and of associated human infections. Petrie (iv. 1911) gave a brief account of the flea infestation of the tarbagan and pointed out the significance of his observations, when considered in the light of knowledge of the transmission of plague amongst rats by means of the rat flea. We have attempted a number of experiments with fleas, lice and ticks from tarbagans, but have up to now failed to obtain a positive result. One difficulty in conducting such experiments is that the tarbagan is a strong vicious animal, not easily handled; its mode of life in wild remote districts is an added difficulty.

The number of cases of natural infection that we have been able to collect from various sources is small (13), but they include examples of cervical, inguinal, and axillary buboes, a distribution that is consistent with a skin infection caused by plague-infected fleas. Although the tarbagan is by nature herbivorous, we have often seen it devouring the carcass of its mates, when kept in confinement. But this means of transmission, if it occurs naturally, must be very rare.

Table II. *Tarbagans with Natural Plague.*

No.	Date found	Locality	Remarks
1	Autumn 1907	Between Lake Dalainor and Manchouli	No buboes, lungs free. Suspicious chronic plague.
2	17. vi. 1911	Lake Charbada	Decomposed. Right axillary bubo. Smears and cultures positive. Expts. negative.
3	24. vi. 1911	Sharasun	Cervical buboes. Haemorrhage in lungs. Expt. on tarbagan positive.
4	26. vi. 1911	Arabulak	No buboes, lungs free. Expt. upon mice positive.
5	16. ix. 1921	Kinkija (5 v. from Sektui)	Cervical and axillary buboes. Haemorrhage lungs. Guinea-pig expt. positive.
6	19. ix. 1921	"	Inguinal buboes. Otherwise as under (5).
7	ix. 1921	"	Remnants only. Smears from muscle positive.
8	22. ix. 1921	Barun Zasulan (10 v. from Sektui)	Cervical bubo. Smears positive.
9	29. iv. 1923	Chistokina (1½ v. from Sektui)	No buboes. Lungs congested. Smears positive. Cultures and expts. negative. Dissected two days after being found.
10	4. vi. 1923	Barun Zasulan	Decomposed. Left cervical bubo. All tests positive.
11	8. vi. 1923	"	No buboes. Haemorrhagic foci in lungs. Nodes in spleen. All tests positive.
12	9. vi. 1923	"	Cervical buboes. Haemorrhagic foci in lungs. All tests positive.
13	23. vi. 1923	"	Decomposed. Left axillary and left cervical buboes. Pneumonic areas in lungs. Guinea-pig expt. positive.
14	4. vii. 1923	Substation 82	Remnants only. Smears from muscle positive.
15	21. vii. 1923	Sun Zasulan	" " "
16	25. vii. 1923	Barun Zasulan	Complete specimen. Harbin museum. Cervical buboes. Pneumonic areas in lungs. All tests positive.

Table II shows that the naturally infected tarbagans were mostly confined to an area around Sektui. The plague detachment worked about this district because of its regular periodic outbreaks. It is possible that other foci might have been located if the same attention had been paid to them, but difficulties of communication and transportation have to be considered.

The mode of conveyance of the plague bacillus from the tarbagan to man: Petrie (iv. 1911) expressed the view that the ability of the tarbagan flea to bite man helped to explain the mode of transference of the infection from the tarbagan to man in bubonic cases. He also noted the possibility that a bubonic or septicaemic case in man originating in this way, might, if a secondary plague pneumonia supervened, give rise to a case of primary pneumonic plague. We think that the risk of transference of the infection by the means of the tarbagan flea is easily conceivable amongst those who hunt this animal or use it as food; but, obviously, direct evidence on this point is difficult to obtain. A concurrent

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risk is that abrasions or small wounds of the hands may become infected as the result of handling infected tarbagans. In a number of instances the infection has been attributed to eating tarbagan flesh, but there seems to be no real foundation for this supposition, and, having regard to the generally accepted view that primary intestinal plague in man is rare or non-existent, it is necessary to receive such reports with scepticism, if unsupported by precise data.

CONCLUSION.

The Delegates to the International Plague Conference¹, which was held in Mukden in April, 1911, at the invitation of the Chinese Government, reached the conclusion, from the evidence presented to them, that "there is strong presumption for believing that tarbagan disease is closely associated with pneumonic plague in Manchuria, Transbaikalia, and north-east Mongolia, and, therefore, with the recent outbreak" (1910-1911).

We now consider it as practically certain that the tarbagan gives rise to the outbreaks of plague which occur almost yearly in Transbaikalia and that it started the outbreaks in Manchuria in 1910-1911 and 1920-1921.

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¹ The signatories of the report of the delegates to the Chinese Government are: Strong, U.S. of America; Worell, Austria-Hungary; Broquet, France; Martini, Germany; Petrie, Great Britain (with the late Dr R. Farrar and Dr D. G. Gray); Galeotti, Italy; Kitasato, Japan; Gonzalez-Fabela, Mexico; Hehewerth, Netherlands; Zabolotny, Russia; and Wu Lien Teh, China.