Trypanosomes of the Domestic Animals in Nyasaland. I. *Trypanosoma simiæ*, sp. nov. Part II.—*The Susceptibility of Various Animals to T. simiæ.*

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Introduction.

In a previous paper* the morphology of this interesting species of trypanosome was described, and it is now proposed to give an account of its action on animals.

One of the first interesting points to be noted about this species is that, as far as is known, the warthog (*Phacochœrus ætheopicus*) is the only animal among the wild game of this district which harbours it.† It is probable that it will also be found in the blood of the bush-pig, but not a single specimen of this animal has as yet been obtained by the Commission. The warthog is numerous in the low country in this neighbourhood, which accounts for the large number of tsetse flies found to be infected with *Trypanosoma simiæ*.‡

It is to be regretted that this species was not named after the warthog instead of the monkey, but at the time the name *Simiæ* was taken the Commission was ignorant of the close connection which exists between the former animal and this parasite.

Another interesting feature in regard to this trypanosome is the virulence it displays towards monkeys and the domestic pig, killing these animals in an incredibly short period of time, whereas it is harmless to oxen, antelope, dogs, and the smaller experimental animals. Curiously enough, this trypanosome also infects goats and sheep, although oxen and antelope escape.

The rapidity with which the virulence of *T. simiæ* becomes modified is also remarkable. When a cage containing wild *Glossina morsitans* is placed on a monkey and a goat, both animals take the disease, and the monkey in such an acute form that the average duration of life is only a few days. But if it is attempted to pass *T. simiæ* from an infected goat to a healthy monkey by the inoculation of the goat's blood, the experiment usually fails, showing

* 'Roy. Soc. Proc.,' 1912, B, vol. 85, pp. 477–481.

† *Ibid.*, "Trypanosomes found in Blood of Wild Animals."

‡ *Ibid.*, "Infectivity of *Glossina morsitans* in Nyasaland."

that a short sojourn in the blood of the goat has almost nullified the virulence of the parasite for the monkey.

T. simiæ belongs to the same group as *T. pecorum*, and it is curious that in the latter species this loss of virulence also occurs. If *T. pecorum*, which is usually more or less infective to the monkey, dog, and rat, lives for some time in the blood of the goat, it loses its power of infecting the other animals. This has given rise to the erroneous idea that a separate species—*T. nanum*—exists. *T. nanum* is in truth nothing but a strain of *T. pecorum* which has lost its virulence for these other animals by its passage through the goat.

T. simiæ is also like *T. pecorum* in general appearance, and in fact it is often difficult or impossible to distinguish between a short individual of the former species and a long one of the latter. The average length of *T. simiæ* is 17·5 microns, with a minimum of 14; the average length of *T. pecorum* is 14 microns, with a maximum of 18. When the coloured plates of the two species are compared this resemblance is at once seen. There is the same well-developed undulating membrane, the same oval nucleus, situated about the middle of the body, and the same eccentrically-placed micronucleus, often appearing to project beyond the margin, as noted in the description of the morphology of *T. simiæ*.

These two species, however, differ essentially in their action on animals. Whereas *T. simiæ* expends its virulence on monkeys and pigs, *T. pecorum* is especially fatal to cattle, goats, sheep, and dogs.

ANIMALS SUSCEPTIBLE TO TRYPANOSOMA SIMIÆ, SP. NOV.

Table I.

Date.	No. of expt.	Source of virus.	Period of incubation in days.	Duration of disease, in days.*	Remarks.
		Cattle.			
1912.					
April 24...	485	From Monkey 405.....	—	—	Never showed trypanosomes.
„ 24...	486	„ 405.....	—	—	„ „
July 17...	904	From Goat 653	—	—	„ „
„ 17...	945	„ 653	—	—	„ „
		Antelope.			
Sept. 25...	1240	From Monkeys 1258 and 1259	—	—	Duiker. Never showed trypanosomes.
Nov. 5...	1238	From Monkey 1541 ...	—	—	Reedbuck. Never showed trypanosomes.
„ 5...	1240A	„ 1541 ...	—	—	Duiker. Never showed trypanosomes.
1913.					
Mar. 5...	1980	„ 1910 ...	—	—	Reedbuck. Never showed trypanosomes.
„ 5...	1981	„ 1910 ...	—	—	Duiker. Never showed trypanosomes.

* Duration includes the days of incubation; it dates from day of infection.

Table I—*continued.*

Date.	No. of expt.	Source of virus.	Period of incubation, in days.	Duration of disease, in days.*	Remarks.
		Goats.			
1912.					
Feb. 1...	109	Wild flies	17	55	Mixed infection.
„ 1...	117	From Monkey 20	11	50	„ „
„ 3...	125	Wild flies	7	36	„ „
„ 9...	175	„	20	88	„ „
„ 19...	247	„	21	30	„ „
„ 27...	262	„	9	—	Still alive after 398 days.
Mar. 23...	363	„	6	42	Mixed infection.
April 19...	428	„	6	13	Died of *T. simiæ*.
„ 24...	425	From Monkey 405.....	22	—	Still alive after 341 days.
„ 24...	426	„ 405.....	—	—	Never showed trypanosomes.
„ 29...	429	Wild flies	12	42	Mixed infection.
May 14...	279	„	16	54	Died of *T. simiæ*.
„ 15...	416	„	5	19	Mixed infection.
„ 18...	553	„	11	112	„ „
June 1...	571	„	11	23	„ „
„ 4...	620	„	3	30	Died of *T. simiæ*.
„ 19...	653	From Goat 620	8	29	„ „
„ 19...	654	„ 620	8	107	„ „
„ 19...	710	„ 620	8	50	Mixed infection.
Aug. 21...	1117	From Warthog 1139...	40	—	Still alive after 222 days.
„ 24...	1113	„ 1186...	23	—	„ „ 219 „
Sept. 12...	1311	„ 1308...	18	—	Killed October 3.
„ 20...	1461	From Goat 1113.....	9	—	Still alive after 183 days.
Oct. 3...	1470	„ 1311.....	21	—	„ „ 179 „
„ 14...	1483	„ 1461.....	14	—	„ „ 168 „
Nov. 5...	1550	From Monkey 1541 ...	6	—	„ „ 146 „
„ 5...	1551	„ 1541 ...	6	—	„ „ 146 „
„ 5...	1552	„ 1541 ...	6	—	„ „ 146 „
„ 15...	1601	From Pig 1585	3	—	„ „ 136 „
„ 20...	1613	Wild flies	9	—	„ „ 131 „
1913.					
Jan. 27...	1810	„	6	52	Mixed infection.
		Sheep.			
1912.					
July 11...	907	From Goat 653	5	36	Mixed infection.
		Pigs.			
Nov. 5...	1553	From Monkey 1541 ...	6	6	Died of *T. simiæ*.
„ 5...	1554	„ 1541 ...	6	6	„ „
„ 5...	1555	„ 1541 ...	6	7	„ „
„ 11...	1585	From Pig 1555	4	5	„ „
„ 15...	1600	„ 1585	3	4	„ „
„ 18...	1609	„ 1600	3	4	„ „
„ 18...	1611	Wild flies	3	7	„ „
„ 23...	1631	From Goats 1113, 1434, 1461, 1470, and 1483	—	—	Never showed trypanosomes.
„ 25...	1636	Wild flies	13	98	Mixed infection.
Dec. 3...	1665	„	6	17	„ „
„ 6...	1674	„	3	10	„ „
„ 11...	1683	„	3	5	Died of *T. simiæ*.
„ 16...	1701	„	6	12	Mixed infection.
1913.					
Jan. 24...	1801	„	3	4	Died of *T. simiæ*.

* Duration includes the days of incubation ; it dates from day of infection.

Table I—*continued.*

Date.	No. of expt.	Source of virus.	Period of incubation, in days.	Duration of disease, in days.*	Remarks.
		Baboons.			
1912.					
April 30...	499	From Monkey 449.....	—	—	Never showed trypanosomes.
„ 30...	500	„ 449.....	—	—	„ „
„ 30...	501	„ 449.....	—	—	„ „
		Monkeys.			
Jan. 20...	20	Wild flies	7	9	Died of *T. simiæ*.
„ 24...	55	„	9	9	„ „
„ 29...	54	„	5	12	„ „
Feb. 2...	49	„	6	8	„ „
„ 6...	59	From Monkey 55	6	8	„ „
„ 8...	58	Wild flies	11	—	Still alive after 318 days.
„ 13...	219	„	7	9	Mixed infection.
„ 27...	286	From Dog 211	6	52	„ „
Mar. 9...	326	From Goat 175	—	—	Never showed trypanosomes.
Apr. 15...	405	Wild flies	5	—	Killed April 24.
„ 18...	447	„	9	—	Still alive after 159 days.
„ 18...	448	„	8	12	Died of *T. simiæ*.
„ 19...	404	„	5	6	„ „
„ 19...	449	From Monkey 404.....	3	10	„ „
„ 23...	465	Wild flies	4	8	„ „
„ 24...	480	From Monkey 405.....	8	10	„ „
„ 26...	488	Wild flies	10	13	„ „
„ 27...	492	From Dog 436	5	63	Mixed infection.
„ 27...	495	Wild flies	7	11	Died of *T. simiæ*.
May 3...	504	„	12	11	„ „
„ 8...	523	„	4	5	„ „
„ 9...	521	„	5	7	„ „
„ 14...	545	„	3	6	„ „
„ 24...	576	From Monkey 545.....	10	14	„ „
„ 31...	601	Wild flies	6	31	Mixed infection.
June 11...	629	„	11	17	Died of *T. simiæ*.
July 17...	906	From Goat 653.....	8	11	„ „
Sept. 18...	1404	„ 1113.....	—	—	Never showed trypanosomes.
„ 18...	1405	„ 1113.....	—	—	„ „
„ 28...	1404	„ 1113.....	—	—	„ „
„ 28...	1405	„ 1113.....	—	—	„ „
Oct. 3...	1468	„ 1311.....	—	—	„ „
„ 3...	1476	„ 1117.....	—	—	„ „
„ 14...	1404	„ 1461.....	—	—	„ „
„ 14...	1405	„ 1461.....	—	—	„ „
„ 23...	1515	Wild flies	6	8	Died of *T. simiæ*.
„ 29...	1404	From Goat 1483.....	—	—	Never showed trypanosomes.
„ 29...	1405	„ 1483.....	—	—	„ „
„ 29...	1535	„ 1483.....	—	—	„ „
Nov. 1...	1541	From Monkey 1515 ...	3	—	Killed for inoculation purposes.
„ 1...	1542	„ 1515 ...	3	11	Died of *T. simiæ*.
„ 11...	1583	From Pig 1555	3	20	„ „
„ 11...	1584	„ 1555	3	—	Still alive after 140 days.
„ 11...	1586	Wild flies	7	12	Died of *T. simiæ*.
„ 19...	1614	From Goat 1601.....	—	—	Never showed trypanosomes.
„ 19...	1617	„ 1550.....	—	—	„ „
„ 27...	1663	„ 1601.....	8	—	Still alive after 124 days.

* Duration includes the days of incubation; it dates from day of infection.

Table I—*continued.*

Date.	No. of expt.	Source of virus.	Period of incubation, in days.	Duration of disease, in days.*	Remarks.
		Monkeys—*continued.*			
1912.					
Nov. 28...	1404	From Monkey 1586 ...	—	—	Never showed trypanosomes.
Dec. 7...	1677	From Goat 1550.....	—	—	,, ,,
,, 11...	1681	Transmission expt. ...	11	23	Died of *T. simiæ*.
,, 14...	1697	From Goat 1551.....	—	—	Never showed trypanosomes.
,, 14...	1698	,, 1601.....	—	—	,, ,,
1913.					
Jan. 16...	1772	Wild flies	14	—	Still alive after 74 days.
		Average	7·6	10·8	
		Dogs.			
1912.					
Feb. 6...	119	From Monkey 55	—	—	Never showed trypanosomes.
,, 6...	128	,, 55	—	—	,, ,,
,, 6...	130	,, 55	—	—	,, ,,
,, 16...	211	Wild flies	—	—	,, ,,
,, 24...	250	From Monkey 219.....	—	—	,, ,,
,, 24...	251	,, 58.....	—	—	,, ,,
,, 24...	254	,, 58.....	—	—	,, ,,
,, 24...	258	,, 219.....	—	—	,, ,,
Mar. 9...	320	From Goat 175	—	—	,, ,,
,, 9...	321	,, 125	—	—	,, ,,
,, 9...	319	,, 175	—	—	,, ,,
,, 9...	322	,, 125	—	—	,, ,,
,, 9...	325	From Monkey 286.....	—	—	,, ,,
,, 13...	330	,, 58.....	—	—	,, ,,
April 5...	409	,, 58.....	—	—	,, ,,
,, 12...	436	Wild flies	—	—	,, ,,
,, 24...	481	From Monkey 405.....	—	—	,, ,,
,, 24...	482	,, 405.....	—	—	,, ,,
,, 27...	489	,, 449.....	—	—	,, ,,
,, 27...	490	,, 449.....	—	—	,, ,,
Oct. 3...	1469	From Goat 1311.....	—	—	,, ,,
,, 29...	1520	,, 1483.....	—	—	,, ,,
		Rabbits.			
Oct. 29...	1522	From Goat 1483.....	—	—	Never showed trypanosomes.
,, 29...	1523	,, 1483.....	—	—	,, ,,
Nov. 5...	1543	From Monkey 1541 ...	—	—	,, ,,
,, 5...	1544	,, 1541 ...	—	—	,, ,,
,, 5...	1545	,, 1541 ...	—	—	,, ,,
Dec. 14...	1543	From Pig 1636	—	—	,, ,,
,, 14...	1544	,, 1636	—	—	,, ,,
,, 14...	1545	,, 1636	—	—	,, ,,
,, 24...	1714	Wild flies	7	11	Mixed infection.
1913.					
Jan. 28...	1827	,, ...	9	—	Mixed infection. Still alive after 62 days.

* Duration includes the days of incubation; it dates from day of infection.

Table I—*continued.*

Date.	No. of expt.	Source of virus.	Period of incubation, in days.	Duration of disease, in days.*	Remarks.
		Guinea-pigs.			
1912.					
April 24...	483	From Monkey 405.....	—	—	Never showed trypanosomes.
Oct. 29...	1524	From Goat 1483.....	—	—	,, ,,
Nov. 5...	1546	From Monkey 1541 ...	—	—	,, ,,
,, 5...	1547	,, 1541 ...	—	—	,, ,,
1913.					
Jan. 4...	1731	Transmission expt. ...	—	—	,, ,,
		Rats.			
1912.					
April 24...	484	From Monkey 405.....	—	—	Never showed trypanosomes.
,, 27...	491	,, 449.....	—	—	,, ,,
Oct. 29...	1521	From Goat 1483.....	—	—	,, ,,
Nov. 5...	1548	From Monkey 1541 ...	—	—	,, ,,
,, 5...	1549	,, 1541 ...	—	—	,, ,,

* Duration includes the days of incubation; it dates from day of infection.

Action of T. simiæ *on Horses, Oxen, and Antelope.*—There has been no opportunity of testing the action of *T. simiæ* on equines. Four oxen were inoculated, two from an infected monkey and two from a goat, but all four remained in good health. Five antelope in confinement were also inoculated without result, and it would seem that these animals are really refractory, since in no instance has *T. simiæ* ever been found in the blood of antelope.

Disease set up in Goats and Sheep by T. simiæ.—Thirty-one goats and one sheep were infected by this parasite, as the result of various experiments. Fifteen of these were used in wild *G. morsitans* feeding experiments, three had warthog blood injected into them, and 14 were inoculated with the blood of infected experimental animals. It has already been remarked that this species of trypanosome varies rapidly in its virulence or power of setting up disease in animals. Its virulence would appear to be exalted by passage through the "fly," or, at least, to have reached its highest virulence after passage through the "fly," and lowered by passage through certain animals. For example, of the 15 goats infected by the bite of the "fly," 13 died, on an average, in 46 days, and only two recovered. The three goats which were infected by the direct injection of warthog blood all recovered; this is curious when it is remembered that in all probability the "fly" must get its infection solely from this animal. Six goats were injected with the blood of "fly"-infected monkeys; only one died, four recovered, and one proved refractory.

Six goats were also infected from goats; of these, three died and three recovered. This variation in virulence may also be expressed, for the sake of clearness, in the following table:—

Table II.—Mortality among Goats infected in Various Ways by *T. simiæ*.

	Mode of Infection.			
	Wild *G. morsitans* feeding.	Warthog blood, injection of.	Monkey blood, injection of.	Goat blood, injection of.
Percentage of deaths	86·7	0·0	16·7	50·0
No. of goats employed	15	3	6	6

What does this table show? It is meant to show that if goats are infected with *T. simiæ* directly by the bite of the "fly," most of them will die, whereas if the parasite is passed for a generation or two through goats, monkeys, or the warthog, the rate of mortality for the goat will fall. But it may be objected that the six goats which were infected with goat's blood have a mortality of 50 per cent., which is almost as large as the wild *G. morsitans* feeding experiments. But if Table I be referred to, it will be found that the three fatal cases were inoculated with blood from a goat which had only recently—some 10 days—been infected by the bite of the "fly," and ought, on account of the shortness of the time, to be included in the first, or "fly"-feeding, column; the other three, non-fatal cases, from goats infected by the injection of warthog's blood, should be included in the second column. If this were done, then the table would appear as follows:—

Table III.

	Mode of infection.		
	Wild *G. morsitans* feeding.	Warthog blood, injection of.	Monkey blood, injection of.
Percentage of deaths	90·0	0·0	16·7
No. of goats employed	18	6	6

It must be confessed, however, that the numbers are small and subject to a large margin of error, but the figures seem sufficiently remarkable to merit record. It may also be remarked that the matter is of little practical

importance, as under natural conditions goats will always be infected by the bite of the "fly"; but it is interesting as showing the fallacy of judging from the action of laboratory strains as to what will occur in nature.

Among the goats infected by wild *G. morsitans*, there are many cases of mixed infection. On referring to Table I it will be seen that there are 15 cases of infection by wild *G. morsitans* among the goats. Of these, only three were cases of pure infection with *T. simiæ*, the remaining 12 were mixed infections. These three died, on an average, in 32 days. There were 12 cases of mixed infection; of these, one recovered and the remaining 11 died, on an average, in 49 days.

From this it would appear that *T. simiæ*, acting alone, is as rapidly fatal to goats as it is when occurring in various combinations with *T. brucei*, *T. pecorum*, or *T. caprœ*. *T. simiæ* infection, when the result of the bite of the "fly," must therefore be looked upon as a fairly deadly enemy to goats.

During life this disease of goats is not marked by any special symptoms. There are neither swellings of the body, limbs, or face, nor corneal opacities, as is sometimes the case in other trypanosome diseases of goats: the animal merely becomes more and more anæmic and emaciated, and finally dies of exhaustion.

Disease set up in the Domestic Pig by T. simiæ.—In the whole range of the trypanosome diseases of animals there is surely nothing so striking as the rapidly fatal action of *T. simiæ* on the domestic pig. In nine experiments the average duration was only 5·3 days. This, not from the time of the appearance of the trypanosomes in the blood, but from the date of infection. Further, this rapid action is not the result of an exaltation of virulence by numerous passages through the pig, but natural to the trypanosome.

In regard to the symptoms of the disease during life, nothing noteworthy happens owing to the rapidity of the disease.

Disease set up in the Monkey by T. simiæ —This trypanosome is also remarkably fatal to the monkey. In 20 experiments with wild *G. morsitans* 17 monkeys died, the duration, on an average, being only 9·5 days from the day the flies were fed. Three are still alive after 318, 159, and 74 days, and have evidently recovered. When a monkey is inoculated with blood from an infected monkey the result is the same, the duration in five cases being 10·6 days. It will be seen, however, from Table I, that these five monkeys were all inoculated with blood from monkeys which had only very recently been infected by the bite of the "fly." On the other hand, when a monkey is inoculated with blood from a goat infected with *T. simiæ*, the result, as a rule, is negative. Ten monkeys were inoculated with blood of

"fly"-bitten goats and only one became infected; the other nine remained negative although the trypanosome had only been in the goats an average of 23 days. From this it would appear that *T. simiæ* loses its virulence for the monkey if exposed to the action of the living goat's blood for even so short a period as 12 or 14 days.

Action of T. simiæ *on the Dog.*—The dog appears to be immune to this species of trypanosome. Many experiments were made by feeding wild *G. morsitans* on dogs and by inoculating the blood of infected goats and monkeys. In not a single case did the trypanosomes appear in the blood nor did the dogs appear to be affected in any way. But in two "fly"-feeding experiments (211 and 436), although *T. simiæ* did not appear in the blood of the dogs on microscopical examination, yet the injection of their blood into monkeys gave rise to an infection with *T. simiæ*, showing that the parasite was present although in numbers too small to be detected by the microscope. It is possible, then, that the dog may act as a reservoir of this disease, but most improbable that it does so to any practical extent.

Action of T. simiæ *on Rabbits.*—The rabbit seems also to be practically immune to this disease. The injection of blood from infected goats, pigs, and monkeys has no effect. But on two occasions after feeding wild *G. morsitans* on rabbits, *T. simiæ* appeared in their blood, in one case (Experiment 1714) in large numbers, in the other (Experiment 1827) only rarely. Both these were examples of mixed infection, the former of *T. simiæ* and *T. pecorum*, the latter of *T. simiæ*, *T. pecorum*, and *T. brucei*. It was attempted to infect a rabbit by feeding on it a fly which was known to be infective with pure *T. simiæ*, but with no result.

This susceptibility, or non-susceptibility, of rabbits to *T. simiæ* is perhaps not a very important matter, but the experiments go to show that the natural mode of infection of trypanosome diseases by means of the "fly" is probably the most effective.

Action of T. simiæ *on Guinea-pigs and Rats.*—Both these species of animals appear to be refractory.

Table IV.—The Average Duration of Life in Various Animals infected by *T. simiæ*, Nyasaland. Mixed infections are not included. The duration includes the days of incubation; it dates from the date of infection. The letter R stands for refractory.

	Ox.	Antelope.	Goat and sheep.	Pig.	Baboon.	Monkey.	Dog.	Rabbit.	Guinea-pig.	Rat.
Average duration in days	R	R	46·6	5·3	R	10·8	R	R	R	R
No. of animals employed	4	5	5	9	3	24	21	10	5	5

Table V.—The Percentages of Recoveries in Various Animals from *T. simiæ* infection. This table includes mixed infections.

	Ox.	Antelope.	Goat and sheep.	Pig.	Baboon.	Monkey.	Dog.	Rabbit.	Guinea-pig.	Rat.
Percentages ...	R	R	37·5	0·0	R	14·3	R	R	R	R
No. of animals employed	4	5	32	13	3	35	21	10	5	5

The Carrier of T. simiæ, Nyasaland.

In Nyasaland the carrier of *T. simiæ* is *G. morsitans*, of which 3·4 per 1000 were found to be infected. A paper on the development of *T. simiæ* in *G. morsitans* is in course of preparation.

The Host, or Reservoir, of T. simiæ.

The warthog.—Thirty-three of these animals were examined, and *T. simiæ* found in three.

Conclusions.

1. *T. simiæ* belongs to the same group as *T. pecorum*, and, like the latter is erratic in its action on animals.

2. *T. simiæ* affects goats, sheep, pigs, and monkeys. Oxen, antelope, dogs, rabbits, guinea-pigs, and rats are practically immune.

3. The carrier is *G. morsitans*.

4. The reservoir of the virus is the warthog.