# THE QUESTION OF THE RELATION OF GAME ANIMALS TO DISEASE IN AFRICA

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The subject of the relation of game animals to the diseases of man and domestic animals in Africa is a very complicated one, and one the importance and scope of which can be adequately understood only by studying the problems of the whole continent and not those of a single district or Protectorate.

Now, there is a very important point in this subject which I should like to draw particular attention to, for it is most essentially important with regard to the preservation of game, on account of the rather general opinion that the game animals should be exterminated in many parts of Africa as a means of stamping out certain diseases. This point is the fact that, up to the present time, far too much attention has been concentrated upon game animals, while the possibility, or, as it is recently coming to light, the certainty of other wild animals being equally implicated has been almost entirely overlooked by the general public.

There are certain diseases in which the possibility must be taken into account of not merely game animals acting as reservoirs or hosts or distributors, but also other wild animals. These may be roughly classed as—

(*a*) The Trypanosomiases (or Tsetse-fly disease).
(*b*) The Piroplasmoses (East Coast Fever, &c.).
(*c*) Rinderpest and Gastro-Enteritis class.
(*d*) Intestinal parasites.

(*a*) Of these far the most important in relation to game are the trypanosomiases, and it is to this subject that the present paper is devoted. The East Africa Protectorate is not nearly so seriously affected by this class of diseases as other parts of Africa, because the districts which are infested by different species of tsetse flies (*Glossina*) are not those which are suitable for white settlement, as will be seen from the accompanying map. Probably the best idea of the position of

affairs in regard to the relation of game to the trypanosomiases will be obtained by a survey of some of the facts which have recently come to light during the investigations of the subject which have been taking place in various parts of Africa.

The following table, taken from 'Sleeping Sickness Bulletin,' No. 32, of December 1911, gives a concise summary of the animals in whose blood trypanosomes have already been found :—

| Observer | Reference | Animal | How Trypanosomes were demonstrated | Type of Trypanosome | Locality |
|---|---|---|---|---|---|
| Bruce | Further Report on Tsetse-fly Disease in Zululand | Kudu (3) | Inoculation into dogs | *T. brucei* | Zululand |
| ,, | ,, | Buffalo | ,, | ,, | ,, |
| ,, | ,, | Bush-buck | ,, | ,, | ,, |
| ,, | ,, | Wildebeest (3) | ,, | ,, | ,, |
| ,, | ,, | Hyæna | ,, | ,, | ,, |
| ,, | Appendix to Further Report | Reed-buck | ,, | ,, | ,, |
| ,, | ,, | Kudu | ,, | ,, | ,, |
| ,, | ,, | ,, | Blood examination | ,, | ,, |
| ,, | ,, | Reed-buck | ,, | ,, | ,, |
| ,, | ,, | Stein-buck | ,, | ,, | ,, |
| Dutton, Todd & Kinghorn | Ann. Trop. Med., i. p. 249 | Bush-buck | Both methods | 'Tadpole type' | Mswata, Congo State |
| ,, | ,, | ,, | Two inoculated guinea-pigs died | Stumpy and long forms | Kasongo, Congo State |
| Montgomery & Kinghorn | Ann. Trop. Med., iii. p. 370 | ,, | Blood examination | 'Tadpole type' | Near Ndol, N.W.Rhodesia |
| ,, | ,, | Hartebeest | ,, | Two trypanosomes only seen. | |
| Brand | Report on the Veterinary Survey of N. Nigeria (and letter) | 16 antelopes, including hartebeest roan & water-buck. | Inoculation into dogs | No information | N. Nigeria |

| Observer | Reference | Animal | How Trypanosomes were demonstrated | Type of Trypanosome | Locality |
|---|---|---|---|---|---|
| Koch, Beck & Kleine | Arbeit a. d. Kais. Gesundheitsamt, xxxi. h.l. | Monkey | [1] Blood examination | *T. gambiense* | Uganda |
| Kleine & Fischer | Zeitschrift für Hygiene, lxx. p. 17 | Pferde-antilope (? hartebeest) (7) | [1] ,, | ? *T. nanum* | Lake Tanganyika |
| ,, | ,, | Water-buck (2) | [1] ,, | ? *T. brucei* (1) | ,, |
| ,, | ,, | Bush-buck | [1] ,, and inoculation | ,, | ,, |
| ,, | ,, | Reed-buck (3) | [1] Blood examination | ? *T. nanum* | ,, |
| ,, | ,, | Pig | [1] ,, | No information | ,, |
| Bruce, Hamerton, Bateman & Mackie | Sleeping Sickness Reports, Roy. Soc. No. xi. p. 102 | Monkey | ,, | *T. gambiense* | Uganda |
| ,, | Loc. cit. p. 103 | Bush-buck | Inoculation into goat | *T. vivax* | ,, |

To this list must also be added the following :—

(i) Numerous trypanosomes were found by Otto Fehlandt in the blood of a freshly killed otter near the east shore of Lake Tanganyika. They were dimorphic. He thinks that the carrier is *Glossina palpalis*, because the otter was killed in a *palpalis* area ('Sleeping Sickness Bulletin,' No. 29, p. 324).

(ii) Crocodiles are well known to carry a trypanosome in their blood. (*T. grayi.*)

(iii) Trypanosomes were found by microscopical examination in the blood of an elephant from the Tana River District in British East Africa by Dr. P. H. Ross, in 1911.

[1] Thick film method.

(iv) In German East Africa Dr. Wolfel found trypanosomes in the blood of a wart-hog ('Sleeping Sickness Bulletin,' No. 34, p. 73).

(v) In the Congo, near Lake Kabwe, trypanosomes of *cazalboui* type were found by Rodhain, Pons, van den Branden, and Bequært, in the blood of six antelopes (no name given) and one eland. All were well nourished and seemed healthy. A kid was inoculated from these antelopes and showed trypanosomes in ten days. At Sankisia twelve goats became successively infected without appearing any the worse. Inoculations made into a guinea-pig, a dog, and a jackal were without result ('Sleeping Sickness Bulletin,' No. 35, p. 120). (This would appear to point to this trypanosome found in these antelopes as being non-pathogenic.—R. B. W.)

(vi) It is also interesting to remember the trypanosome of the little owl, *Athene noctua* (see 'Sleeping Sickness Bulletin,' No. 36, p. 139), as well as to notice the numerous trypanosomes which are being discovered in various parts of the world in animals which are not game. In Canada, Watson and Hadwen have found trypanosomes in rabbits (*Lepus sylvaticus*), deer-mice (*Peromyscus maniculatus* and *P. nebracencis*), ground-squirrels (*Citellus richardsoni*), voles (*Evotomys saturatus*), shrews (*Sorex vagrans*), and also in a cow. A trypanosome has also been found by Mensil and Brimont in French Guiana in the blood of an ant-eater ('Sleeping Sickness Bulletin,' No. 21, p. 373). None of these trypanosomes have so far been shown to be pathogenic. It does not appear unreasonable to conjecture that if search is made trypanosomes will be found in African mammals of similar kinds which are not game.

In examining the above table two points particularly call for notice. Firstly, that *T. gambiense*, the parasite of sleeping sickness, is shown only twice, and on both occasions

from the blood of a monkey and not from any game animal. Secondly, that nearly all the animals shown in the table in which trypanosomes have been found are game animals. I maintain, however, that this is due not so much to the fact that other animals do not harbour trypanosomes as to the fact that so much attention has been concentrated upon game animals that comparatively few animals other than game have been examined.

After examining the information given in this table it is important to turn to the antelope experiments carried out by the Sleeping Sickness Commission of the Royal Society in Uganda 1908–10, and summarised in 'Sleeping Sickness Bulletin,' No. 35, p. 98, where further observations on these same antelopes made by Fraser and Duke in Uganda are recorded; and it is also important to refer to other experiments with wild animals in German East Africa.

It is only necessary here to mention some of the more important conclusions which were arrived at as the result of these experiments—

(i) Water-buck, bush-buck and reed-buck can readily be infected with a human strain of the trypanosome of sleeping sickness by the bites of infected *Glossina palpalis* ('Sleeping Sickness Bulletin,' No. 25).

(ii) Antelope of the water-buck, bush-buck and reed-buck species, when infected with the virus of sleeping sickness, can transmit the infection to clean laboratory-bred *Glossina palpalis* ('Sleeping Sickness Bulletin,' No. 25).

(iii) And *Glossina palpalis* infected in this manner can transmit the virus to susceptible animals ('Sleeping Sickness Bulletin,' No. 25).

(iv) No antelope up to the present has been found naturally infected with *Trypanosoma gambiense* ('Sleeping Sickness Bulletin,' No. 25).

Later in 1911 Fraser and Duke in Uganda arrived at the following conclusions:—

(i) Antelope may remain in apparently perfect health

for a year after having been infected with a human strain of *T. gambiense* ('Sleeping Sickness Bulletin,' No. 35).

(ii) One antelope was shown by inoculation to be capable of infecting a white rat 327 days after its infection ('Sleeping Sickness Bulletin,' No. 35).

(iii) As the interval after the infection of the antelope increases their infectivity appears to diminish.

It, therefore, seems probable that the trypanosomes gradually die off, but it would be premature to conclude so ('Sleeping Sickness Bulletin,' No. 35).

In Bulletin No. 36, issued April 3, 1912, further investigations of Fraser and Duke in Uganda are reported. Wild animals were examined with a view to ascertaining whether they were naturally infected with trypanosomes. Ten Water-buck, 20 bush-buck, and 2 situtungas (*Tragelaphus spekei*) were obtained within two miles of the shore of Lake Victoria, where the *Glossina palpalis* were known to be infected with *Trypanosoma gambiense, T. vivax,* and *T. uniforme.*

The conclusions arrived at were—

(i) *T. uniforme* was the only species of trypanosome obtained as the result of examination of wild animals, including thirty-six lake-shore antelope ('Sleeping Sickness Bulletin,' No. 36).

(ii) The available evidence (which is small—R. B. W.) points to bush-pigs, crocodile, monitor, frog, and domestic fowls being refractory to *T. gambiense* ('Sleeping Sickness Bulletin,' No. 36).

(iii) The edible rat, which is susceptible to *T. gambiense,* can, by virtue of its habits, be of little importance in considering the question of a reservoir ('Sleeping Sickness Bulletin,' No. 36).

(iv) The available evidence points to *Glossina palpalis* as being the carrier of this species of trypanosome ('Sleeping Sickness Bulletin,' No. 36).

In German East Africa Dr. Wolfel examined forty animals for trypanosomes ('Sleeping Sickness Bulletin,' No. 34, p. 73). These consisted of 31 antelope of various species, 7 wart-hogs, a leopard, and a hare. Of these, a reed-

buck, a water-buck, a hartebeest, and a wart-hog were found to contain trypanosomes. One of these animals was much emaciated, it is not stated which, but it is a point of considerable interest if the ill-health was due to the presence of trypanosomes in its blood, particularly in view of the fact that the antelope artificially infected with *T. gambiense* by the Sleeping Sickness Commission in Uganda remained apparently in perfect health for a year afterwards. Dr. Wolfel injected blood from 10 of the above 40 animals into dogs; and cultures in both were attempted from the blood of 6 others. The dogs did not sicken and no trypanosomes were found in the broth.

It is worthy of note that of the above 40 wild animals all are game animals except 9, which only include 3 species.

In German East Africa also Professor F. K. Kleine and O. W. Fischer examined 54 wild animals, including hartebeest, topi (*Damaliscus corrigum*), water-buck, bush-buck, reed-buck, and wild pigs. Of these, 7 hartebeest, 2 water-buck, 1 bush-buck, and 1 pig (total 11) showed trypanosomes ('Sleeping Sickness Bulletin,' No. 31, p. 406). It will be noticed that of these 54 wild animals all are game animals, except the 4 pigs. No small animals, such as rodents, apparently were examined.

The above conclusions have been arrived at as the result of experiments, particularly the experiments of the Sleeping Sickness Commission in Uganda 1908–10, which were most carefully devised and carried out; but in examining the conclusions arrived at, there are three very important points which are apparent:—

(i) Attention has been almost entirely concentrated upon game animals.

(ii) Up to the present no wild animal has been found naturally infected with a trypanosome of sleeping sickness, except two monkeys, one found by the Sleeping Sickness Commission in Uganda 1908-10, and the other by Koch, Beck and Kleine's Commission. It was caught on Sesse Island ('Sleeping Sickness Bulletin,' No. 32, p. 444).

(iii) It does not appear certain, in the cases in which wild animals have been found naturally infected with trypanosomes, whether these trypanosomes are, invariably, or only occasionally, pathogenic for domestic animals, or whether they are pathogenic at all.

It is also interesting at this point to compare the experiments carried out by Sir David Bruce in Zululand in 1895–6. In his 'Further Report on the Tsetse-fly Disease or Nagana in Zululand' a table is given on page 24 in which the results of the inoculation of the blood of wild animals into dogs are shown. Thirty-five animals were used, and of these 9 were shown to contain trypanosomes. But here again a most important point is conspicuous. Out of the 35 wild animals examined all, except 3, were game animals, chiefly wildebeest and buffalo, while only 3 non-game animals, 2 pigs and a hyæna, were examined, one of which, the hyæna, contained trypanosomes. Of the 9 dogs which showed trypanosomes, 4 died of the disease, 2 were shot—for what reason is not stated—and of the remaining 3 no information is given as to their fate.

Now, it will be seen from the above summary that—

(i) It has not yet been found that antelope act as reservoirs for the virus of sleeping sickness in nature.

(ii) It has been found that antelope do act as reservoirs for other trypanosomes, some of which are pathogenic for domestic animals. But it has also been found at the same time, and a very important point, that other wild animals which are not game act as reservoirs for these trypanosomes. And this has come to light in spite of the fact that comparatively very few non-game animals have been examined.

It is next of importance to ascertain whether domestic animals themselves, such as cattle, sheep, goats, and dogs, act as reservoirs of trypanosomes.

In 'Sleeping Sickness Bulletin,' Vol. 2, No. 19, p. 235, the experiments of the Sleeping Sickness Commission of the Royal Society 1908–10 are given which were carried out for the purpose of investigating this question.

It had been found that the fly on the shores of Lake Victoria

remained infective two years after the removal of the native population. Experiments were therefore carried out, from which the following conclusions were arrived at :—

(i) It has been proved by experiment that cattle may act as a reservoir of the virus of sleeping sickness, and that healthy animals may be infected from them by means of *Glossina palpalis*.

(ii) It has also been proved that cattle in the fly area do naturally harbour *Trypanosoma gambiense* in their blood and apparently remain in good health ('Sleeping Sickness Bulletin,' No. 19, p. 236).

It appears, therefore, that cattle are equally or more dangerous as reservoirs of sleeping sickness than antelope; for the trypanosome of sleeping sickness has actually been found in their blood, which up to the present has not been done in the case of game animals in a state of nature.

In the French Congo, Dr. P. Aubert thought that the large herds of cattle were acting as reservoirs of sleeping sickness in that district ('Sleeping Sickness Bulletin,' No. 34, p. 78).

In German East Africa Professor Dr. F. K. Kleine and O. W. Fischer carried out a series of experiments to ascertain whether sheep and goats can act as reservoirs of sleeping sickness ('Sleeping Sickness Bulletin,' Vol. 3, No. 31, p. 402). As a result of these experiments it was concluded that—

(i) Sheep and goats can act as reservoirs for the virus of sleeping sickness, but as the interval after their infection increases their infectivity appears to diminish. (This was noticed also in the case of the antelopes in the Uganda experiments of the Royal Society's Commission.—R. B. W.)

It is not stated whether sheep and goats were found naturally infected with *Trypanosoma gambiense* (R. B. W.).

With regard to trypanosomes other than human. 'It has been proved that sheep and goats and cattle can act as reservoirs for trypanosomes which are fatal to cattle, and that cattle themselves may harbour these trypanosomes without becoming diseased.' (Extract from 'Sleeping Sickness Bulletin.')

Referring to a bull used for experimental purposes, which apparently possessed immunity, it is pointed out ('Sleeping

Sickness Bulletin,' No. 31, p. 410) that 'such trypanosome carriers as this bull have been found in many parts of tropical Africa. They are probably at least as dangerous as reservoirs of infection as are wild animals.'

On the eastern coast-lands of Lake Tanganyika in German East Africa Professor Dr. Kleine received a report that cattle, sheep, and goats had a trypanosome in their blood, but were in health.

On investigation he found trypanosomes, but the cattle in which they were found are said to have looked ill. Cattle, goats, sheep, dogs, monkeys, and a pig were inoculated; only the cattle and goats became infected ('Sleeping Sickness Bulletin,' No. 21, pp. 367–8).

Later, however, Fischer and Fehlandt found trypanosomes in ten out of thirty goats. Goats, sheep, calves, dogs, and monkeys were inoculated; only the goats and sheep became infected. The illness is very chronic. Kleine thinks this trypanosome is pathogenic for cattle, and proposes to call it *Trypanosoma capræ* ('Sleeping Sickness Bulletin,' No. 21, p. 368).

Later, in 'Sleeping Sickness Bulletin,' No. 29, p. 322, further investigations by Otto Fehlandt are reported from the same locality. He found a well-characterised trypanosome in sheep and goats, which was pathogenic only for these two species. Cattle, dogs, guinea-pigs, and monkeys failed to become infected when inoculated with the blood of infected sheep or goats. This is the trypanosome named *T. capræ* by Professor Kleine ('Sleeping Sickness Bulletin,' No. 21, p. 368).

Two other trypanosomes found in goats and sheep by Fehlandt were considered to be *T. congolense* and *T. dimorphon* ('Sleeping Sickness Bulletin,' No. 29, p. 323).

A paper by Dr. Erich Weissenborn is summarised in 'Sleeping Sickness Bulletin,' No. 29, p. 324. The following conclusions were arrived at:—

(i) In the blood of a pony from the hinterland of Togo small trypanosomes with short flagella were found. The animal after eighteen months is apparently healthy. One is therefore justified in saying that it has some degree of resistance to the trypanosome.

(ii) The trypanosome proved of inconstant virulence in the experimental animals. It was most virulent for mice, much less so for rabbits, cats, and monkeys. Transmission to rats was successful only in a few cases. Guinea-pigs were refractory. In dogs the parasites only of the first passage produced a fatal infection.

(iii) Some of the experimental animals resisted infection, and were immune to later infections.

In 1909 Leo Frobenius presented to the Zoological Gardens at Hamburg four ponies said to be immune to tsetse. Trypanosomes were found in one. Attempts to infect mice, rats, and guinea-pigs were unsuccessful. (It will be remembered that in the case of the pony from Togo the trypanosome was most virulent for mice.—R. B. W.) A dog was infected and died, and from its blood mice and rabbits became infected, but rats and guinea-pigs did not. A cat and a monkey which became infected recovered and are said to have become immune. The pony showed no signs of illness. (See 'Sleeping Sickness Bulletin,' No. 29, pp. 324–325.)

There appears to be some evidence that *Trypanosoma brucei* or *pecandi* occurs in dogs in the Sudan as a natural infection ('Sleeping Sickness Bulletin,' No. 33, p. 31). *Trypanosoma brucei* has also been made to infect certain birds, goose, kestrel, fowl ('Sleeping Sickness Bulletin,' No. 25, pp. 87–89).

From the above summary it will be seen at once how very important domestic animals are in Africa as possible reservoirs of trypanosomes.

It is also interesting to remember that trypanosomiasis, both human and of domestic animals, is not confined to Africa.

The human trypanosomiasis of Brazil was discovered by Dr. Carlos Chagas when organising measures against malaria. The parasite *Schizotrypanum cruzi* is transmitted to human beings by a biting insect (*Conorrhinus megistus*), which resembles the common bed bug in habits. It is also pathogenic for guinea-pigs, rabbits, dogs, and monkeys. (See 'Sleeping Sickness Bulletin,' Vol. 2, No. 16, p. 117.)

'In India Lingard found the trypanosome of surra in the blood of two species of rats (*Mus decumanus* and *Mus rufescens*): 1107 rats were examined, and trypanosomes were found to be present in 421. The infected rats were apparently in perfect health. Horses inoculated with blood from these rats developed virulent surra after a rather prolonged incubation period, but horses inoculated from a horse thus infected develop surra after the usual incubation period of seven to eight days.' (See 'A Further Report on Tsetse-fly Disease or Nagana in Zululand,' by Surgeon-Major (now Sir) David Bruce, May 1896, p. 19.)

In England Mr. S. Stockman discovered trypanosomes indistinguishable from *T. theileri* in the blood of pedigree cattle. This trypanosome appeared to produce no disease in the infected cattle, and Mr. Stockman considered that it would not appear to give rise by itself to any serious illness in domestic animals. Three puppies, 2 guinea-pigs, 2 rabbits, 2 white mice, 1 pigeon, 1 pig, 2 heifers, 1 calf, 4 ewes, and 6 lambs were inoculated from these cattle. No trypanosomes could be found by microscopical examination or sub-inoculations. One lamb was killed eight days after inoculation, and two died emaciated on about the hundredth day after receiving the injection of blood from the infected cattle. (See 'Sleeping Sickness Bulletin,' No. 30, p. 376.)

Besides this, trypanosomes have been grown in cultures from the blood of cattle in Germany, France, Denmark, Russia, Japan, the Philippines, Siberia, Algeria, Tunis, Greece, Holland, the United States, and Brazil. (See 'Sleeping Sickness Bulletin,' Vol. 4, No. 34, p. 78.)

It is also interesting to notice that in France numbers of cattle, sheep, and goats have been infected with various virulent trypanosomes brought from Africa (F. Mesnil and M. Leger) from which they have recovered, and as a rule they acquire complete immunity afterwards. (See 'Sleeping Sickness Bulletin,' No. 35, p. 105.)

The next point of importance in regard to trypanosomiasis is the question of what blood-sucking insects act as the transmitting agents of the various trypanosome diseases, and whether

such insects are entirely dependent upon or associated with antelope and other game animals.

It was formerly believed that in Africa the only carriers of any trypanosome belonged to the genus *Glossina* or tsetse flies, and that of these only the one species *Glossina palpalis* was capable of transmitting the human trypanosome of sleeping sickness.

It is unnecessary here to go into the details of the numerous experiments and discoveries which have gradually dispelled this illusion, and it will be sufficient to say that—

(i) In Rhodesia *Glossina morsitans* has been proved to transmit the human trypanosome causing sleeping sickness in that country (*T. rhodesiense*, a separate species from *T. gambiense* of Uganda);

(ii) while the genus *Stomoxys* has been proved to transmit a trypanosome in Mauritius and the Philippines, and in 'Sleeping Sickness Bulletin,' No. 35, p. 117, it is pointed out that 'There is now not inconsiderable evidence from several parts of Tropical Africa that domestic animals may, in the absence of tsetse, become infected with trypanosomes pathogenic to them. Since other species of biting flies are in such cases present, it is suspected that these are the carriers. The flies incriminated are species of *Tabanus*, *Hæmatopota*, *Stomoxys*, *Pangonia*, and *Lyperosia*.'

Besides this it will be remembered that it has already been mentioned that trypanosomes have been found in almost all parts of the world, and as the tsetse flies (*Glossina*) are confined to Africa and a corner of south-east Arabia, it is obvious that in other countries the transmitting agents, many of which are now known, must be blood-sucking insects other than tsetse flies. Experiments to settle this question are badly needed, but there is at present great difficulty experienced in keeping the above-mentioned species of blood-sucking flies alive in captivity, and until this difficulty is overcome and satisfactory transmission experiments carried out, the question of what insects are concerned in the transmission of trypanosomes will remain uncertain. There is, however, sufficient evidence already to show that tsetse flies are not the only blood-sucking

insects against which war must be waged. (See 'Sleeping Sickness Bulletin,' No. 35, p. 119.)

Now with regard to the question as to what extent tsetse flies are dependent on or associated with game animals. There is no doubt now that 'big game' is not the only source from which the tsetse flies draw their blood supply. It is to be expected that they would, for choice, feed upon such animals as buffaloes, large antelope, and domestic cattle; but the latter are almost entirely absent in some localities in which tsetse flies are numerous. There is no doubt that the tsetse fly will feed upon other animals, such as hyænas, jackals, pigs, baboons, small monkeys, and probably other smaller mammals, such as rats and hares, and even birds and reptiles.

During the investigations of the Sleeping Sickness Commission of the Royal Society 1908-10 in Uganda, in two cases blood corpuscles taken from the stomachs of wild lake-shore *Glossina palpalis* were recognised as being derived from monkeys, since the characteristic parasites of monkey malaria were found in the corpuscles ('Sleeping Sickness Bulletin,' No. 19, p. 245).

Again, in 'Sleeping Sickness Bulletin,' No. 32, p. 444, it is tated that 'The pig is an animal which should be kept in view as a possible reservoir of sleeping sickness virus.' It was believed to be refractory, but Beck managed to infect one for at least six weeks. It is stated that on Principe Island pigs' blood is the staple diet of *Glossina palpalis*, and in most of these pigs a trypanosome is found, for which they are none the worse. Two rats and two guinea-pigs which were inoculated failed to become infected.

In some of the sleeping-sickness areas in Uganda pigs are very numerous.

Dr. Montgomery and Dr. Kinghorn writing on this subject expressed the opinion, 'That the distribution of *Glossina morsitans* is entirely dependent upon the nature of the country and its flora, the association with the fauna being largely fortuitous, and that a perpetual supply of mammalian blood is not imperative to its, at least, temporary existence' ('Sleeping Sickness Bulletin,' No. 22, p. 405).

Sir Alfred Sharpe, writing in the 'Bulletin of Entomological Research' for October, was of opinion that tsetse flies are no

more dependent upon the blood of mammals for their existence than are mosquitoes, and goes on to say, ' Unless I am right in this opinion I am at a loss to understand how the enormous numbers of tsetse fly which are found in some districts can exist, as in many of these areas game is either extremely scarce or almost non-existent. In Nyasaland it is distinctly noticeable that many of the fly areas are almost destitute of game, whereas, on the other hand, some parts of the country where game is most abundant, such as the valley of the Rukuru River, are entirely free from tsetse; and in this locality, as in others, buffaloes are fairly numerous ' (' Sleeping Sickness Bulletin,' No. 22, p. 404).

In 1908 Major Hamilton, the Game Warden of the Transvaal game reserves, and the British Consul at Lourenço Marques, made a journey from Port Amelia to Nyasaland. For a stretch of about ninety miles large numbers of tsetse fly were found, but no big game and very little small game. There was thick bush and very little water. After they crossed the Lugenda river, game, including buffalo, became very plentiful, but there was no tsetse fly. This statement is the more worthy of belief because Major Hamilton is a careful observer and a keen hunter (' Sleeping Sickness Bulletin,' No. 28, p. 270, and Bulletin No. 30, pp. 362–63).

Similar cases are to be met with in British East Africa. In some parts of the dry arid bush country in the neighbourhood of Kibwezi numbers of tsetse flies are to be found; yet game animals of any kind are scarce, with the exception of the tiny dik-dik antelope.

It will also be remembered that Mr. F. C. Selous has pointed out cases in South Africa where the range of tsetse flies is quite sharply defined, although beyond the fly belt the vegetation appears identical with that inside the belt, and that game abounds both inside and outside of the fly area.

I have myself (R. B. W.) witnessed this phenomenon in Bechuanaland in South Africa, and it is a mystery without explanation, unless upon Mr. Selous' theory that the presence or absence of buffalo is the determining factor. I hesitate to accept this explanation, and am more inclined to the opinion

that the presence or absence of game has little or nothing to do with the distribution of tsetse flies.

Besides this, there is absolute proof that tsetse flies will in nature feed upon birds and reptiles when they cannot obtain mammalian blood.

In Uganda the Sleeping Sickness Commission of the Royal Society 1908–10 examined the stomach contents of numbers of wild *Glossina palpalis* caught on the lake shore. In a considerable number remains of blood were found which was sufficiently undigested to allow of the nucleated corpuscles being distinguished from the non-nucleated (i.e. the avian, reptilian, and amphibian from the mammalian). In this way it was proved that many of the *Glossina palpalis* on the shores of Lake Victoria feed naturally upon birds, or crocodiles, lizards and snakes, or frogs and toads. In the laboratory, however, it was found that *Glossina palpalis* fed with more avidity on birds than on monkeys, while they could hardly be tempted to feed upon young crocodiles or lizards ('Sleeping Sickness Bulletin,' No. 19, p. 245). The possibility of separating avian blood corpuscles from reptilian or amphibian under the above circumstances is of course open to doubt ('Sleeping Sickness Bulletin,' No. 32, p. 445), but the important fact remains clearly proved, namely, that the blood upon which the flies had fed was not mammalian, and was either avian, reptilian, or amphibian.

Further experiments were carried out in Uganda by this Commission to ascertain if *Glossina palpalis* would feed on lizards or frogs. 'None of these experiments were very successful, and generally a large proportion of the flies were devoured before they could attempt to feed; even when the caged flies could bite in safety they did not do so. Escaped flies, however, fed on chameleons, a number of which were kept in the laboratory for the purpose of catching flies. And flies were observed at least on one occasion sucking the blood of a lizard' ('Sleeping Sickness Bulletin,' No. 32, p. 445).

The discovery of Roubaud that *Glossina palpalis* will readily bite large caterpillars is of great importance, for if tsetse flies can feed upon the fluids of caterpillars, and perhaps other insects, it will help to explain a phenomenon which has always

been somewhat of a mystery, namely, how it is that in some places there are great numbers of tsetse flies, although game and other animals of any kind are not to be found or are very scarce in these places.

Also in Japan Dr. Pryer states that sand-flies have been found to feed upon the larvæ of other insects, and suggests that other larger blood-sucking flies may do the same ('Sleeping Sickness Bulletin,' Vol. 3, No. 31, pp. 419–20).

The possibility also of tsetse and other blood-sucking flies being able to exist upon a diet of plant juices must not be lost sight of. Personally I am sceptical of the likelihood of such specialised insects as blood-sucking flies being able to breed until they have fed upon blood, but it is conceivably possible that they might exist upon such a diet, or upon nothing, without breeding for several months. Conversely, however, it must also not be forgotten that some butterflies whose natural food is honey and plant juices will feed greedily off dead carcases, even when in an advanced stage of decomposition, and also on the dung of animals.

Mr. R. C. F. Maugham, H.B.M. Consul of Lourenço Marques, in answer to a letter writes as follows :—

'I have seen tsetse flies sucking vegetable juices on two occasions. The first was in swampy ground south of Shupanga Forest on the Zambesi in 1905, when the fly, a common *Glossina morsitans*, alighted on a stem of a young marsh grass (*Phragmites communis*) and, as I watched it, deliberately inserted its proboscis and unmistakably sucked for a period of about two minutes and a half. At this stage I caught it, and found on examination that it was partly full of the moisture from the plant.

'On the second occasion, in 1908, I was taking an expedition from the coast of this province at Ibo to Lake Nyassa. There is one district which my caravan traversed, between M'salu and Fort Dom Luiz Fillipe I believe, where for nearly three days, in absolutely gameless and practically waterless country, *Glossina morsitans* occurred in such numbers as to be a source of the greatest annoyance. Halting at midday on one occasion during this portion of my journey, one of my servants, who had bought some green sugar-cane on the way and was gnawing it, left the fragment close to my chair whilst the table was being

laid. I saw a tsetse fly settle on the cane, gradually walk along to the part where the pith was exposed, insert his proboscis and feed. After some little time I made an attempt to catch this fly, but unfortunately failed to do so. Of the accuracy of my observation in each case I have not the smallest doubt, and have referred to these two instances on many occasions in my writings on this and kindred subjects.'

Confirmation of these observations would be very interesting. It would explain why it is that tsetse flies have been found by many observers in areas where animal life was apparently quite absent. At present Mr. Maugham's observations stand alone. (See 'Sleeping Sickness Bulletin,' Vol. 3, No. 28, p. 271.)

It will be seen from the above survey of the recent discoveries which have been made with regard to the relation of game animals to the trypanosomiases that there is at present not sufficient scientific evidence to justify the extermination of game as a means of clearing a district of diseases transmitted by blood-sucking insects. Evidence on the subject is difficult to collect, and often most untrustworthy. Microscopical examinations of blood are not usually conclusive, because the trypanosomes are frequently so scanty in the blood of an infected animal that the prospects of discovering one in the minute field of the microscope are extremely small. The method which appears to give the most reliable results is the injection of blood from the suspected animal into an animal which is known to be susceptible to the species of trypanosome about which information is required.

In the controversy of 'Game *versus* Disease,' what is so urgently needed is a very extensive series of inoculations, carried out in different districts on as large a scale as possible. And it is of the greatest importance that the susceptible animals should be inoculated *not only* with the blood of game animals, but also with that of all other animals, both wild and domestic, in the infected areas.

Only by such experiments can it be definitely proved whether or not the game acts as a reservoir for the virus of the different trypanosome diseases, and whether it is the only reservoir. And it is these inoculation experiments that

the friends of game preservation and true scientists should call for and insist upon.

From the point of view of game preservation there are six questions which need answers, and until these questions are answered it is impossible to decide upon a definite and practically useful plan of campaign. Briefly these six questions are :—

1. Are game animals the *only* wild animals which are acting as ' reservoirs ' for trypanosomes ?
2. Are the trypanosomes found in the blood of game animals pathogenic for man and domestic animals ? And if so, are not the trypanosomes found in the blood of other animals also pathogenic ?
3. Are tsetse flies the only transmitting agents of these trypanosomes in the infected areas ?
4. Are game animals the only source from which the tsetse flies or other transmitting agents draw their blood supply ? And if not, what are the other sources of supply ?
5. Can tsetse flies live and breed upon food other than blood, such as plant juices ?
6. Are the distribution, increase and spread of tsetse flies, if this latter occurs, dependent upon game alone ? And if not, what are the governing factors ?

The first two of these questions can only be answered definitely by carrying out an extensive series of inoculation experiments, and it is essential that the susceptible animals should be inoculated not only with the blood of game animals, but also with the blood of all other animals and reptiles in the infected areas.

The third question suggests its own necessary experiments.

The fourth question is more difficult, but will be answered to some extent by the inoculation experiments and by the discovery of the pathogenic trypanosomes in the blood of other animals.

For the fifth question I should like to suggest some such experiment as the following :—

That a freshly killed bird or small mammal should be quickly skinned and the skin filled with honey or crushed banana

(or some other fruit which could represent 'plant juices'), which must of course be brought up to blood temperature. The skin might then be pressed against the gauze of a tsetse-fly cage, to determine whether blood-sucking flies can subsist upon such food as honey or plant juices.

The sixth question is a difficult one, but will be greatly simplified when an answer is obtained to the fourth.

I am willing to admit that it is highly probable that human trypanosomes will eventually be found in the blood of antelope, but it is to be sincerely hoped that it will not tempt the discoverer to make an incautious and sensational declaration of the fact which can be interpreted by the public as indicating that at last the whole problem is solved. The public will be only too ready to take this opportunity to attack the policy of caution which has been wisely adopted in the past, and will clamour for the immediate extermination of the game.

This will make it the more difficult for those who are really acquainted with the magnitude of the problem to prevent rash actions and panic legislation.

What will have been achieved if the game is exterminated in an infected area at great expense and trouble, and it is then found that the tsetse flies or other transmitting agents remain and are still highly infective? Little or nothing which could not have been achieved by other and less drastic and costly measures.

Take for example the experiment of removing the native population from the infected areas of Lake Victoria in Uganda which has been carried out. After three years it has been found that the tsetse flies are still infected with *Trypanosoma gambiense*; that is to say, that *the* or at least *a* reservoir of infection still exists.

Next, suppose that all the game in these areas is exterminated, an undertaking which will only be carried out with great difficulty and expense, and it is then found that the tsetse flies are still infective, a highly probable result.

To describe the situation as 'disappointing' would be utterly inadequate, and the word 'hopeless' is far more appropriate to such a method. For the position then apparently resolves itself into the extermination of all vertebrate

life in the infected areas, and even then there appears to be no absolute guarantee that success will follow. Such a process may be described as *reductio ad absurdum* in more senses than one, for it is open to the gravest doubt whether it is possible to exterminate all vertebrate life, even in a limited area, and it is certainly impossible on a practical scale.

In the New Cameroons Professor Schillings thought that to get rid of all the animals, both wild and domestic, which might act as a reservoir of sleeping sickness was impossible, and that every endeavour should be made to advance chemotherapeutic discoveries ('Sleeping Sickness Bulletin,' No. 34, p. 89).

Professor Dr. M. Beck is of opinion that immunity in larger animals and cure in others will eventually be obtained ('Sleeping Sickness Bulletin,' No. 21, p. 364).

It appears therefore that before any extensive measures of extermination are undertaken in any part of Africa it will be the wiser plan, if not absolutely essential, first to ascertain definitely all the animals (taking into consideration not game animals alone) which are acting as reservoirs for the virus of any trypanosomiasis.

This is an undertaking of great difficulty, but it is certainly more practical and less costly and destructive than a policy of extermination, and will prevent what might possibly prove to be the useless extermination of countless numbers of beautiful game animals. For it would certainly be a useless proceeding if it was afterwards found that many other animals were acting as reservoirs of infection.

In view of these facts I wish to draw particular attention to a subject which has not received from the general public the attention that it merits, and that is the question of immunity and the possibility of producing it or hastening it artificially. The task of exterminating all animal life in the infected areas, or the insects which transmit the diseases, is such a gigantic one that it appears almost impossible, and the prospects of success by producing an immunity appear to many more hopeful.

This applies also to the piroplasmoses. Some important information will be found under the heading 'Studies in

Immunity,' by B. T. Terry, p. 310 of 'Sleeping Sickness Bulletin,' No. 29, which gives a most interesting account of a long series of experiments with different trypanosome infections, with special reference to the immunity following cure. Some of these experiments gave most encouraging results. A paper by Paul Behn in 'Sleeping Sickness Bulletin,' No. 35, p. 111, on the same subject, and Bulletin No. 25, p. 127, should also be consulted.

It is interesting but not very profitable to speculate upon the past history of immunity in nature. Such parasitical forms of life as trypanosomes and piroplasms may have evolved, zoologically, comparatively recently or may have been recently promoted to a life cycle in the blood-stream of vertebrates. There are many blood parasites known, such as halteridia and certain leucocytozoons, and also certain trypanosomes, which produce no disease in the animals in which they are found at the present day, but they may have caused great mortality among these animals in the past, before their hosts developed an immunity and became tolerant of them. In 'Sleeping Sickness Bulletin,' No. 36, p. 142, some interesting information is given on 'The Life-History of Trypanosomes in Vertebrate Blood,' by C. Franca.

The question of immunity therefore appears to be one of great importance. If wild animals can acquire an immunity in nature and domestic native cattle can also acquire immunity, is it not possible that the greatest success may eventually result from an artificially produced immunity?

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## THE ORGANIC CELL

### Part II.—Its Methods of Division and Status in the Process of Heredity

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As we saw in the last article the term 'cell' is badly selected, and was used by the seventeenth-century botanists to describe