Photocopies of Sir David Bruce's papers re trypanosomiasis, 1895-1915

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Preliminary Report

ON THE

TSETSE FLY DISEASE OR NAGANA,

IN ZULULAND.

BY

SURGEON-MAJOR DAVID BRUCE, A.M.S.

UBOMBO, ZULULAND,
DECEMBER, 1895.

BENNETT & DAVIS, PRINTERS, FIELD STREET, DURBAN.

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To His Excellency

The Hon. Sir Walter Hely-Hutchinson, K.C.M.G.,

Governor of Natal and Zululand, &c., &c.

Your Excellency,—I have the honour to inform you that in accordance with instructions received from you, I left Pietermaritzburg on the 21st August, 1895, and arrived at Ubombo, Zululand, on the 8th September, 1895, for the purpose of continuing the investigation of the Tsetse Fly Disease, or Nagana, as it occurs in Zululand.

I have now the honour to forward a Preliminary Report, containing a statement of the results of the investigation up to the present date.

I may here state that on my arrival in Zululand the Tsetse Fly Disease and Nagana were looked upon as separate and distinct diseases, and one of the first results of this investigation was to show that they are undoubtedly one and the same.

This Preliminary Report contains:—

1.—A description of the Hæmatozoon discovered by me in 1894, in the blood of animals affected by this disease, a parasite not previously discovered in Africa.

2.—A description of the Tsetse Fly, with experiments designed to show the part (if any) this Fly takes in the causation of the disease.

3.—The result of experiments having for their object, proof of the connection (if any) which is supposed to exist between the Big Game and the spread of the disease.

4.—A description of the disease as it affects domestic animals, with illustrative cases.

5.—Inoculation and feeding experiments to show the communicability of the disease from affected to healthy animals.

I have the honour to be,

Sir,

Your most obedient Servant,

DAVID BRUCE,

Surgeon-Major A.M.S.

Ubombo,

Zululand, 12th December, 1895.

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LIST OF ILLUSTRATIONS.

Tsetse Fly Disease or Nagana.

1.—DEFINITION.

The Fly Disease or Nagana is a specific disease which occurs in the horse, donkey, ox and dog, and varies in duration from a few days or weeks to many months. It is invariably fatal in the horse, donkey and dog, but a small percentage of cattle recover. It is characterised by fever, infiltration of co-agulable lymph into the subcutaneous tissue of the neck abdomen or extremities, giving rise to swelling in these regions, by a more or less rapid destruction of the Red Blood Corpuscles, extreme emaciation, and the constant occurrence in the blood of an infusorial parasite, either identical with or closely resembling the Trypanosoma Evansi found in Surra, a disease of India and Burmah. On *post mortem* examination, deposition of a yellow jelly like material in the sub-cutaneous tissue, intermuscular layers and under the serous covering of the heart, with purplish stains or ecchymosis in various regions as on the inner aspect of the skin, the serous membrane covering the lungs, and outer and inner surfaces of the heart, enlargement and softening of spleen and congestion and fatty degeneration of the various organs.

2.—NOMENCLATURE.

This disease in South Africa may generally be said to have been called the "Fly Disease" by European travellers and hunters, and Nagana by the natives and those white settlers in Zululand who have come much in contact with the natives. The term "Fly Disease" has of course been given on the supposition that the disease is caused by the bite of the Tsetse Fly, and the term Nagana from the symptoms presented by the animals suffering from the disease, the word Nagana meaning in Zulu, to be low or depressed in spirits. In past times the disease was known by the name Injoko, and at the present in some parts of the country, as in the valley of the Black Umfulosi, it is called Munca, from the sucked out appearance of the diseased animals.

M. Scloss, a Belgian Engineer, who came from the Congo to the Selati Railway in 1894, recognised the disease as being the same as "la mouche" in the Congo State.

3.—DISTRIBUTION IN ZULULAND.

For the purpose of future reference it would be well to give as fully as possible in this Report the distribution of the disease in Zululand, and to this end I intend to address the various Resident Magistrates in their several districts asking for information to enable me to prepare a map showing the localities where the disease is endemic.

A map of this kind will be more useful than a mere list of places.

Broadly it may be stated that the disease is limited to certain tracts, the physical conditions of which imply heat and moisture. These tracts in Zululand are situated in the level coast plain which extends some 50 miles inland, and river valleys which enter or debouch on this plain. From Ubombo, situated on the summit of one of the hills forming the chain of the Lebombo Mountains, a good view is obtained of this level coast plain, stretching from the base of the mountains to the sea some 60 miles off. It looks as level as a billiard table, and is covered as far as the eye can reach with a dense thorny scrub of mimosa, which at this time of the year, and at this distance is olive green in colour. Streaking the level expanse are numerous open spaces or glades covered with grasses, vivid green in colour. This huge plain stretches as far as the eye can reach to the North and South and merges in the blue of distance and of the sea to the Eastward. A few miles to the South, the River Imkusi can be seen winding across the plain, having just passed through the Lebombo Range by a deep canon or poort, to fall into St. Lucia Lake, its course being marked by the denser vegetation along its banks; and some dozen miles to the North, another river, the Pongola runs out into the plain in the same manner, to turn Northward to Delagoa Bay. The strip of country opposite, lying between the two rivers and extending some 15 miles out, is "Fly Country," the home of Nagana and Malaria and uninhabited except by wild animals.

4.—HISTORICAL ACCOUNT.

In a fuller report it may be interesting to trace the history of this disease as it has occurred in Zululand during the last half century. How it has broken out in certain districts in certain years where it was before unkown, or disappeared in others where in previous years it had existed. Suffice it to say in this preliminary Report that the disease has

Further Report

ON THE

TSETSE FLY DISEASE OR NAGANA,

IN ZULULAND.

BY

SURGEON-MAJOR DAVID BRUCE, A.M.S.

Ubombo, Zululand,
29th May, 1896.

London:
HARRISON AND SONS, ST. MARTIN'S LANE,
PRINTERS IN ORDINARY TO HER MAJESTY.

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To His Excellency

The Hon. Sir Walter Hely-Hutchinson, K.C.M.G.,

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Your Excellency,—I have the honour to inform you that in accordance with instructions received from you, I left Pietermaritzburg on the 21st August, 1895, and arrived at Ubombo, Zululand, on the 8th September, 1895, for the purpose of investigating the Tsetse Fly Disease, or Nagana, as it occurs in Zululand.

I had the honour to submit to you a Preliminary Report, containing a statement of the results of the investigation up to the beginning of December 1895, and I now beg to forward a Further Report.

This Further Report contains:—

1.—A description of the Tsetse Fly, with experiments designed to show the part this Fly takes in the causation of the disease.

2.—A description of the Hæmatozoon or Blood Parasite, which is the cause of the disease.

3.—The results of experiments having for their object proof of the connection which exists between the Big Game and the spread of the disease.

4.—A description of the disease as it affects domestic animals, with illustrative cases.

5.—Inoculation and feeding experiments to show the communicability of the disease from affected to healthy animals.

6.—Treatment of the disease, prophylactic and curative.

I have the honour to be,

Sir,

Your most obedient Servant,

DAVID BRUCE,

Surgeon-Major A.M.S.

Ubombo,

Zululand,

29th May, 1896.

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TO

Further Report

ON THE

TSETSE FLY DISEASE OR NAGANA IN ZULULAND.

BY

LIEUT.-COL. DAVID BRUCE, F.R.S., R.A.M.C.

London:
HARRISON AND SONS, ST. MARTIN'S LANE,
PRINTERS IN ORDINARY TO HIS MAJESTY.
1903.

Tsetse Fly Disease or Nagana

IN ZULULAND.

INTRODUCTION.

On the 29th May, 1896, I sent to H.E. the Governor of Natal a "Further Report on the Tsetse Fly Disease or Nagana," which was printed by the Royal Society, at the request of the Natal Government, and issued on the 4th February, 1897.

I remained at Ubombo, in Zululand, until the 30th July, 1897, when I was driven away by the fact that the Nagana had overspread its usual boundaries and was destroying all the domestic animals, not only on the Ubombo, but for 50 miles further inland.

There was a widespread epidemic among the native cattle which was thought might be rinderpest. At the request of the Government I visited several of the native kraals, and everywhere found the disease to be Nagana. Many of the cattle belonging to the natives living near us on the Ubombo died. The Magistrate lost nearly all his trek donkeys, and several of the horses succumbed to the disease. My pointer, who had lived in good health for nearly two years on the top of the Ubombo, also took Nagana at this time and died.

It was impossible to find any reason for this sudden activity on the part of the Tsetse Fly, in so leaving its haunts in the low country and spreading far inland. It probably had something to do with the long-continued drought, which had driven herds of wild animals to seek for greener pasture in the mountain valleys. It was evident that Ubombo had lost its character as a healthy experimental station. It was now part of the Fly Country. I therefore abandoned the investigation, and returned to Pietermaritzburg and military duty.

Since then, my long-continued absence from England, on account of the Boer War, has prevented me from publishing the few further observations I made on Nagana in the beginning of 1897. As some of these notes are not without interest, I propose to bring them out as an Appendix to the last Report. Since 1897 many papers have been published on the Tsetse Fly Disease.

My offer made at the end of the "Further Report" to supply anyone with living Trypanosoma was taken advantage of. The Royal Society, in London, and Messrs. Bordet and Danyz, in Pretoria—the former by means of dogs, the latter by means of a horse—received the living disease.

At this point I would place on record my most hearty thanks to the Hon. Sir Walter Hely-Hutchinson, G.C.M.G., at that time Governor of Natal and Zululand. The initiation of the inquiry into the nature of Nagana is wholly due to him. In spite of much difficulty and obstruction he persevered in the furtherance of the investigation, and certainly without his active aid and encouragement the little that has been done could never have been attempted.

I also beg to thank Lieutenant-Colonel Sir Marshal Clarke, K.C.M.G., Acting Administrator, Zululand, and his successor, C. R. Saunders, C.M.G., for their aid and countenance. I ought also to express my indebtedness to the Tsetse Fly Committee of the Royal Society, and especially to Sir Michael Foster, for their encouragement and suggestions in the carrying out of this investigation.

My wife also has my best thanks. In her capacity of sole laboratory assistant she worked throughout the enquiry.

68, Victoria Street,
London, S.W.,
13th January, 1903.

1.—TOPOGRAPHY AND PHYSICAL FEATURES OF THE UBOMBO FLY DISTRICT.

In order to show the general features of this Fly District, I have prepared the accompanying Map, which was made partly by myself and partly from a map with which I was supplied shortly before leaving Ubombo.

JOURNAL OF THE ROYAL ARMY MEDICAL CORPS
(1904) III, pages 17 - 41

"SLEEPING SICKNESS IN UGANDA."[1]

By Colonel DAVID BRUCE, F.R.S.
Royal Army Medical Corps.

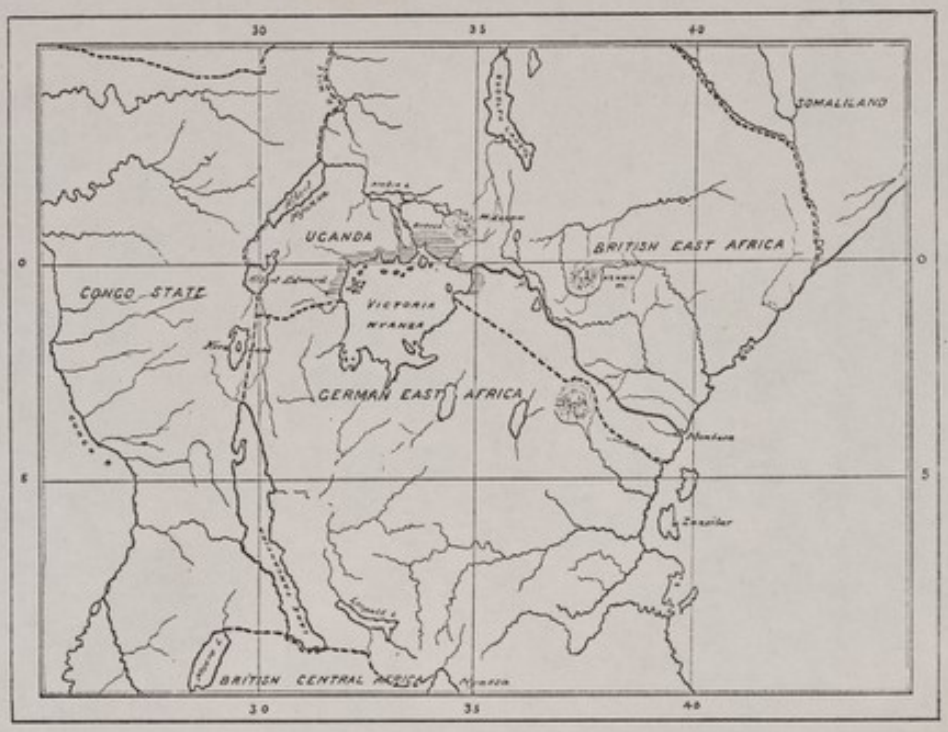
First allow me to remind you of the general position of Uganda in Central Africa, which is represented in the following map. The port of entry into the country is Mombasa, the Uganda railway running from here to Victoria Nyanza. On the north-west shore of the lake is Entebbe, the seat of the English Government in the Uganda Protectorate. Kampala, or Mengo, the native capital, lies some 20 miles to the north-east. Uganda proper lies to the north-west of the lake, Ankole and Unyoro to the west of Uganda, and Busoga to the east. The other lakes, Albert Nyanza, Lake Albert Edward and Lake Tanganyika, form the boundary between the Uganda Protectorate and the Congo State. To the east of Busoga is British East Africa.

The portion of the map which is shaded with horizontal lines represents the part of the country in which sleeping sickness is raging—that is the sleeping sickness area. And first let us consider how the disease was introduced into the country. There are various theories in regard to this. It is quite impossible, in my opinion, that the disease could have been indigenous in the country. None of the chiefs or missionaries, who have been many years in the country, ever saw a case of the disease before the year 1901. In April of that year the Drs. Cook, Medical Missionaries at Kampala, reported the first case.

It first broke out in the part of the country lying to the east, called Busoga. Dr. Moffatt, C.M.G., the Principal Medical Officer of Uganda, is of opinion that the disease was introduced into this part of the country when Emin Pasha's Soudanese and their wives and followers, numbering some 10,000, were brought into and settled in Busoga. These natives were brought from the edge of the Congo territory lying to the west, and therefore from a country in which sleeping sickness has been endemic for an unknown time. It seems, then, quite probable that some of these natives, brought in with the remains of Emin Pasha's expedition, may have brought the disease into Busoga, and that from this focus it slowly spread to the neighbouring population. Be that as it may, the disease broke out in this part of the country some time between 1896, according to

[1] A discourse delivered at the Royal Institution, London, Friday, April 22, 1904.

Dr. Hodges, and 1901, when the disease was definitely diagnosed, and in a short time reduced a populous and richly cultivated country to a depopulated wilderness.



Map showing Position of Uganda.[1]

Now, having discussed the introduction of sleeping sickness into Uganda, let me for a few minutes draw your attention to the disease

[1] The maps, tables and illustrations in this paper are taken, with the permission of the Royal Society, from the "Further Report on Sleeping Sickness in Uganda," by Lieut.-Col. David Bruce, R.A.M.C., F.R.S., David Nabarro, M.D., and Capt. E. D. W. Greig, I.M.S. Harrison & Sons, London.

The illustrations showing the parasites have been kindly lent by the *British Medical Journal*.

Fig. 1. – "Kitaroma."

FIG. 2.—"Sabiri."

itself. Sleeping sickness is a curious disease, and is essentially a disturbance of the functions of the brain. A slow chronic inflammatory process takes place in the brain substance, which after a time gives rise to the peculiar symptoms of the disease. But for a long time, sometimes years, the preliminary symptoms of sleeping sickness may be of so slight a character that no one suspects there is anything wrong. That is to say, the sleeping sickness patient may go about doing his ordinary work for years without his friends noticing there is anything the matter. But gradually a slight change in his demeanour becomes evident; he is less inclined to exert himself; he lies about more during the day, and at last his intimates see that he has the first symptoms of this absolutely fatal malady.

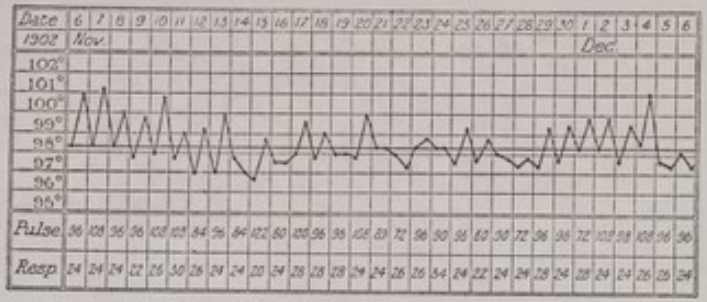
Fig. 1 is a photograph of a typical case of sleeping sickness.

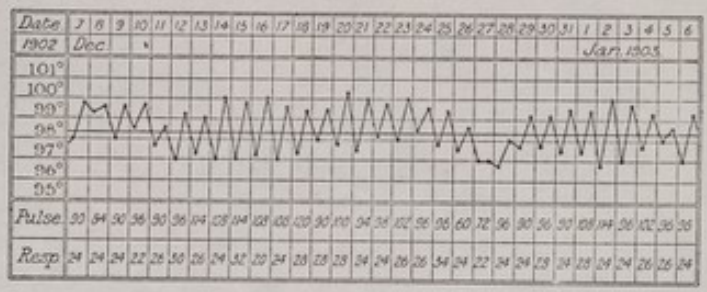
Mark the sad, heavy, dull-eyed, apathetic face. The man is, however, well nourished, and this is the rule if the patients are well nursed and fed. If you examine this man's pulse, you find it rapid and weak. If you ask him to hold out his hands, you find that they are weak and tremulous. When asked to walk, his gait is weak and uncertain. When he answers a question, his voice is weak, indistinct and monotonous. The symptoms gradually deepen, and after several months the patient is unable to walk, unable to speak, and unable to feed himself. He is then, of course, altogether confined to his bed, lying in an absolutely lethargic condition all day long. It is in this stage that the sick are often neglected by their friends, they remain unfed, and so become emaciated, as Fig. 2 shows.

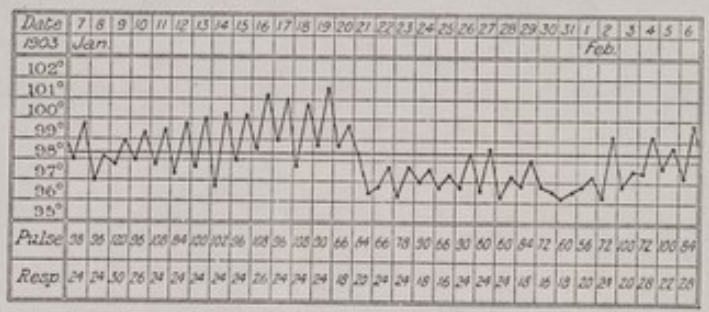
In regard to other symptoms it may be mentioned that during the illness the temperature has shown some elevation of an irregular character, often normal in the morning and rising to 102° or so in the evening. (Fig. 3.)

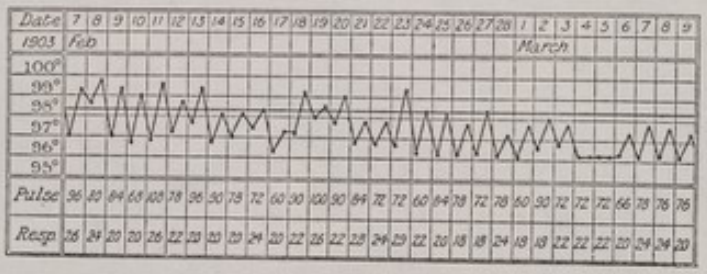
Here you see the irregular course of the fever, and also that during the last few weeks of life the temperature falls several degrees below the normal line, showing the gradual extinction of the vital forces.

This then is a short description of this peculiar disease called sleeping sickness; and now the question arises, what is it that causes this peculiar disease, and gives rise to these curious symptoms? I may pass over without notice the various theories which have been held up to the present time to account for this disease, and ask your attention to what is revealed on a careful microscopical examination of the blood of these cases. If the blood


Date
1902
Nov.
Dec.
102°
101°
100°
99°
98°
97°
96°
95°
Pulse
Resp


Date
1902
Dec.
Jan. 1903.
101°
100°
99°
98°
97°
96°
95°
Pulse
Resp


Date
1903
Jan.
Feb.
102°
101°
100°
99°
98°
97°
96°
95°
Pulse
Resp


Date
1903
Feb.
March
100°
99°
98°
97°
96°
95°
Pulse
Resp

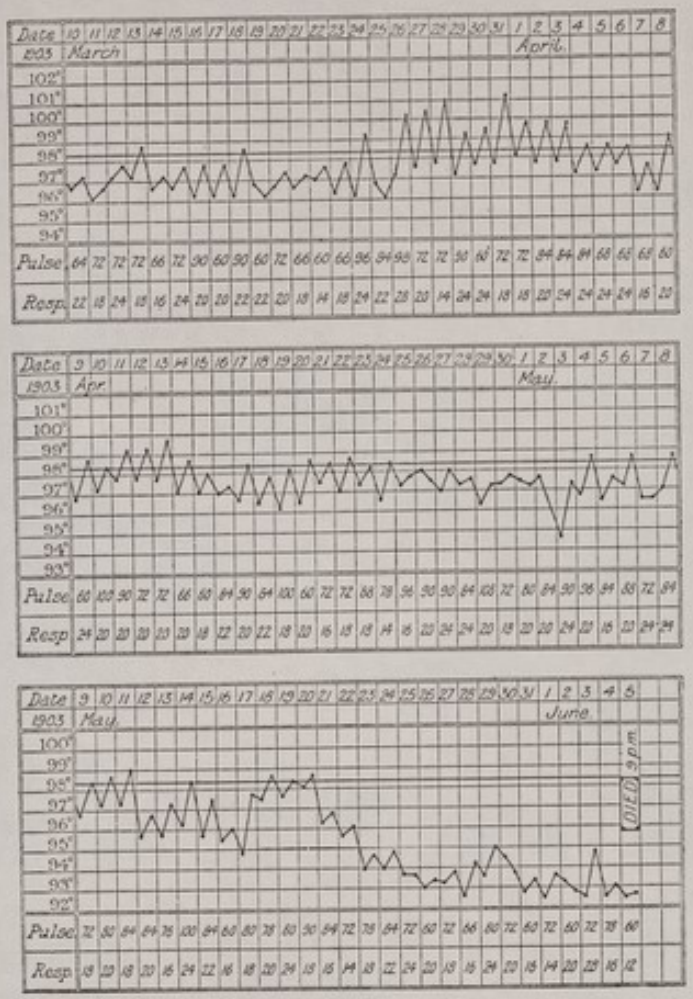

Date
1903 March
April.
102°
101°
100°
99°
98°
97°
96°
95°
94°
Pulse
Resp.
Date
1903 Apr.
May.
101°
100°
99°
98°
97°
96°
95°
94°
93°
Pulse
Resp
Date
1903 May.
June.
100°
99°
98°
97°
96°
95°
94°
93°
92°
Pulse
Resp
Died 9 p.m.

Fig. 3.

from a case of sleeping sickness is examined under a high power of the microscope, an active, wriggling parasite may be seen, which is known by the name of trypanosome.

Here is a representation of the trypanosome found in sleeping sickness:—

Fig. 4.—Blood Parasites.

These blood parasites belong to the lowest group in the animal kingdom, viz., the protozoa. The trypanosome consists of a single cell, and in its best known form is a sinuous, worm-like creature, provided with a macronucleus and a micronucleus, a long terminal flagellum, and a narrow fin-like membrane, continuous with the flagellum and running the whole length of the body. When alive it is extremely rapid in its motions, constantly dashing about, and lashing the red blood corpuscles into motion with its flagellum. It swims equally well with either extremity in front.

Among the first to draw attention to these blood parasites was the late Surg.-Major Timothy Lewis, F.R.S., R.A.M.C.; he discovered a trypanosome, in 1888, in the blood of rats in India, to

which was afterwards given the name of *Trypanosoma Lewisi*. This rat trypanosome is found all over the world, and even in Uganda the blood of the ordinary common wild field rat was often found to contain myriads of these creatures. This trypanosome does not appear to do any great harm, or to have any effect on the health of the rats. The next important trypanosome was found also in India, in the blood of horses suffering from surra. This disease, surra, is closely related to the tsetse fly disease of South Africa, or, as it is called by the natives, nagana.

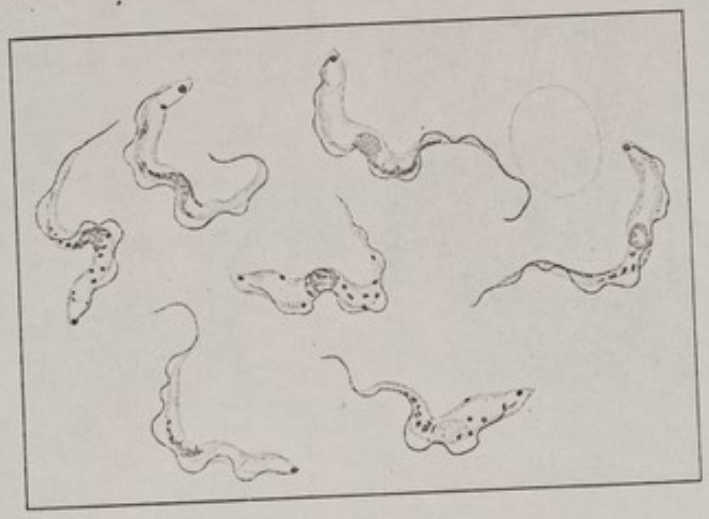


Fig. 5.—Blood of Sleeping Sickness Cases.

The trypanosome which causes tsetse fly disease lives in the blood of the wild animals, such as the buffalo and various antelopes, without evidently interfering with their health, but, when transferred by the tsetse fly from the blood of these wild animals to that of the domestic animals, it causes the death of the latter. Almost all the domestic animals are highly susceptible to nagana, especially horses, dogs and cattle, and even monkeys, but curiously enough man himself is insusceptible.

But now let us return to our examination of the blood of cases of sleeping sickness. The method of examination is simple: 10 c.c. of blood are drawn, by means of a hollow needle, from one of

the veins of the arm, and this is then centrifuged to get rid, as far as possible, of the red blood corpuscles. When this has been done the clear fluid is decanted off and again centrifuged, and the sediment now resulting is subjected to microscopical examination.

Date.	Name.	Sex.	Age.	Duration of disease.	Trypanosoma.
1903.					
Apr. 16	Benjamini	Male	28	1st stage	Present.
„ 18	Esaka	„	28	1st „	„
„ 18	Waiswa	„	10	1st „	„
„ 18	Kidorme.....	„	20	2nd „	„
„ 18	Zebuganza	„	40	1st „	„
„ 18	Budara	„	22	2nd „	„
„ 20	Kimbra	„	30	2nd „	„
„ 20	Matasa.....	„	24	1st „	„
„ 21	Seera	„	25	2nd „	Absent.
„ 22	Waresansa	„	32	2nd „	Present.
„ 22	Katola	„	25	1st „	„
„ 27	Kesgoffa	„	30	1st „	„
„ 27	Kitaroma	„	20	1st „	„
May 12	Nakaiba	Female	8	1st „	„
„ 12	Musa	Male	20	1st „	„
„ 14	Diwarana	„	14	1st „	„

I draw your attention to this table giving the result of the examination of sixteen cases, and here you find that in every case, with the exception of one, this trypanosome is found. In all probability it would have been found in the sixteenth case if there had been opportunity for further examination, but the man unfortunately died before the trypanosomes had been discovered in his blood.

But there is another fluid in the body which is more easily examined than blood for such a small parasite, and that is the cerebro-spinal fluid.

This cerebro-spinal fluid is a clear transparent fluid, exactly resembling water in outward appearance, which fills the various cavities of the brain and surrounds the spinal cord so as to prevent damage to these delicate organs. It is easily obtained by introducing a hollow needle between the vertebræ in the lumbar region. Ten to fifteen cubic centimetres of the fluid are drawn off, which is then centrifuged and the sediment examined. As there are few or no red corpuscles in the fluid to interfere with vision, naturally the actively moving trypanosomes are more easily detected.

I now give a table showing the result of the examination of the cerebro-spinal fluid of cases of sleeping sickness.

Date.	Name.	Sex.	Age.	Duration of case.	No. of examination.	Trypanosoma.
1903.						
May 14	Kaperi	Male	8	3rd stage	1	Present.
Mar. 26	Seera	"	25	1st "	1	"
" 26	Budara	"	22	2nd "	1	"
" 26	Kimbra	"	30	2nd "	1	"
" 26	Kagoya	Female	20	3rd "	1	"
" 27	Zebogaaza	Male	40	1st "	2	"
" 27	Yakuba	"	12	2nd "	1	"
" 28	Kidorme	"	20	2nd "	1	"
" 28	Leobeni	"	25	3rd "	1	"
" 29	Waiswa	"	10	1st "	1	"
" 31	Dekodemo	"	25	3rd "	1	"
Apr. 1	Fatoma	Female	18	1st "	2	"
" 6	Katola	Male	25	1st "	1	"
" 6	Esaka	"	28	1st "	1	"
" 6	Nakaiba	Female	10	1st "	1	"
" 6	Zakibu	Male	20	2nd "	1	"
" 6	Waresansa	"	32	2nd "	1	"
" 8	Jansi	"	25	1st "	1	"
" 9	Feragi	"	12	1st "	1	"
" 10	Katooda	"	20	1st "	1	"
" 10	Donah	"	38	1st "	1	"
" 10	Asumani	"	25	1st "	2	"
" 10	Kainavidi	"	20	1st "	1	"
" 10	Moosura Madunga	"	30	1st "	2	"
" 10	Msabwa	"	30	1st "	1	"
" 10	Adam	"	30	2nd "	1	"
" 13	Nonbi	Female	30	1st "	2	"
" 13	Benjamini	Male	24	1st "	5	"
" 13	Kiagoffa	"	30	1st "	1	"
" 13	Kitaroma	"	20	1st "	1	"
" 14	Nateneri	"	25	1st "	1	"
" 14	Mutaisa	"	15	1st "	1	"
" 14	Erissa	"	20	1st "	1	"
" 14	Bagwibwa	Female	18	1st "	1	"
" 14	Johana	Male	20	1st "	1	"
" 14	Mwasa	Female	18	1st "	1	"
" 14	Rukina	Male	25	2nd "	1	"
" 20	Matasa	"	24	1st "	4	"
May 4	Kiagabidoia	"	50	1st "	5	"
" 14	Divarana	"	14	1st "	1	"

Here, as you see, forty cases have been examined and the trypanosomes found in every case. This is rather a suggestive fact, and it begins to appear probable that these parasites may have some causal relationship to the disease.

But it may be that this trypanosome is a mere accidental concomitant of the disease, living in the blood and cerebro-spinal fluid without affecting the health, much in the same way as the rat

trypanosome lives in rats, or the nagana trypanosome in the wild animals. So it may be that natives suffering from other diseases also harbour these trypanosomes in their cerebro-spinal fluid. To find out if this were so we must examine the cerebro-spinal fluid of natives who come into hospital for other complaints than sleeping sickness. The following table shows the result of the examination of the cerebro-spinal fluid of fifteen cases, and here the trypanosomes are absent in every case.

Date.	Name.	Sex.	Age.	Locality.	Trade.	Disease.	Trypanosoma.
1903.							
Mar. 24	Landu	M.	..	Hospital	Marine	Suppurating fem. glands	Absent.
„ 30	Zake	M.	25	„	Patient	Swelling under pectoralis	„
„ 30	Icongo	M.	..	„	„	..	„
„ 30	Pio	M.	12	„	„	Fracture	„
„ 30	Kapere III	M.	25	„	„	Itch	„
„ 30	Eliza	F.	18	„	„	Yaws	„
„ 31	Bofralour	M.	16	„	„	Pleuritis	„
„ 31	Zanabu	F.	30	„	„	Headache	„
Apr. 1	Nabujam	F.	45	„	„	Cerebral tumour	„
„ 8	Kamsa Mahomed	M.	25	„	„	Madura foot	„
„ 23	Daudi	M.	..	Entebbe	Prisoner	Patient in civil hospital	„
„ 24	Nathaniel	M.	..	Hospital	Patient	Not diagnosed	„
„ 29	Arkadi	M.	..	„	„	Suppurating bubo	„
May 8	Matea	M.	..	„	„	Circumcision	„
„ 6	Kavera	M.	..	„	„	Rheumatism	„

But now, having seen that this trypanosome is found in the blood and cerebro-spinal fluid of all cases of sleeping sickness, and that it is not found in the cerebro-spinal fluid of natives suffering from other diseases, let me ask you to consider that in a slow and chronic disease such as this, sometimes taking years to develop, there must be many natives living in the sleeping sickness area who have these trypanosomes in their blood without as yet showing any manifest symptoms of the disease. This seems to be an important point, because if this trypanosome is in reality the cause of sleeping sickness, a certain proportion of the natives inhabiting the sleeping sickness area ought to harbour these parasites in their

FIG. 6.—Sick monkey.

blood. On the other hand, if this parasite is the true cause of this disease, then no native living in a non-sleeping sickness area ought to harbour a single trypanosome in his blood. It will, therefore, be interesting to examine the blood of natives in the sleeping sickness area and the non-sleeping sickness area of Uganda. Further, it will act as a check if we examine natives living in a non-sleeping sickness area, say in Nairobi, in British East Africa, which is some hundreds of miles away from any infected place. (See Tables A, B and C.)

Eighty natives from the sleeping sickness area were examined with the result that twenty-three were found to have trypanosomes in their blood, giving a percentage of 28·7. One hundred and seventeen were examined from non-sleeping sickness areas, but not a single trypanosome was found.

You will all agree with me that these results make it very highly probable that the trypanosome under discussion is the real cause of this disease; but there are other methods of adding to this proof, for example, by experiments on animals. If this trypanosome gives rise to symptoms of sleeping sickness in one of the lower animals, this will be a great addition to the proof that this parasite is the cause of sleeping sickness.

The best animals procurable in Entebbe for the purpose of animal experimentation are monkeys. The infective material is injected under the skin, into the spinal canal, and also into the cavity of the brain. The animals show no symptoms for a long time; their temperature remains absolutely normal, and they appear to be in perfect health, but after some months fever of an irregular type sets in and the animals begin to show symptoms of lethargy, sitting about all day, and taking very little interest in their surroundings. Towards the end they sit all day long with their heads bent on their chests, apparently asleep, and show a strong resemblance to the later symptoms of the disease in man.

During this time the monkeys show, constantly, trypanosomes in their blood, sometimes in fairly large numbers.

Fig. 6 is a photograph of one of these sick monkeys.

Therefore it is shown that the trypanosomes derived from cases of sleeping sickness give rise to a long chronic disease in the monkey with symptoms closely resembling those seen in man. From these animal experiments, taken in connection with the other observations, we may now assert that these trypanosomes are the cause of sleeping sickness.

Incidence of Trypanosomes in the Blood of General Population.

A.—Sleeping Sickness Area.

Date.	Name.	Age.	Sex.	District.	Shamba.	Name of Chief.	Trypanosomes	Filaria.
June 12 ..	Wagononye	25	M.	Sese Island ..	Sewana	—	+	+
,, 13 ..	Zamala	20	M.	,, ..	Kaganda Island	—	—	+
	Sibolyamba	25	M.	,, ..	Semagala Island, Malanga ..	—	+	+
	Lusaka	30	M.	,, ..	Kaganda Island, Bubeki ..	—	—	+
	Byasi	20	M.	,, ..	Semagala Island, Busendeni	Serumaga ..	—	+
	Nalyonzi	25	M.	,, ..	Buvovu Island, Kasange ..	Nokuba ..	—	+
	Sagala	25	M.	,, ..	Kaganda Island, Bukasa ..	Kaganda ..	—	+
,, 16 ..	Paulo	20	M.	,, ..	Semagala Island, Dajs ..	Bugambi ..	—	+
	Luwercheti	30	M.	,, ..	Buvu Island	Namamba ..	—	+
	Balyokwakwe ..	35	M.	,, ..	Semagala Island, Burigo ..	Kakobogo ..	—	—
	Kapere	20	M.	,, ..	,, ,, Busowa ..	Sawadu ..	—	—
	Kewaza	20	M.	,, ..	,, ,, Bungo ..	Kakobogo ..	—	+
	Takirambala ..	40	M.	,, ..	Lubamba Island, Impenja ..	Sabawabo ..	—	—
	Gumira	40	M.	,, ..	Bugaba Island	Bugu ..	+	+
	Kitungula	25	M.	,, ..	Semagala Island, Buswa ..	Kezekia ..	+	—
	Tevamukopi ..	35	M.	,, ..	Bunami Island	Buvaro ..	+	+
	Kajerero	25	M.	,, ..	Buninga Island	Savawan ..	—	+
,, 18 ..	Zwaki	23	M.	Kome Island ..	Kome Island	—	+	+
	Nutaba	24	M.	Bugaba Island	Bugaba Island	—	+	+
	Nmmugula	25	M.	Sewaia Island ..	Sewaia Island	—	—	—
,, 19 ..	Sibaganga	30	M.	Bussi Island ..	Bulenge	Mugema ..	+	—
,, 23 ..	Tangamalala ..	25	M.	,, ..	Bussi Island	Rasto ..	+	+
	Nassjago	30	M.	,, ..	,, ...	,, ..	+	+
	Tabula	10	M.	,, ..	,, ...	,, ..	—	+
	Mundu	25	M.	,, ..	,, ...	,, ..	—	+
,, 27 ..	Mondu	20	M.	,, ..	,, ...	Mugema ..	—	+
	Buza	30	M.	,, ..	,, ...	,, ..	+	+
	Sabakake	20	M.	,, ..	,, ...	,, ..	+	+
	Bagamatuba ..	30	M.	,, ..	,, ...	,, ..	—	+
	Nangibwa	30	M.	,, ..	,, ...	,, ..	—	+
,, 8 ..	Magwanjemba ..	40	M.	Kagagara ..	—	—	+	+
,, 13 ..	Rotate	45	M.	Nkumba ..	Nkumba	Sebugwa ..	—	+
	Junguberase ..	25	M.	,, ..	,, ...	,, ..	—	—
	Mucase	25	M.	,, ..	,, ...	,, ..	+	—
	Sefebedi	40	M.	,, ..	,, ...	,, ..	—	—
	Mundu	30	M.	,, ..	,, ...	,, ..	—	+
	Kikocharwasi ..	35	M.	,, ..	,, ...	,, ..	—	—
,, 19 ..	Petero	20	M.	Entebbe ..	Ugonga	—	—	—

June 19 ..	Sibasoboke ..	30	M.	Bussi Island ..	Gombe	Mugema ..	—	+
,, 20 ..	Arikisi ..	40	M.	Magema ..	Mugema	Sebugwao ..	—	+
	Antonio ..	20	M.	,, ..	,,	,, ..	—	—
	Kiguaku ..	30	M.	,, ..	,,	,, ..	—	—
	Brahmi ..	25	M.	,, ..	,,	,, ..	—	—
	Musoke ..	14	M.	,, ..	,,	,, ..	—	—
	Daniel ..	12	M.	,, ..	,,	Sebanji ..	—	—
	Balumedeni	20	M.	,, ..	,,	,, ..	—	—
	Semone ..	20	M.	,, ..	,,	,, ..	—	+
	Muagazi ..	30	M.	,, ..	,,	Mugema ..	—	+
	Nyasi ..	12	M.	,, ..	,,	Sebanja ..	—	—
,, 22 ..	Saulo ..	18	M.	,, ..	,,	Mugema ..	+	—
	Zake ..	20	M.	,, ..	,,	,, ..	—	+
	Kalulwe ..	40	M.	Entebbe ..	Kigungu	Mugula ..	+	+
	Kakulwana ..	18	M.	,, ..	,,	Wasanye ..	—	+
,, 23 ..	Zirimanye ..	18	M.	,, ..	,,	Mugula ..	—	—
	Danielli ..	16	M.	,, ..	,,	Batende ..	—	—
	Daudi ..	20	M.	,, ..	4 miles	Kalunga ..	—	+
	Bafirawara ..	16	M.	,, ..	Zinderi	Mugula ..	—	—
	Mutesenda ..	20	M.	,, ..	3 miles	,, ..	—	—
	Lugwana ..	18	M.	,, ..	Kabale	Sebugwao ..	—	—
	Gabula ..	20	M.	,, ..	—	,, ..	+	—
March 12 ..	Karala Barigi ..	—	M.	,, ..	Policeman	—	+	+
,, 28 ..	Kumsarasbba ..	—	M.	,, ..	,,	—	+	—
,, 31 ..	Jordien Murjan ..	—	M.	,, ..	Prisoner	—	+	—
April 15 ..	Tabula ..	—	M.	,, ..	Marine	—	+	+
,, 21 ..	Bara Risgallah ..	—	M.	,, ..	Policeman	—	+	+
,, 23 ..	Airara ..	—	M.	,, ..	Prisoner	—	—	—
	Biggity ..	—	M.	,, ..	,,	—	—	—
,, 24 ..	Nathaniel ..	—	M.	,, ..	Hospital	—	—	—
,, 28 ..	Aradiki ..	—	M.	,, ..	,,	—	—	—
,, 29 ..	Chia Msoga ..	—	M.	,, ..	,,	—	—	—
	Arkadi ..	—	M.	,, ..	,,	—	—	—
	Mandandiki ..	—	M.	,, ..	,,	—	—	—
May 6 ..	Jumabini ..	—	M.	,, ..	,,	—	—	—
,, 8 ..	Matea ..	—	M.	,, ..	,,	—	—	—
,, 13 ..	Bifarawala ..	—	M.	,, ..	Prisoner	—	—	—
,, 16 ..	Amuri Abdulla ..	—	M.	,, ..	,,	—	—	—
,, 18 ..	Serewamo ..	—	M.	,, ..	,,	—	—	—
,, 21 ..	Juma Bin Abdulla ..		M.	,, ..	,,	—	—	—
,, 22 ..	Baraca Bin Salimi ..	—	M.	,, ..	,,	—	—	—
April 2 ..	J. M. ..	—	M.	,, ..	Hospital	European ..	+	—

Incidence of Trypanosomes in the Blood of General Population.

B.—Non-Sleeping Sickness Area, Uganda.

Date.	Name.	Age.	Sex.	District.	Shamba.	Name of chief.	Trypano-soma.	Filaria.
June 2.....	Wagalla	40	M.	Kampala	..	..	–	+
	Zemadari	20	M.	"	..	..	–	+
	Mutakanja	25	M.	"	..	..	–	–
	Suziga	20	M.	"	..	..	–	–
" 3.....	Burrigardi	30	M.	Toro.....	Kaima.....	..	–	–
	Ntaragi	40	M.	Makota	5 days N. of Kampala..	..	–	–
	Bassaga	15	M.	"	" ..	..	–	–
	Kilongazi	50	M.	Jalamba	Near Makota	..	–	–
" 4.....	Kianju	40	M.	Buganga	..	..	–	+
	Nsali	40	M.	"	..	..	–	–
	Jagenda	35	M.	Singo	Matiana	..	–	–
	Sengova.....	50	M.	Buganga	..	..	–	–
	Kidormori	30	M.	Nakolia.....	..	..	–	–
	Bagusagera	25	M.	"	..	..	–	+
" 5.....	Laganda	20	M.	Kalagala	..	..	–	–
	Birila.....	35	M.	Matuntotora	..	..	–	–
	Kagema	45	M.	"	..	..	–	+
	Kasoka	35	M.	Kibali	..	..	–	+
	Bulabiki	40	M.	Kiwangole	..	..	–	–
" 8.....	Kongura.....	35	M.	Kikanda	..	..	–	–
" 10.....	Watagana	35	M.	Bulemwezi	Busibika	..	–	–
	Karimuemba	40	M.	Kalagala.....	Kalagala	..	–	–
	Watesaka	20	M.	Bulemwezi.....	Sambwao	..	–	–
	Matamburire.....	35	M.	"	Busindi..... ..	..	–	+
	Roukinju	30	M.	"	Sambwao	..	–	–
	Kaisi.....	40	M.	"	"	..	–	+
" 11.....	Gustude	25	M.	Mawokota	Kaniki	..	–	+
	Murianzeki	30	M.	"	"	..	–	–
	Tandamuwaka	30	M.	"	"	..	–	+
	Banegwira	30	M.	"	"	..	–	+
	Basaga.....	30	M.	"	"	..	–	+
	Muayowa	35	M.	"	"	..	–	+

Non-Sleeping-Sickness Area, Uganda—*continued.*

Date.	Name.	Age.	Sex.	District.	Shamba.	Name of chief.	Trypanosoma.	Filaria.
June 12	Kawaratuli	45	M.	Buddu	Masaka	..	–	+
	Kyalwazi	45	M.	„	„	..	–	+
	Byempulidi	40	M.	„	„	..	–	–
	Ganantawa	40	M.	„	..	..	–	+
	Sabugwera	25	M.	„	Dinnu ?	..	–	+
„ 15.....	Kubolikoza	20	M.	Mawokota	Kaima	Rutalo	–	–
	Semukota	30	M.	„	Kabire	Muhaia	–	–
	Muogozi	25	M.	„	Kagenda	Kagenda	–	–
	Muinda	30	M.	„	Dozda	Muquerwa	–	+
	Bamutarye	45	M.	„	Kaima	Dukadyi	–	+
	Mitickula	23	M.	„	Keango	Kabodyi	–	–
„ 17.....	Kida	25	M.	Busiro	Lucka	Mukulu	–	+
	Zambatise	25	M.	„	Kiengaza	„	–	–
	Ibu	25	M.	„	Lucka	„	–	+
	Zinazi	20	M.	„	Kisiba	Kasola	–	–
	Takaridia	20	M.	Singo	Bujonkola	Kajongolo	–	–
	Malugyo	20	M.	„	Ksagembi	Mbugano	–	–
	Bafirawala	20	M.	„	Kalungu	Mutesa	–	–
	Buzibwa	20	M.	Busiro	Kireha	Kikwabanga	–	–
	Nume	35	M.	Singo	Kagembe	Mukwenda	–	+
„ 18.....	Kirimentao	40	M.	Unyoro	Buianja	Kimbaranga	–	–
	Tamanya	40	M.	„	„	„	–	–
	Makogoto	40	M.	„	Kikumbis	„	–	–
	Sabagabu	25	M.	„	Seresi	Museresi	–	–
	Lukala	25	M.	„	Pachwa	Kimbaranga	–	–
	Kowemi	25	M.	„	Bubangu	Kasoro	–	–
	Kahirebu	35	M.	„	Buisanja	Kimbaranga	–	–
	Rukubywa	40	M.	„	Pachwa	„	–	–
	Kieka	20	M.	„	„	Peteri	–	–
	Murumbia	30	M.	„	..	„	–	+
„ 19.....	Zezefu	25	M.	Bulemwezi	Kaswa	Kasiba	–	–
	Katagu	18	M.	Buddu	Kagandu	Kakembo	–	–
	Mukasa	14	M.	Busiro	Maganja	Mudmauliba	–	–
	Name unknown	20	M.	(?)	(?)	Bruci	–	–

Incidence of Trypanosomes in the Blood of General Population.

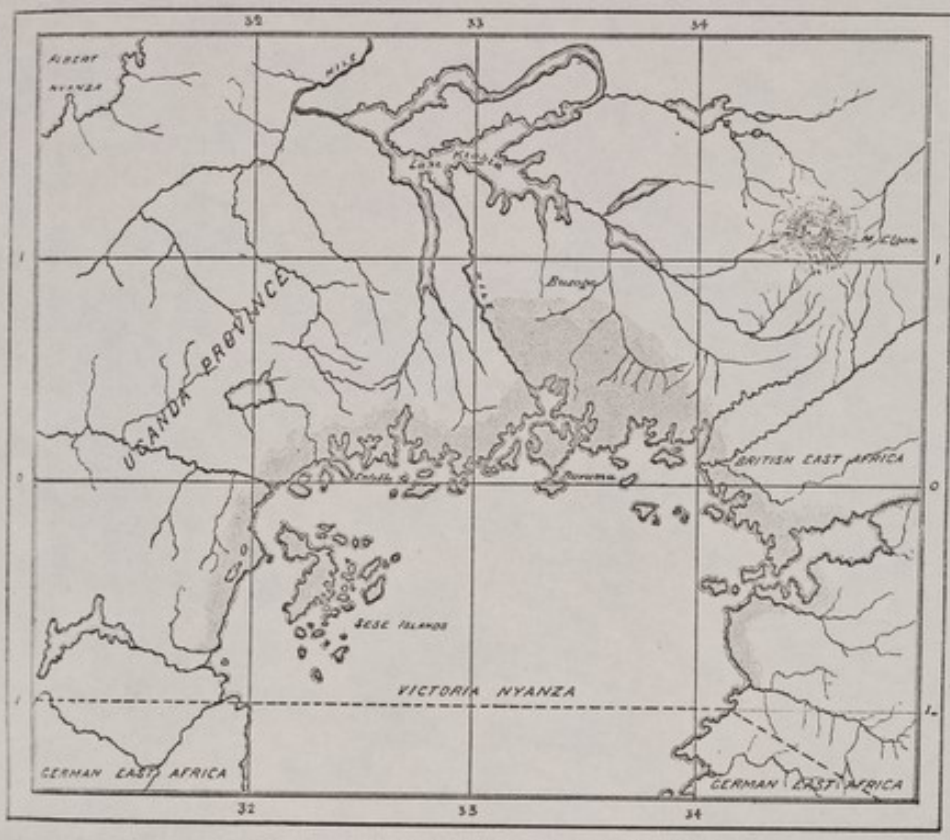
C.—Non-Sleeping Sickness Area, Nairobi, British East Africa.

(Examined by Capt. Greig, I.M.S., and Dr. Wiggins.)

Date.	Name.	Occupation.	District.	Trypanosoma.	Filaria.
July 14..	Sinandi	Askaris ..	Masai	–	–
	Gila	„	„	–	–
	Massina	„	„	–	–
	Barugo	„	„	–	–
	Matolo	„	„	–	–
„ 15..	Nandi	„	„	–	–
„ 15..	Tomana	„	„	–	–
	Rosani	„	„	–	–
	Rosi	„	„	–	–
	Lendiana	„	„	–	–
	Gingili	„	„	–	–
„ 16..	Rangue	„	„	–	–
	Kabede	„	„	–	–
	Kamia	„	„	–	–
	Tabangi	„	„	–	–
„ 17..	Karmongi	Labourer	Kukuyu ...	–	–
	Yurimgo	„	„ ...	–	–
	Girewamatwo	„	„ ...	–	–
	Katono	„	„ ...	–	–
	Gomi	„	„ ...	–	–
	Kayaro	„	„ ...	–	–
18..	Ati	Prisoner	„ ...	–	–
„ 20..	Gmosi	„	„ ...	–	–
	Luwi	„	„ ...	–	–
	?	„	Masai	–	–
	Nana	„	„	–	–
	Seri	„	„	–	–
	Goma	„	„	–	–
„ 20..	Kinare	„	„	–	–
	Mahone	„	Kukuyu ...	–	–
„ 21..	Masagai	„	Masai	–	–
	Desa	„	„	–	–
	Muenda	„	„	–	–
	Morandat	„	„	–	–
	Joke	„	Wakamba..	–	–
	Waweme	„	Masai	–	–
	Zabe	„	Wakamba..	–	–
	Kalango	„	Kukuyu ...	–	–
	Harya	„	„ ...	–	–
„ 22..	Nabo	Askaris ..	Masai	–	–
	Legina	„	„	–	–
	Kisikas	„	„	–	–
	Mandasingero	„	„	–	–
	Magome	„	„	–	–
	Longotoematabut ..	„	„	–	–
	Gomi	„	„	–	–
	Lulgini	„	„	–	–
	Zeru	Labourer	Kukuyu ...	–	–
	Jarogo	„	„ ...	–	–
	Kanosi	„	„ ...	–	–

I now pass on to the "distribution of sleeping sickness in Uganda."

This has been investigated by Dr. Hodges, one of the Uganda Colonial Surgeons, and he has prepared this map, which discloses a



Dr. Hodges' Map of Distribution of Sleeping Sickness.

remarkable fact. Sleeping sickness is found to have a very peculiar distribution. It is found to be restricted to the numerous islands which dot the northern part of the lake, and to a narrow belt of country a few miles wide skirting the shores of the lake. In no

part of Uganda can a single case be found more than a few miles from the lake shore. This part of the country, the islands and the shore of the lake, is, however, the most thickly populated, there being here a population of more than a 100 to the square mile. In this area since 1901 the disease has raged, and many places have become depopulated.

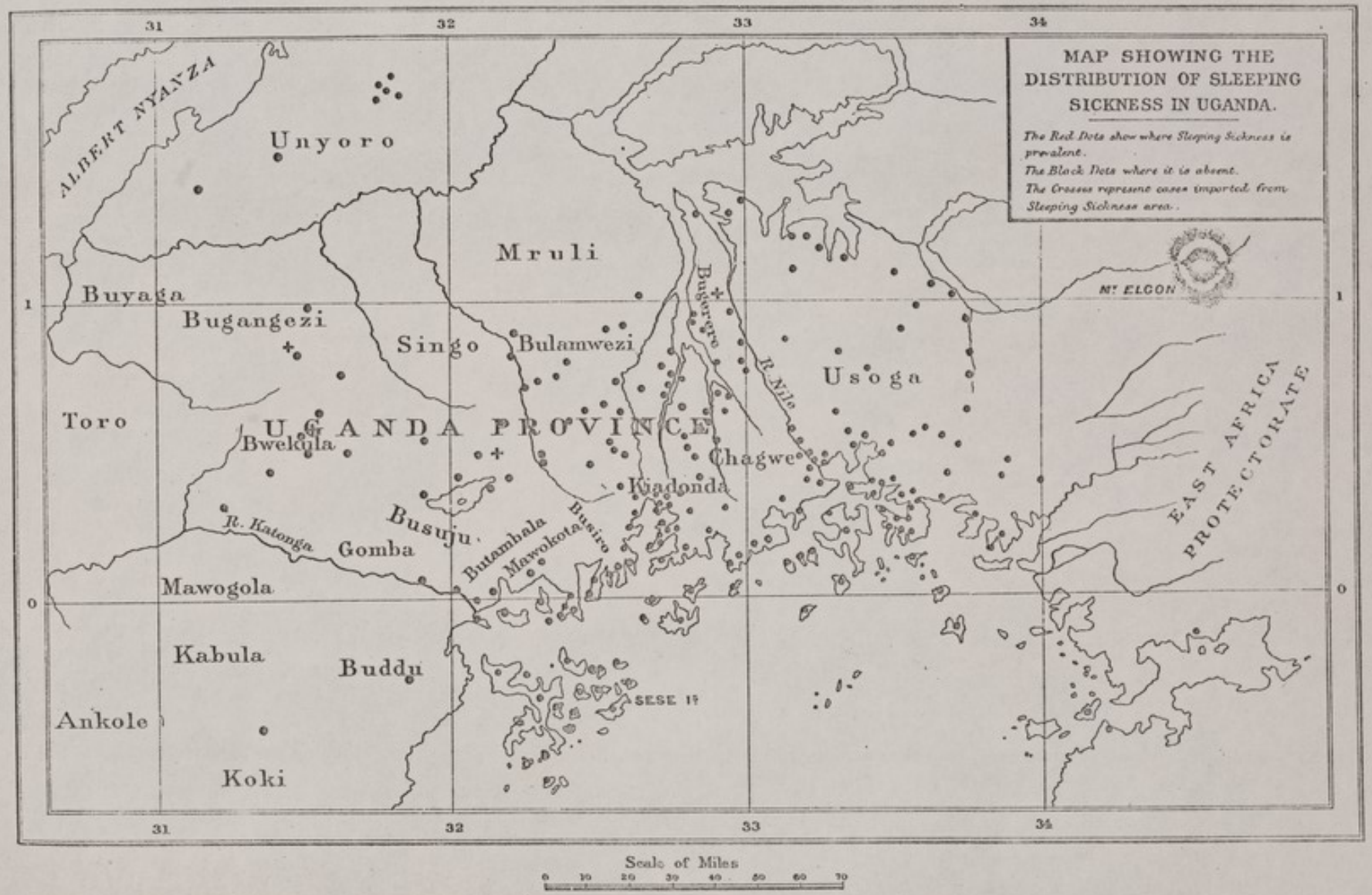
In Busoga, where, as we saw, the disease first broke out, cases are found further inland than in Uganda, but here also the same rule holds good. As Mr. Cubbitt, Assistant Collector in Busoga, wrote: "It would seem to be a fairly accurate statement to make, that sleeping sickness confines itself to the territories adjoining the lake, roughly speaking, from a ten to twenty mile radius of the coast." The Uganda Prime Minister, Apolo, also gives it as his opinion that a strip along the lake shore, ten miles broad, would cover the infected area, and that any cases found further inland are always imported cases. The islands have been specially affected by the disease. For example, the Island of Bavuma in 1901 had a population of 22,000; in 1903 only 8,000 remained alive.

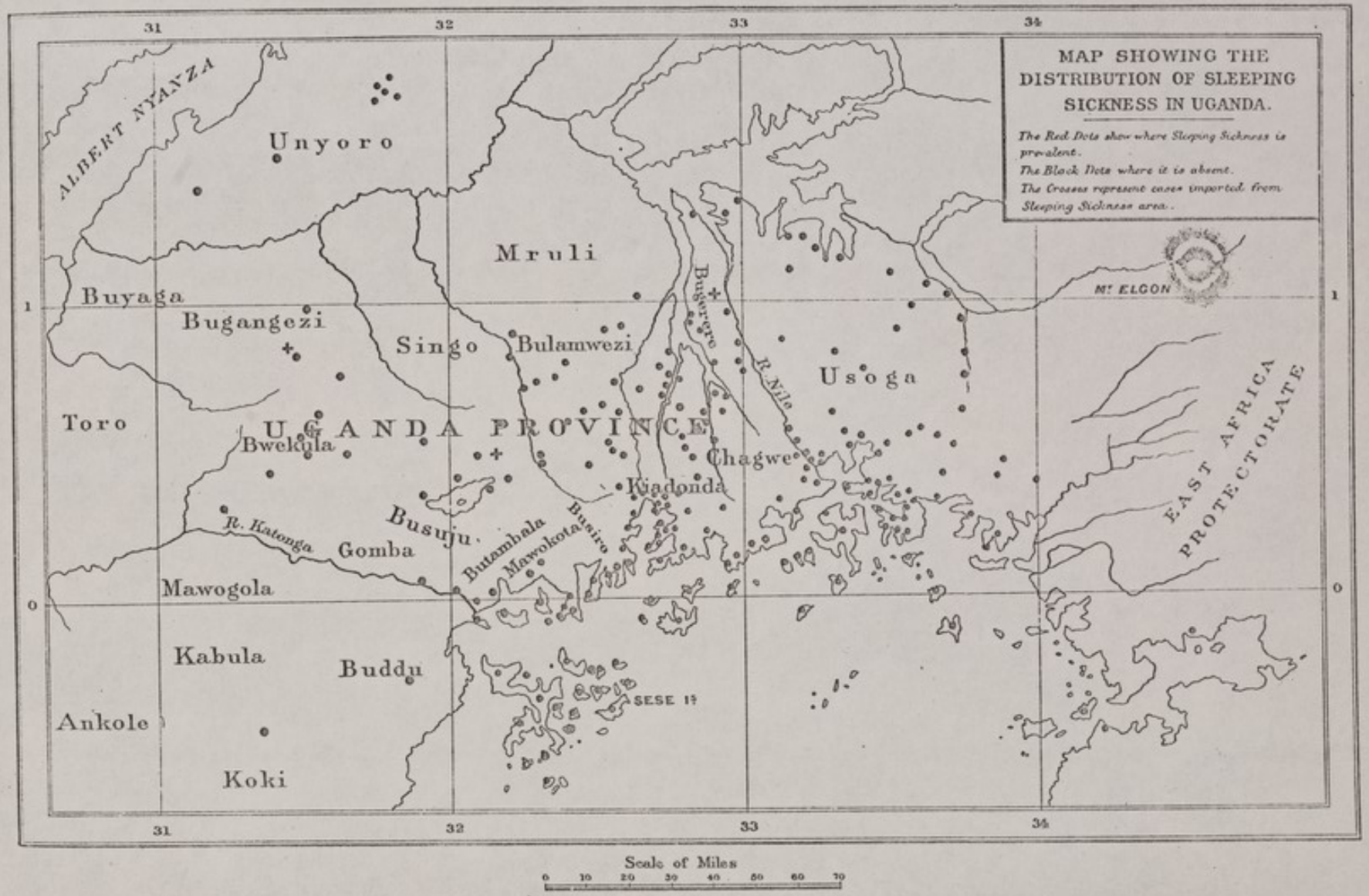
Now there must be some cause for this peculiar distribution. Sleeping sickness, evidently, cannot be due to a food poison, as has been suggested, since the people living outside the sleeping sickness strip eat the same food, and have the same habits as those living on the lake shore.

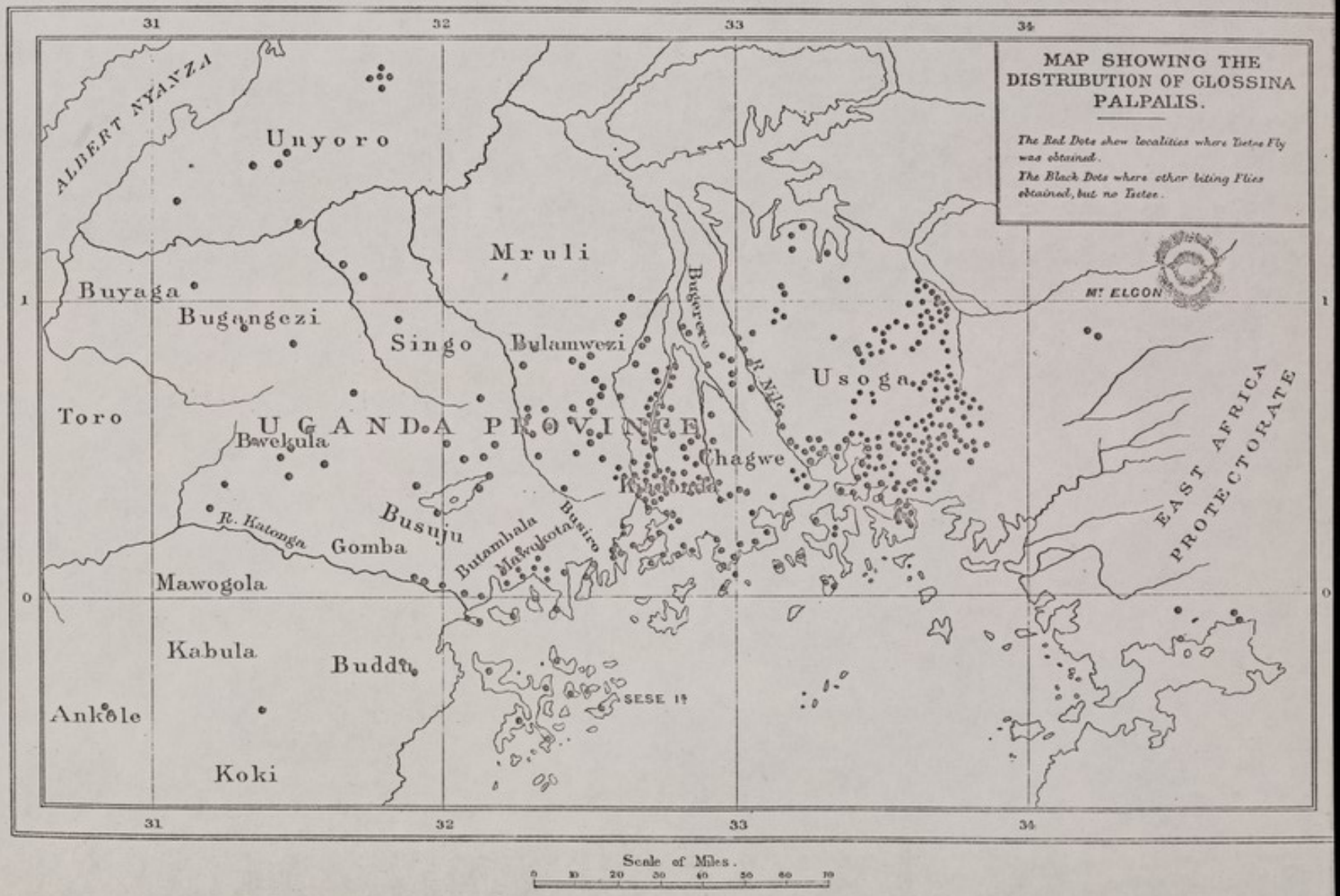
Then again, we have found that the cause of the disease is a trypanosome, a blood parasite, which is not likely to be conveyed in food or clothes, or directly from man to man, but most probably must be carried by some blood-sucking insect.

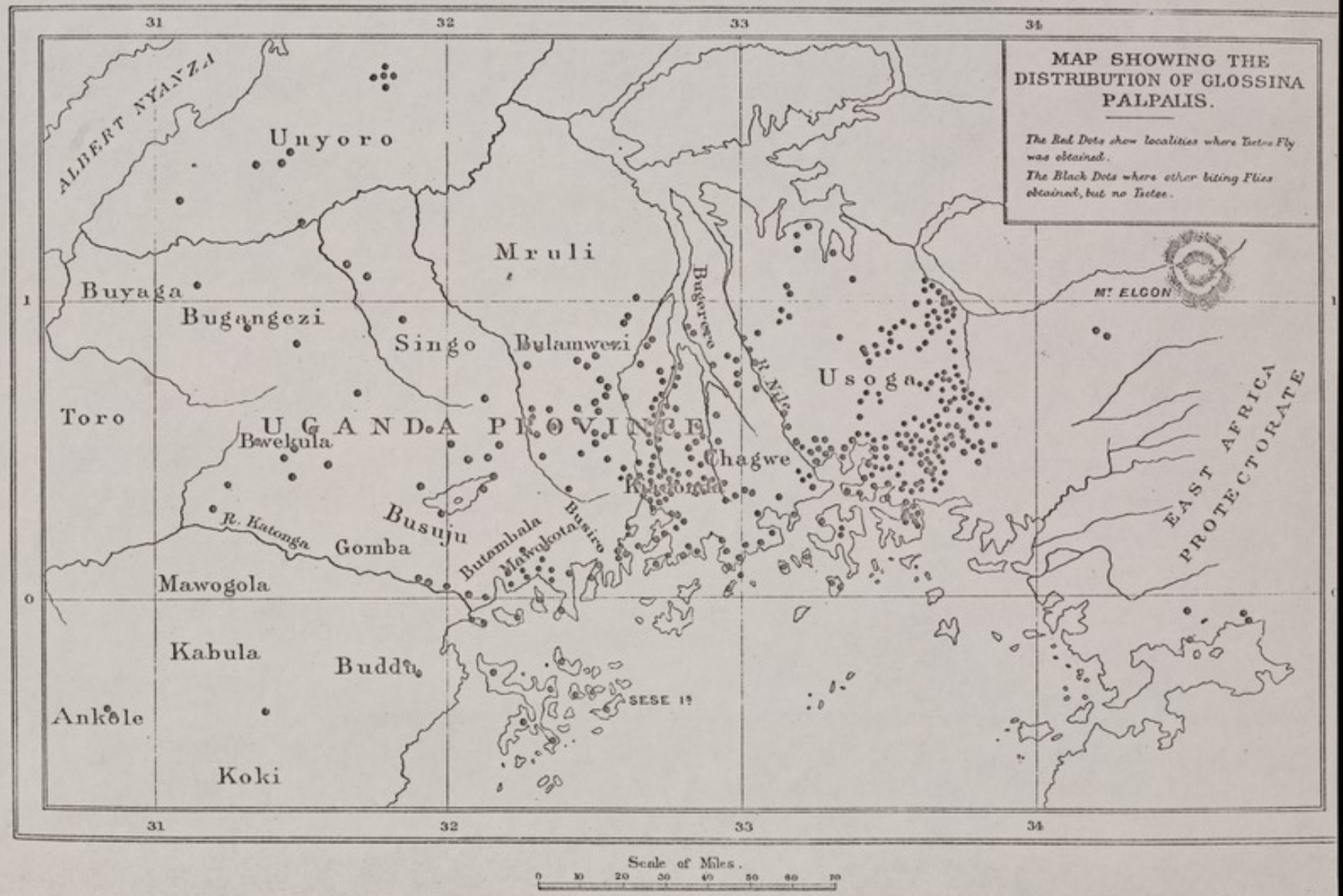
This leads to the question: "Does the distribution of sleeping sickness in Uganda coincide with the distribution of any particular biting insect"?

Knowing that we are dealing with a trypanosome, and knowing that the trypanosome of Nagana is carried in South Africa by a tsetse fly (*G. Morsitans*), naturally we will suspect that the trypanosome of this disease is also carried by a tsetse fly. Now on the lake shore near Entebbe a tsetse fly (*G. Palpalis*) is found in large numbers. This may be the insect carrier we are in search of. The Prime Minister and Regents, on being consulted, recognised the fly as one known to the Muganda as the Kivu, and said it was found along the shores of the lake. They were supplied with several dozen nets, killing bottles and boxes, and on their part promised to have the distribution of this fly and of sleeping sickness worked out. The bishops, missionaries, and Government officials also promised their assistance.


MAP SHOWING THE DISTRIBUTION OF SLEEPING SICKNESS IN UGANDA.
The Red Dots show where Sleeping Sickness is prevalent.
The Black Dots where it is absent.
The Crosses represent cases imported from Sleeping Sickness area.
31
32
33
34
1
0
ALBERT NYANZA
Unyoro
Mruli
Buyaga
Bugangezi
Singo
Bulamwezi
Toro
UGANDA PROVINCE
Bwekula
Busuju
R. Katonga
Gomba
Mawogola
Kabula
Buddu
Ankole
Koki
Butambala
Mawokota
Busiro
Kiadonda
Chagwe
Usoga
Bugerere
R. Nile
Mt ELGON
EAST AFRICA PROTECTORATE
SESE Is
Scale of Miles
0 10 20 30 40 50 60 70


MAP SHOWING THE DISTRIBUTION OF SLEEPING SICKNESS IN UGANDA.
The Red Dots show where Sleeping Sickness is prevalent.
The Black Dots where it is absent.
The Crosses represent cases imported from Sleeping Sickness area.
31
32
33
34
1
0
ALBERT NYANZA
Unyoro
Mruli
Buyaga
Bugangezi
Singo
Bulamwezi
Bugerere
R. Nile
Usoga
Mt ELGON
Toro
UGANDA PROVINCE
Bwekula
Chagwe
Kiadonda
EAST AFRICA PROTECTORATE
R. Katonga
Busuju
Butambala
Mawokota
Busiro
Gomba
Mawogola
Kabula
Buddu
Ankole
Koki
SESE Is
Scale of Miles
0 10 20 30 40 50 60 70


MAP SHOWING THE DISTRIBUTION OF GLOSSINA PALPALIS.
The Red Dots show localities where Tsetse Fly was obtained.
The Black Dots where other biting Flies obtained, but no Tsetse.
31
32
33
34
1
0
ALBERT NYANZA
Unyoro
Mruli
Buyaga
Bugangezi
Singo
Bulamwezi
Bugerere
R. Nile
Mt. ELGON
Usoga
Toro
UGANDA PROVINCE
Bwelgula
Chagwe
Kyagwe
EAST AFRICA PROTECTORATE
R. Katonga
Busuju
Gomba
Butambala
Mawokota
Busiro
Mawogola
Kabula
Buddu
SESE Is
Ankole
Koki
Scale of Miles.
0 10 20 30 40 50 60 70


MAP SHOWING THE DISTRIBUTION OF GLOSSINA PALPALIS.
The Red Dots show localities where Tsetse Fly was obtained.
The Black Dots where other biting Flies obtained, but no Tsetse.
31
32
33
34
1
0
ALBERT NYANZA
Unyoro
Mruli
Buyaga
Bugangezi
Singo
Bulamwezi
Toro
UGANDA PROVINCE
Bwelgula
Busuju
Gomba
R. Katonga
Butambala
Mawokota
Busiro
Mawogola
Kabula
Buddu
Ankole
Koki
SESE Is
Victoria Nile
Usoga
Chagwe
Kyadondo
Mt ELGON
EAST AFRICA PROTECTORATE
Scale of Miles.
0 10 20 30 40 50 60 70

During June, July and August of last year some 460 collections of biting flies were sent in from all parts of Uganda. As each package came in it was examined for tsetse flies. If the parcel contained one or more tsetse flies, a red disc was stuck on a large map over the locality from which the flies had been sent. If, on the other hand, no tsetse flies were found, a blue disc was fixed over the spot.

In the same way and at the same time a second map was prepared, to show the distribution of sleeping sickness. That is to say, if the note accompanying the collection of flies stated that sleeping sickness was prevalent, then a red disc was placed over the locality, and if, on the contrary, no cases of sleeping sickness were reported, a blue disc was affixed.

It is evident that two maps so prepared should show at a glance whether the distribution of sleeping sickness and this tsetse fly corresponds or not.

The accompanying maps are prepared from these two maps. On comparing them the similarity of the distribution of sleeping sickness and *Glossina palpalis* is self-evident.

In order to work out more minutely the habits of the *Glossina palpalis*, the peninsula on which Entebbe stands was taken in detail and carefully searched for the fly.

The result of this showed that the fly is only found on the shore of the lake where there is forest. This forest is thick jungle with high trees and dense undergrowth. The fly is never found on open sandy beaches backed by grass plains, even although there may be some small scrub near the water's edge. It is never found in the grass of the grassy plains, even though the grass be long and tangled. It has not been found by us in banana plantations, and not at any time far from the lake shore.

The habitat, then, of this fly is the shore of the lake where there is forest. In Busoga, on the other hand, it appears to be found further inland, but what the physical characters of this province are which would account for this I have not learnt. The fly also passes down the Nile as far as Kakoge Ferry, some 50 miles north of the Ripon Falls, and it has even been received from Fajao on the Somerset Nile, and from Tengri and the Achwa River, still further north and near Wadelai, and also from Lake Albert.

It is important that the distribution of this fly should be fully worked up, but enough has been done to show that the distribution of this species of tsetse fly is, like sleeping sickness, confined to the shores of the lake and the islands. It is on the densely-wooded

EXPERIMENT 114.—Monkey (*Cercopithecus* sp.).

Feeding tsetse flies on a healthy monkey 8 hours after they had been fed on a Sleeping Sickness patient.

Date.	Number of flies fed on—		Trypanosomes.	Date.	Number of flies fed on—		Trypanosomes.
	Patient.	Monkey.			Patient.	Monkey.	
May—				June—			
20	22	0	Absent	22	16	2	
22	4	5		23	24	14	
23	11	2		24	31	10	
23	9	7		25	25	17	Absent
24	9	6		26	28	8	
25	15	1		27	17	15	
26	10	4		28	0	0	
27	6	5		29	26	26	
28	8	7	Absent	30	24	22	
29	5	4		July—			
30	9	3		1	18	15	Absent
31	5	1		2	29	16	
June—				3	28	11	
1	1	9		4	27	14	
2	6	2		5	19	13	
3	8	1		6	31	16	
4	4	2	Absent	7	32	11	
5	4	3		8	23	13	
6	5	5		9	12	15	
7	0	0		10	14	0	
8	13	9		11	14	28	
9	8	4		12	28	6	
10	9	5		13	22	18	
11	10	6	Absent	14	19	12	
12	8	5		15	18	8	
13	9	6		16	17	13	
14	0	0		17	24	9	Absent
15	4	12		18	20	8	
16	8	10		19	12	11	
17	2	1		20	23	17	
18	2	5	Absent	21	16	13	
19	7	4		22	17	11	
20	5	4		23	..	..	Present
21	0	0					

EXPERIMENT 115.—Monkey (*Cercopithecus* sp.).

Feeding tsetse flies on a healthy monkey 8 hours after they had been fed on a Sleeping Sickness patient.

Date.	Number of flies fed on—		Trypanosomes.	Date.	Number of flies fed on—		Trypanosomes.
	Patient.	Monkey.			Patient.	Monkey.	
May—				June—			
20	12	0	Absent	22	29	9	
21	0	3		23	18	9	
22	10	2		24	21	21	
23	6	1		25	23	14	Absent
24	7	2		26	17	6	
25	11	5		27	16	9	
26	8	4		28	0	0	
27	11	1		29	33	27	
28	6	3		30	28	21	
29	9	8	Absent				
30	9	4		July—			
31	9	3		1	22	17	Absent
June—				2	22	19	
1	2	9		3	21	13	
2	9	7		4	24	10	
3	5	2		5	33	10	
4	6	4	Absent	6	33	10	
5	2	3		7	29	12	
6	8	7		8	10	16	
7	0	0		9	10	12	
8	4	10		10	16	13	
9	5	4		11	6	18	
10	5	4		12	29	8	
11	9	5	Absent	13	18	11	
12	2	7		14	14	9	
13	3	3		15	18	12	
14	0	0		16	18	7	
15	6	12		17	30	7	Absent
16	12	12		18	35	17	
17	7	2		19	28	8	
18	14	2	Absent	20	30	8	
19	4	2		21	25	7	
20	3	4		22	21	14	
21	0	0		23	..	..	Present

EXPERIMENT 99. Monkey *Cercopithecus* (sp.).

Feeding tsetse flies on a healthy monkey 24 hours after they had been fed on a Sleeping Sickness patient.

Date.	Number of flies fed on—		Trypanosomes.	Date.	Number of flies fed on—		Trypanosomes.
	Patient.	Monkey.			Patient.	Monkey.	
May—				June—			
15	16			19	..	12	
16	..	7	Absent	20	15		
17	6			21	..	0	
18	..	6		22	..	11	
19	16			23	21		
20	..	3		24	..	23	
21	12	2		25	26	..	Absent
22	..	5		26	..	20	
23	9			27	19		
24	..	7		28	..	10	
25	5			29	32		
26	..	8		30	..	46	
27	11						
28	..	5		July—			
29	7	..	Absent	1	15	..	Absent
30	..	9		2	..	20	
31	6			3	31		
				4	..	45	
June—				5	27		
1	..	7		6	..	27	
2	9			7	40		
3	..	6		8	..	17	
4	5			9	15		
5	..	4	Absent	10		15	
6	8			11	15		
7	..	0		12	..	21	
8	10			13	27		
9	..	6		14	..	28	
10	17			15	21		
11	..	18		16	..	24	
12	18			17	23	..	Absent
13	..	17		18	..	23	
14	0			19	36		
15	8			20	..	16	
16	..	11		21	26		
17	0			22	..	20	
18	10	..	Absent	23	..	..	Present

EXPERIMENT 116.—Monkey (*Cercopithecus* sp.).

Feeding tsetse flies on a healthy monkey 48 hours after they had been fed on a Sleeping Sickness patient.

Date.	Number of flies fed on—		Trypanosomes.	Date.	Number of flies fed on—		Trypanosomes.
	Patient.	Monkey.			Patient.	Monkey.	
May—				June—			
20	10	..	Absent	22	19		
21				23			
22	..	10		24	..	15	
23				25	..	..	Absent
24	9			26	26		
25				27			
26	..	5		28	..	16	
27				29	9		
28	9			30			
29				July—			
30	..	6	Absent	1	..	49	
31				2			
June—				3	51	..	Absent
1	6			4			
2				5	..	29	
3	..	7		6			
4	..	..	Absent	7	40		
5	11			8			
6				9	..	20	
7	..	4		10			
8				11	25		
9	6			12			
10				13	..	26	
11	..	7	Absent	14			
12				15	25		
13	16			16			
14				17	..	16	Absent
15	..	8		18			
16				19	64		
17	17			20			
18	11	..	Absent	21	..	46	
19				22			
20	..	3		23	..	..	Present
21							

shore of the lake that the half-naked natives of the mainland and islands meet in thousands to trade in fish, bananas, earthenware, &c. If the *Glossina palpalis* can act as a carrier of the trypanosome of sleeping sickness, the circumstances could not be made more favourable than they are for the spread of the disease.

The next point, therefore, to solve is: "Can this tsetse fly carry this trypanosome from persons suffering from sleeping sickness to healthy animals?"

The best animal to carry out these experiments on, of course, is the monkey. The method used is simply to feed tsetse flies on a sleeping sickness case, and, at varying intervals of time, to place the same cage of flies on a monkey. The sleeping sickness patients do not seem to feel the bites of the flies, as they make no complaints or other signs of inconvenience. It is convenient to have, as a rule, about 30 flies in each cage, but only those which fill themselves are to be reckoned as having fed. The tables on pp. 36-39 show the result.

This proves that this tsetse fly can convey the infection from the sick to the healthy. But as 28 per cent. of the natives of the sleeping sickness area have this trypanosome in their blood, doubtless the tsetse flies caught in this area, which feed on these natives, will be able to convey the disease to a healthy animal without any artificial feeding.

Let us, therefore, try what will be the effect of catching the ordinary wild tsetse flies and placing them straightway on healthy monkeys. This is a very crucial experiment, and the following table gives the result:—

EXPERIMENT 94.—Monkey (*Cercopithecus* sp.).

To ascertain if tsetse flies, freshly caught in the vicinity of Entebbe, are carrying trypanosomes.

May 13, 1903.	Blood examined.	No trypanosomes.	No malaria.
May 13	Fed 31 flies freshly caught near Entebbe.	May 19	Fed 20 flies.
		„ 20	„ 13 „
„ 15	Fed 15 flies.	„ 21	„ 16 „
„ 18	„ 10 „		
	Blood examined.	Trypanosoma absent.	Malaria absent.
May 22	Fed 20 flies.	May 25	Fed 31 flies.
„ 23	„ 25 „	„ 26	„ 18 „
„ 24	„ 17 „	„ 27	
	Blood examined.	Trypanosomes *present*.	Malaria absent.

EXPERIMENT 130. Monkey (*Cercopithecus* sp.).

To note the effect of feeding freshly-caught tsetse flies on a healthy monkey.

June 10, 1903	Fed 60 freshly-caught flies.	
„ 11 „	„ 23 flies.	
Blood examined.	Trypanosomes absent.	Malaria present.

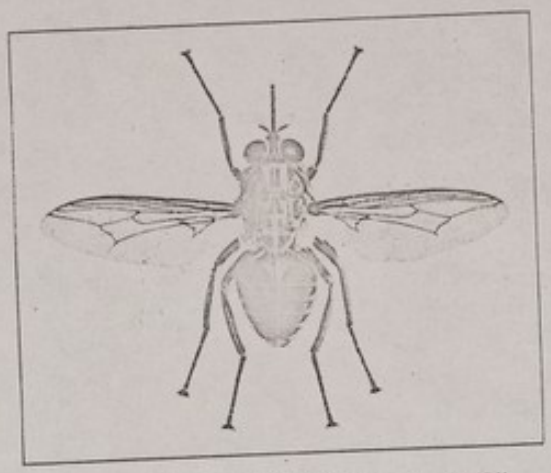


FIG. 7.—*Glossina palpalis*, Rob. Desv., ♂. (× 3¾.)[1]

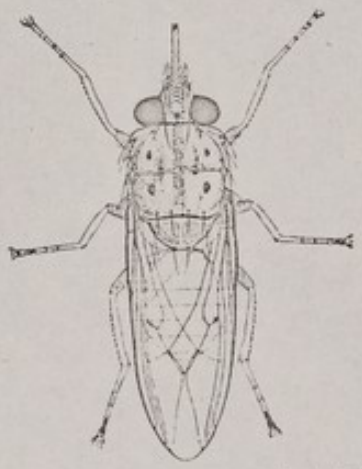


FIG. 8.—A Tsetse fly (*Glossina longipennis*, Corti, from Somaliland) in resting attitude, showing the position of the wings. (× 3¾.)[1]

[1] These two illustrations are taken from "A Monograph of the Tsetse flies," by Ernest Edward Austen, British Museum (Natural History), Cromwell Road, S.W.

June 12	Fed 12 flies.	June 17	Fed 25 flies.
,, 13	,, 26 ,,	,, 18	,, 10 ,,
,, 14	,, 20 ,,		
Blood examined.	Trypanosomes absent.	Malaria present.	

June 19	Fed 9 flies.	June 23	Fed 74 flies.
,, 20	,, 19 ,,	,, 24	,, 31 ,,
,, 21	,, 30 ,,	,, 25	,, 28 ,,
,, 22	,, 7 ,,		
Blood examined.	Trypanosomes absent.	Malaria present.	

June 26	Fed 83 flies.	June 29	Fed 38 flies.
,, 27	,, 64 ,,	,, 30	,, 62 ,,
,, 28	,, 27 ,,	July 1	,, 62 ,,
Blood examined.	Trypanosomes absent.	Malaria present.	

July 2	Fed 140 flies.	July 6	Fed 44 flies.
,, 3	,, 35 ,,	,, 7	,, 14 ,,
,, 4	,, 34 ,,	,, 8	,, 34 ,,
,, 5	,, 23 ,,	,, 9	
Examined blood.	Trypanosomes *present*.	Malaria present.	

EXPERIMENT 131. Monkey (*Cercopithecus* sp.).

Feeding freshly-caught tsetse flies on a healthy monkey.

July 17	Fed 5 flies.	July 19	Fed 7 flies.
,, 18	,, 3 ,,	,, 20	,, 17 ,,
Examination of blood.	Trypanosomes absent.	Malaria present.	

June 21	Fed 23 flies.	June 24	Fed 39 flies.
,, 22	,, 7 ,,	,, 25	,, 13 ,,
,, 23	,, 28 ,,		
Examination of blood.	Trypanosomes absent.	Malaria present.	

June 26	Fed 53 flies.	June 29	Fed 17 flies.
,, 27	,, 47 ,,	,, 30	,,108 ,,
,, 28	,, 5 ,,	July 1	,, 36 ,,
Examination of blood.	Trypanosomes absent.	Malaria present.	

July 2	Fed 98 flies.	July 7	Fed 17 flies.
,, 3	,, 45 ,,	,, 8	,, 36 ,,
,, 4	,, 28 ,,	,, 9	,, 57 ,,
,, 6	,, 38 ,,	,,10	,, 30 ,,
Examination of blood.	Trypanosomes *present*.	Malaria present.	

This then concludes the story of sleeping sickness in Uganda. We have seen that probably this disease was introduced from the Congo on account of the greater movement of natives under the march of civilisation and the Pax Britannica. We have seen that the disease is caused by the entrance into the blood of a protozoal parasite, and that the infection is carried from the sick to the healthy by a species of tsetse fly. We have seen that the distribution of this fly corresponds with the distribution of the disease. Where there is no fly there is no sleeping sickness. In other words, we are dealing with a human tsetse fly disease.

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HAVE TRYPANOSOMES AN ULTRA-MICROSCOPICAL STAGE IN THEIR LIFE-HISTORY?[1]

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BY an ultra-microscopical stage in the development of a micro-organism is meant a stage in which the parasites are so small as to be invisible to the highest powers of the microscope, and to be capable of passing through the pores of a porcelain filter. For example, a drop of South African horse-sickness blood will give rise to the disease if injected under the skin of a healthy horse. If a similar drop is examined under the highest available powers of the microscope, nothing in the shape of a micro-organism can be seen. If this blood is filtered through a porcelain filter, the virus passes through, and the filtrate is found to be as infective as the original blood. Horse-sickness is therefore looked upon as a disease caused by an ultra-microscopical micro-organism.

For some time it has been reported by various workers that an ultra-microscopical stage exists among the trypanosomes. For example, Plimmer informs us that he found the filtered blood of nagana animals to be infective. Salvin Moore and Breinl write that the blood of animals suffering from *Trypanosoma gambiense* infection, although apparently containing no trypanosomes at all, and even if properly filtered, is still capable of infecting other animals

[1] Reprinted from the *Proceedings of the Royal Society*, B. vol. 80.

into which it may be introduced. MacNeal also makes a similar statement in regard to *T. lewisi*. He states that "in culture, on blood-agar, *T. lewisi* may give rise to much smaller forms, and that such cultures, after passage through a Berkefeld filter, still infect rats." Finally, it may be noted that the late Dr. Fritz Schaudinn, whose too early death we all lament, expressed the belief that trypanosomes may multiply by longitudinal division so rapidly as to become small enough to pass readily through a Chamberlain filter.

This subject is an important one, as the discovery of an ultra-microscopical stage in these trypanosomes might throw light on the causation of some diseases in which no parasite can be found. In kala-azar, for example, the intra-corporeal form is small, and the extra-corporeal a fairly large flagellated organism. Let us imagine that the Leishman body lying inside the splenic cells had still further subdivided and become ultra-microscopical, then we would have an invisible parasite causing a serious disease in man and developing outside the body into a clearly visible flagellate. It is evidently important, then, in studying such diseases as South African horse-sickness, to try the effect of planting out the blood on various media, and looking for a visible stage of development in different insect hosts.

The following experiments were made to test the truth of the statement that trypanosomes have this invisible stage. The filters used were Berkefeld's ordinary filters for laboratory use. They were tested before use and found to readily keep back *Micrococcus melitensis* from the filtrate. The apparatus was attached to a Sprengel's pump:—

To ascertain if the Filtered Blood of Rabbits suffering from Nagana is infective.

Experiment 23.

March 20th, 1908.—A rabbit which was inoculated on February 7th, 1908, with *T. brucei*, was killed to-day in an advanced stage of nagana. On microscopical examination of the peripheral blood and blood from the heart, no trypanosomes were seen. Portions of the heart, lungs, liver, spleen, kidneys, and bone-marrow were pounded up in a mortar with 1 per cent. sodium citrate in normal saline. The resulting emulsion was then filtered through a Berkefeld filter, and 1 cc. of the filtrate injected subcutaneously into each of two white rats.

April 30th, 1908.—Both rats healthy. No trypanosomes have appeared in their blood.

Experiment 26.

April 24th, 1908.—Rabbit inoculated with *T. brucei* on March 26th, 1908. Same procedure as in Experiment 23.

May 21st, 1908.—Both rats healthy.

Experiment 35.

March 31st, 1908.—Rabbit inoculated February 7th, 1908. Same procedure as in Experiment 23.

May 4th, 1908.—Both rats healthy.

Experiment 51.

January 31st, 1908.—Rabbit inoculated January 10th, 1908. Same procedure as in Experiment 23.

March 25th, 1908.—Neither rat showed trypanosomes at any time in its blood.

Experiment 53.

February 3rd, 1908.—Rabbit inoculated January 10th, 1908.

March 30th, 1908.—Result negative. Both rats healthy.

Conclusion.

From these five experiments it would appear that the blood or organs of rabbits suffering from nagana does not contain ultramicroscopical forms of *T. brucei*.

To ascertain if the Filtered Blood of White Rats Suffering from Nagana is Infective.

Experiment 40.

December 17th, 1907.—A white rat, suffering from nagana, and whose blood was swarming with *T. brucei*, was killed to-day. The organs and bone-marrow were made into an emulsion with 1 per cent. sodium citrate in salt solution and filtered in the usual way. Half a cubic centimetre of the filtrate was then injected into the peritoneal cavity of a white rat.

March 16th, 1908.—This rat has never shown trypanosomes in its blood.

Experiment 41.

December 17th, 1907.—This rat was also injected with the same quantity of filtrate as in Experiment 40.

April 1st, 1908.—Trypanosomes have never appeared in the blood.

Experiments 42 *and* 43.

December 24th, 1907.—A nagana rat, whose blood was swarming with trypanosomes, was killed, and the organs, &c., emulsified

and filtered. One cubic centimetre of the filtrate was injected intra-peritoneally into two white rats.

March 30th, 1908.—Both rats healthy.

Experiments 44, 45, 46, 47, 48, 49, *and* 50.

This procedure was repeated seven times in exactly the same way and always with a negative result.

Conclusion.

From these eleven experiments it would appear that the blood of nagana rats filtered through a Berkefeld filter is not infective.

To ascertain if the Filtered Blood of White Rats Suffering from Nagana or Surra, and treated for various Periods with Antimony, is infective.

It was thought that the effect of treatment on animals suffering from nagana might lead to the development of small resting forms of the *T. brucei* which might be capable of passing through a Berkefeld filter. The effect of certain drugs on animals suffering from nagana is marvellous. The blood may be swarming with trypanosomes, yet within an hour of the injection not a single one can be seen. They may remain out of the blood for weeks or months in some out-of-the-way place, and, perhaps in some resistant form.

Experiment 28.

March 26th, 1908.—A white rat, whose blood was swarming with *T. brucei*, was treated with ½ cc. of a ¼ per cent. solution of sodium antimonyl tartrate. The rat died half an hour after receiving this dose. The organs and bone-marrow were emulsified and filtered in the usual way, and 1 cc. of the filtrate injected subcutaneously into a white rat.

May 7th, 1908.—Trypanosomes have not appeared in the blood.

Experiment 29.

March 27th, 1908.—A white rat, whose blood was swarming with *T. evansi*, was injected with ½ cc. of a ¼ per cent. solution of sodium antimonyl tartrate. This rat died half an hour after receiving the dose. Emulsion of the organs and bone-marrow made and filtered in the usual way, and 1 cc. of the filtrate injected into two white rats.

April 29th, 1908.—Both rats remain well.

Experiment 33.

March 30th, 1908.—A white rat, whose blood was swarming with *T. evansi*, was injected subcutaneously with ½ cc. of a ¼ per cent. solution of sodium antimonyl tartrate. This treatment was continued for a month, the animal receiving in all eleven doses.

May 4th, 1908.—Rat killed and its organs and blood emulsified and filtered. Half a cubic centimetre of the filtrate was injected intra-peritoneally into two rats.

June 4th, 1908.—Both rats healthy.

Experiment 66.

March 8th, 1908.—A white rat, whose blood was swarming with *T. brucei*, was injected with 2 drops of a 1 per cent. solution of sodium antimonyl tartrate. This treatment was continued for a month, the animal receiving in all eight doses.

April 10th, 1908.—Rat killed and its organs emulsified and filtered in the usual way. One cubic centimetre of the filtrate injected into two rats.

May 11th, 1908.—Both rats healthy.

Experiment 19.

March 8th, 1908.—A nagana rat, whose blood was swarming with *T. brucei*, was injected on the third day of disease with 2 minims of a 1 per cent. solution of sodium antimonyl tartrate.

March 9th, 1908.—Repeated injection. A few trypanosomes in blood.

March 11th, 1908.—Repeated injection. A few trypanosomes in blood.

March 13th, 1908.—No trypanosomes in blood.

March 18th, 1908.—Blood swarming with trypanosomes. Injected ½ cc. of a ¼ per cent. solution of sodium antimonyl tartrate. Rat died five minutes later. Organs emulsified and filtered and ½ cc. of the filtrate injected into a white rat.

March 26th, 1908.—This rat's blood is found to be swarming with trypanosomes. It is evident that something has passed through the filter capable of infecting a rat with nagana; but it is possible that the filter has become defective on account of wear. It was tried again with a cultivation of *Micrococcus melitensis* in broth and failed to keep back the micrococci from the filtrate. It was therefore concluded that the filter was defective, and this experiment null and void.

Conclusion.

From these experiments it may be concluded that the blood of white rats suffering from nagana and treated for varying times with antimony salts does not contain ultra-microscopical forms of *T. brucei*.

To ascertain if the Cultivation of Trypanosomes on Blood-agar will give rise to Ultra-microscopical Forms which are capable of passing through a Berkefeld Filter.

Experiment 24.—*White Rats.*

March 20th, 1908.—The water of condensation from six flasks of blood-agar, upon which *T. lewisi* had been planted out for eighteen days, was to-day filtered through a Berkefeld filter, and ½ cc. of the filtrate injected into two white rats.

April 28th, 1908.—These rats have remained in good health and no trypanosomes have appeared in their blood.

Experiment 37.—*White Rats.*

April 1st, 1908.—A test-tube of blood-agar (2—1), which contained a luxuriant growth of *T. lewisi*, was shaken up with 25 cc. of normal salt solution, and the resulting emulsion filtered through a Berkefeld filter. The filtrate was then injected into the peritoneal cavity of three white rats.

April 30th, 1908.—All three rats remained well, and trypanosomes never appeared at any time in their blood.

Experiment 36.—*White Rat (Control).*

March 31st, 1908.—To ascertain if the culture used in Experiment 37 was virulent, three drops of the condensation fluid were injected into a small white rat.

April 6th, 1908.—*T. lewisi* appeared in the blood of this rat.

Experiment 64.—*White Rats.*

April 9th, 1908.—A blood-agar tube containing a growth of *T. lewisi*, first generation, forty-sixth day of growth, was shaken up with normal saline and filtered in the usual way. The filtrate was injected intra-peritoneally into two rats.

May 11th, 1908.—Both rats well. Trypanosomes have never appeared in their blood.

Experiment 98.—*White Rats.*

May 7th, 1908.—Two blood-agar tubes, twenty-seventh day of growth. Same procedure as in Experiment 64.

June 2nd, 1908.—Both rats healthy.

Experiment 97.—*White Rat* (*Control*).

May 7th, 1908.—To ascertain if the culture used in Experiment 98 was infective, ½ cc. of the condensation fluid was injected intra-peritoneally.

May 18th, 1908.—*T. lewisi* in the blood.

Conclusion.

From these experiments it may be concluded that cultures of *T. lewisi* on blood-agar do not give rise to ultra-microscopical forms which are capable of passing through a Berkefeld filter.

The final conclusion arrived at is that neither *T. brucei* nor *evansi* develops in the body of an animal forms so small as to be capable of passing through the pores of a Berkefeld filter, and that in cultures of *T. lewisi* on blood-agar such small forms are also absent.

THE 1908 SLEEPING SICKNESS COMMISSION OF THE ROYAL SOCIETY.

By Colonel Sir DAVID BRUCE, C.B., F.R.S.

This, the third Commission sent out to Uganda since 1902, under the direction of the Royal Society, for the study of sleeping sickness, was formed in 1907, at the suggestion of His Excellency Sir H. Hesketh Bell, K.C.M.G., Governor of Uganda, to the Secretary of State for the Colonies, for the purpose of continuing the investigation and utilising the laboratory built for the Commission in 1906.

The *personnel* of the 1908 Commission is as follows: *Director:* Colonel Sir David Bruce, C.B., F.R.S. *Members:* Captains A. E. Hamerton, D.S.O., and H. R. Bateman, Royal Army Medical Corps, and Captain F. P. Mackie, Indian Medical Service. *Laboratory Assistant:* Sergeant A. Gibbons, Royal Army Medical Corps. *Secretary:* Mr. James Wilson.

The Commission left England on September 16th, 1908, and reached Mombasa, British East Africa, on October 14th. Here the Commission was received, and the rough places made smooth for it, by Mr. Waller, the Coast Agent to the Uganda Protectorate, and Mr. Stanley, the Assistant Traffic Manager to the Uganda Railway. The Commission was also most hospitably entertained by Dr. Hinde, the Acting Commissioner.

After spending two days at Mombasa waiting for a train, a start was made for the Lake. At Nairobi, the Commission met the Principal Medical Officer, Lieutenant-Colonel J. Will, Royal Army Medical Corps, who, unfortunately, was on the point of leaving the country to return to military duty. Here also the Commission received a telegram from His Excellency Sir J. Hayes Sadler, K.C.B., Governor of British East Africa, with the information that he would meet them at Naivasha, higher up the line. At Naivasha the Commission's carriage was attached to the Governor's special train, and proceeded with him to Port Florence. At Nakuru His Excellency Sir H. Hesketh Bell, K.C.M.G., Governor of Uganda, and his staff also joined the train.

From the Governor the Commission heard that sleeping sickness had of late been making sad havoc among the Kavirondo on the eastern shores of the Lake, a large percentage of whom are reported to be infected. This seems to be due to the habit these people

have of fishing, a pastime the Kavirondo people are much addicted to, in the rivers which run into this part of the Lake, where the wooded banks swarm with tsetse-flies.

During the journey up country the Commission had a good view of the snow-capped Kilimanjaro from the Kapiti Plains, and moreover saw on the Athi Plains an enormous number of wild animals, including several giraffe.

On arriving at Entebbe on Monday, October 19th, the Commission was most kindly received by Dr. Hodges, the Principal Medical Officer, Mr. Russell, the Director of Transport, and others of the Uganda officials, who had come down to the landing-place in full canonicals to welcome officially the Governor, who had been for a short shooting excursion into British East Africa.

In Entebbe the Commission remained until Wednesday, October 21st, being most hospitably entertained by the Governor at the new Government House, while others of the members were equally kindly looked after by the Principal Medical Officer.

A great improvement was seen in the Government Cantonment of Entebbe. In 1903, all the houses were thatched with grass, productive of many fires, there were no glass windows except in the then newly built Government House, there was no Club, no golf course, and no means of conveyance into the native capital of Kampala. Now all the roofs are of corrugated iron, all the houses have windows, there is a still newer and more palatial Government House, a first-rate Club, an excellent golf course, and a motor-bus which runs into Kampala daily.

The Commission remained in Kampala for one night, where they have to thank Captain Ireland, King's African Rifles, for his hospitality, and at last reached their destination, Mpumu, on Thursday, October 22nd.

Here they found the Royal Society's laboratory and two good houses built, while another was in course of construction. The laboratory and one of the houses had been brought from the spot on the Lake shore some three miles from Entebbe, where they had been built in 1906. Previous to that the laboratory had been situated in Entebbe. This camp at Mpumu (0° 14′ N. latitude, 32° 50′ E. longitude) is on the top of a flat-topped hill with steep sides, standing some 500 feet above the surrounding country. It is 750 yards long and, roughly, 250 yards broad; its long axis runs in a north-westerly and south-easterly direction. It lies 6 miles from the Lake at its nearest point—Kibanga, on Buka Bay. The surrounding country is very hilly, Mpumu, about 4,300 feet above

sea-level, being on a level with most of the adjacent hills; many of these are wooded, and between the hills the country is swampy.

The Commission shortly after their arrival set up a meteorological station, the instruments being lent by the Botanical, Forestry and Scientific Department, and observations made during November and December show, for the former month a temperature ranging between 59° and 82° F. and for the latter month between 57° and 85° F. Mpumu has, therefore, a temperate and pleasant climate. The rainfall is, of course, high; over 9 inches fell in November, and 5½ inches in December, in spite of the latter being one of the driest months.

Kampala, the native capital, where supplies are obtained, is 27 miles to the west, and headquarters another 22 or 23 miles further on. The position chosen for the camp is, therefore, isolated and difficult of access, which will probably render the work of the Commission more difficult and slower than if a more accessible site had been chosen. In all probability experience will show that a mistake has been made in placing the laboratory in such an isolated place, and it will be found that the laboratory had better have been left on the spot near Entebbe, where it was originally erected. No doubt the difficulty of choosing a suitable site was great, especially if the principle was followed that the camp must be in the vicinity of a sleeping sickness concentration camp as well as the Lake. But the nearest sleeping sickness concentration camp is 7 miles of steep native paths away, and for all practical purposes might be 70.

It may seem ungracious to criticise the site chosen for the purposes of this investigation; but, on the other hand, if the results of the work are less than had been expected, then it is only right and just that the difficulties the Commission have to cope with should be known. Undoubtedly, our isolated position does double or treble our difficulties.

The Laboratory, 45 feet long and 18 feet wide, is built of corrugated iron. It is capable of accommodating six workers, and is excellently adapted for the work. It is well furnished with all the essentials, and has a supply of pure rain water from the roof, collected in two tanks, each of 400 gallons capacity. The rain water collected in the pure atmosphere of Mpumu is equal to *aqua distillata*, and we use it as such. The photograph (fig. 1) shows the laboratory and the office.

Monkey House.—Fig. 2 is the monkey house. This is a large fly-proof shed, 30 feet square. Monkeys are much healthier and

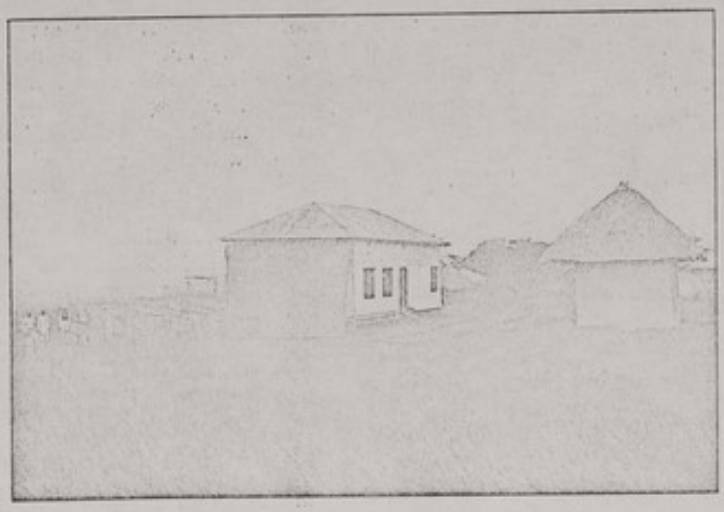

Fig. 1.

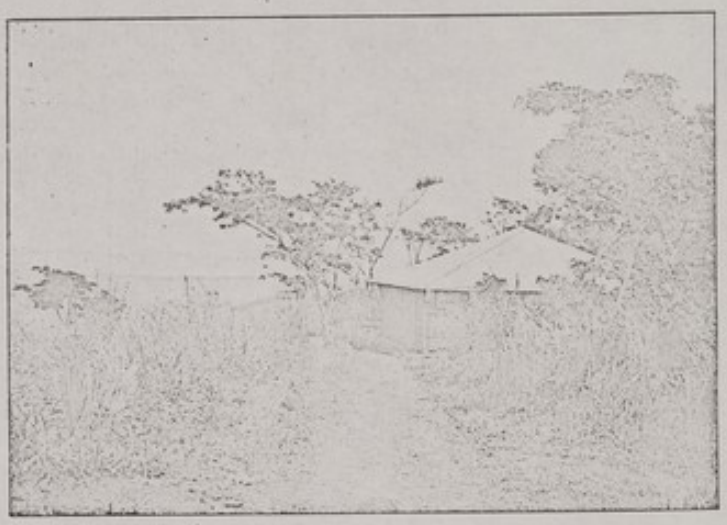

Fig. 2.

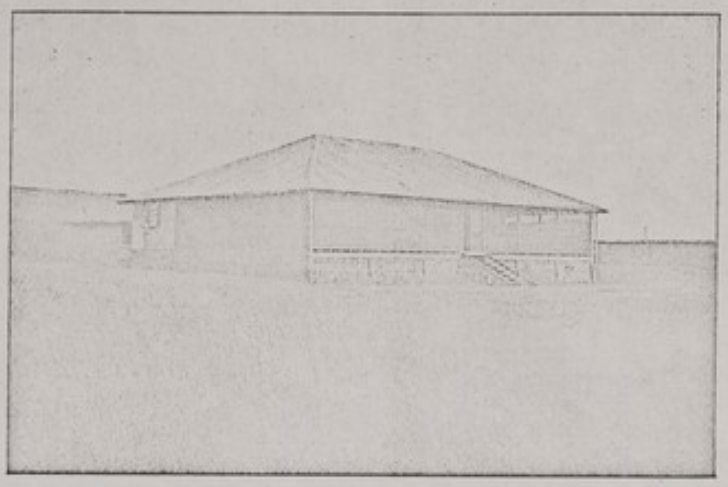

Fig. 3.

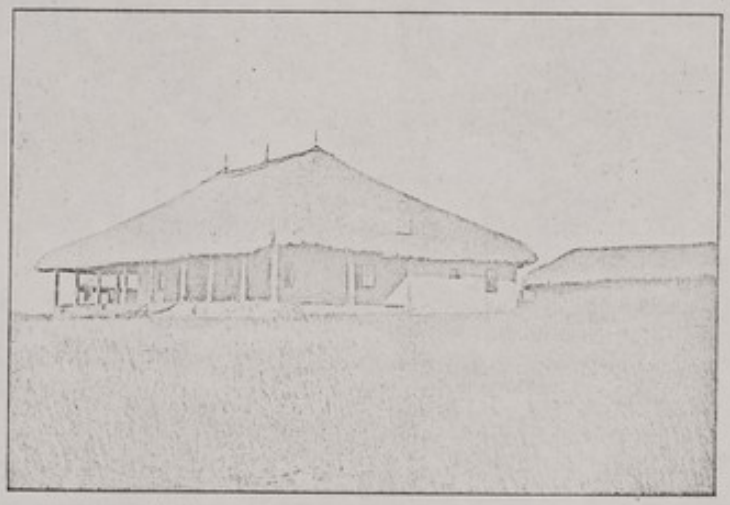

Fig. 4.

happier in the open air, and as there has been a good number of deaths among the monkeys confined in this house, it is being gradually emptied in favour of open-air boxes. Experience teaches that the common wild monkey in Uganda will live for years in captivity in perfect health if kept in the open air. As it is sometimes necessary to keep experimental monkeys under observation for months, it is evident that all closed-up monkey houses are a delusion and a snare. What can be more annoying than to lose the work of months by an experimental monkey dying of some extraneous malady?

Director's House.—This, as can be seen from fig. 3, is a large house, constructed of corrugated iron.

The Mess.—Fig. 4. This and the other houses erected are the ordinary wattle and daub huts, thatched with grass, which are used in this country by the better class natives. They are cool, comfortable and picturesque, but have one disadvantage, and that is, their liability to be set on fire by lightning. There is, however, little danger of this in the vicinity of iron-roofed houses, as the latter will probably attract the lightning to a much greater extent.

The hill is formed of ironstone, and violent thunderstorms are common. A few days ago a tree was struck within a hundred yards of the Director's house, and torn to ribbons.

The Water Supply.—The natural water supply of Mpumu is a small mud hole some 5 feet in diameter and 1 foot deep, situated at the foot of the hill to the south-east. This is surrounded by native huts and cultivated ground, and as ankylostomiasis is almost universal among the natives of Uganda, there seemed reasonable ground for looking on this water supply as dangerous, even for bathing purposes. Mr. S. Caink, the District Engineer, however, came to the rescue by digging a cistern to hold 3,000 gallons in the ironstone rock. This, like the widow's cruse, has been full and overflowing ever since with beautifully clear and cool water collected from the iron roof of the Director's house. For every inch of rain which falls 1,300 gallons of water run into the cistern, giving a total of 20,000 gallons during the months of November and December, or 46 gallons per head per diem of the white population on the hill. This water supply was gained at small cost and has been an unqualified success.

Conservancy Arrangements.—In order to keep the surroundings of the camp clean, a destructor has been built to burn up the rubbish. This has also been cut out of the ironstone rock, and consists, as will be seen from fig. 5, of a chamber some 5 feet

square, fed from above through a circular opening 16 inches in diameter. The front and roof are made out of sheets of corrugated iron, enclosing a thick layer of clay. The chimney, which is also made of corrugated iron sheeting, is 9 feet high. This is also a success, and all refuse from cook-houses, &c., is brought here and

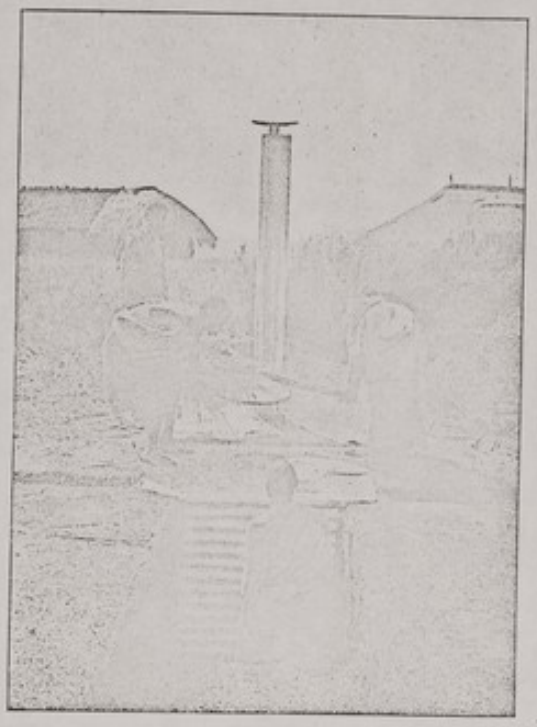

FIG. 5.

burnt, instead of being thrown away among the long grass, and so causing in time an unsightly nuisance.

Cattle Sheds.—As the Commission is, in addition to sleeping sickness work, trying to find out the nature of the various animal trypanosome diseases of Uganda, as well as an important disease among calves called m'kebe, three separate cattle sheds and cattle

runs have been constructed—one for healthy oxen, another for trypanosome disease, and the third for m'kebe. The trypanosome disease is causing a large number of deaths among the Government transport oxen, as well as among the native cattle, and neither its true nature nor its carrier is as yet known. M'kebe is said to cause a mortality among calves of from 40 to 60 per cent.

Collection of Flies.—As the study of *Glossina palpalis* and its relation to sleeping sickness naturally stands in the front rank as a subject of study by the Commission, it is necessary to have a large supply of tsetse-flies to work with. The Lake shore is 6 miles away, so that it is not possible for the fly-boys to walk up and down every day, and also find time for catching the flies. The six fly-boys therefore live in a hut near the Lake shore at Kibanga, one of the authorised cleared landing places. This landing place on the arrival of the Commission was found to be in a neglected and overgrown condition, and tsetse-flies were quite numerous. As a market is held here once a week, at which some hundreds of natives congregate from Buvuma and other infected islands, to sell earthenware pots and dried fish to the natives on the mainland, the danger of such a state of affairs is unmistakable. This on being pointed out to the Sekibobo was at once remedied, and now not a single tsetse-fly has been caught at Kabanga for a long time. But as a consequence the fly-boys have now to use a canoe to reach a spot where flies can be caught. A suitable place is found a short distance away, and the flies are so numerous along the Lake shore that although the boys catch from two to three hundred flies daily at the same spot, the supply shows no signs of diminishing.

Programme of Work.—Immediately on arriving here a programme of work was made out. The following are some of the items, which will serve to show the lines on which the Commission propose to pursue this investigation :—

Trypanosoma gambiense (*Dutton*).

(1) *Staining.*—For anything save the merest clinical observations, films must be mounted by the moist method.

(2) Study the fate of *T. gambiense* in *Glossina palpalis* fed artificially on infected animals. Examine 200 flies at different stages; repeat this experiment as often as possible with flies reared in the laboratory. Make the same experiment with stomoxys, tabanus, fleas, lice, bugs, *Ornithodorus moubata*, and the Congo floor-maggot.

(3) Mount *T. gambiense* blood as a fresh preparation, mixed with various sera—birds', lizards', goats', &c.—and note how long it retains its motility and apparent vitality.

(4) Attempt the cultivation of *T. gambiense* from blood of infected animals and also from intestinal contents of infected *G. palpalis*.

(5) Is the filtered blood of animals suffering from *T. gambiense* infective?

(6) Repeat experiments made by chopping up *G. palpalis* artificially infected with *T. gambiense*, and then injecting the emulsion into susceptible animals. How long, under these conditions, does *T. gambiense* remain infective?

(7) The examination of animals, domestic and wild, from the sleeping sickness area, to find if any of them act as a reservoir of the virus.

Glossina palpalis.

(1) Examination of the natural *G. palpalis* as to the following points:—
- (*a*) How many naturally infected *G. palpalis* are there?
- (*b*) What percentage are infected with *T. grayi*?
- (*c*) What percentage are infected with *T. tullochii*?
- (*d*) What percentage are infected with both species?
- (*e*) What other parasites can be found in the intestine and organs of *G. palpalis*?
- (*f*) Koch says he can distinguish four species of trypanosomes in *G. palpalis*. How many can the Commission distinguish?
- (*g*) Koch is also of opinion that *T. tullochii* is in reality *T. gambiense*. Does the Commission agree with this?

(2) Biology of *G. palpalis*.
- (*a*) How do these diptera breed?
- (*b*) Where do they lay their pupæ? Where are the breeding places.
- (*c*) How long does the fly live?
- (*d*) How many pupæ does it lay?
- (*e*) Habitat. Why does the fly like water?
- (*f*) Food of the fly.
- (*g*) Enemies of the fly, &c., &c.

Sleeping Sickness.

(1) Why is one species of animal susceptible and another immune? Todd thinks the answer to this will be found in the enlarged glands.

(2) What is the pressure in the cerebro-spinal canal? Some of the symptoms may be due to this.

(3) What is the nature of the auto-agglutination of red cells in trypanosome infection?

(4) What percentage of insane natives are really cases of sleeping sickness?

(5) Puncture all cases of much enlarged glands. Note if any obvious cause of enlargement is present. Todd thinks if chronic sleeping sickness is found to be widely spread, then sleeping sickness epidemics probably represent the spread of more virulent strains. Does this apply to Uganda?

(6) Careful leucocytic counts should be made when opportunity offers.

(7) Study modes of spread of sleeping sickness other than by biting flies: saliva, close contact, &c.

(8) What percentage of early sleeping sickness cases will gland palpation fail to detect?

(9) Duration of disease.

(10) Mortality.

(11) Deaths in Uganda.

(12) Present position of the epidemic in Uganda.

Distribution of Sleeping Sickness and G. palpalis.

(1) Continue the work done in 1903, and since then by Dr. Bagshawe and others, on the distribution of sleeping sickness and *G. palpalis* in Uganda.

(2) Work out and prepare maps showing the distribution in Uganda of other species of *Glossina* and other biting flies, mosquitoes, ticks, &c.

Treatment.

(1) Atoxyl: the results of treatment by this drug. The after-history of Koch's cases should be reported on. Atoxyl alternating with mercury, antimony, or any drug which can be combined with it to advantage.

(2) Antimony salts.

(3) Atoxyl-proof. Is there any proof that this occurs in man? If so, is this strain more virulent, *e.g.*, for monkeys.

(4) Experiments with new remedies.

(5) Try feeding experiments (*G. palpalis*) or injection experiments with blood from native undergoing atoxyl treatment. Does atoxyl render natives innocuous?

(6) Is there any evidence that a single case of cure in man has taken place?

Prevention.

(1) Effects of clearing the Lake shore.

(2) Is it possible to destroy the fly?

(3) Is it possible to stamp out the disease in Uganda?

(4) Effect of segregation of sick in sleeping sickness camps.

Miscellaneous Cattle trypanosomes. M'kebe. Monkey malaria. Auchmeromyia luteola. Ticks, &c.

(1) The eggs (length of time to hatch) and larva of *A. luteola* have never been described. The distribution of this fly is fairly universal. Does it transmit?

Filaria perstans? (Todd.)

(2) Does monkey malaria blood give rise to the disease if injected?

(3) Work out, if opportunity offers, the development of monkey malaria.

(4) Find out species of human ticks.

(5) What is the best way to destroy ticks?

(6) Will mosquitoes transmit spirochætæ?

(7) Examine spirochætæ-infected animals by day and night for sexual forms. Filtrates of spirochætæ are infective. What is in them? (Todd.)

(8) Watch nose, larynx and trachea carefully in native *post mortems* for pneumonyssus; also liver for porocephalus, &c. (Todd.)

(9) A good histological study of lesions in trypanosomiasis is much needed.

(10) Deaths from trypanosomes and spirochætæ often seem to be toxic. Attempts to isolate these toxins have so far failed.

(11) Get early cases of tick fever and determine definitely the duration of the first attack.

(12) A Guinea-worm was found in baboons in the Gambia, but was lost. (Todd.)

(13) Examine a series of monkeys for worms. Determine species and mode of entrance of worm. (Todd.)

(14) Get Glossina and ticks to bite through a celloidin membrane, in order to collect saliva extruded, and so ascertain what the infecting bodies are in sleeping sickness, tick fever, &c. (Todd.)

(15) Do the trypanosomes of the wild animals belong to the type *T. brucei*, *T. dimorphon*, or to other species?

(16) Work out the nature of the trypanosome disease of cattle in Uganda and find its carrier.

(17) Work out the nature of the m'kebe in calves.

Circular.—In order to arouse the attention and excite the interest of the various officials, missionaries and traders in Uganda, the following circular has been printed and sent round.

SLEEPING SICKNESS COMMISSION OF THE ROYAL SOCIETY, 1908.

(1) This Commission has been sent out to Uganda, at the suggestion of His Excellency Sir H. Hesketh Bell, K.C.M.G., by the Colonial Office, to continue the investigations initiated in 1903.

(2) In 1903 the Commission discovered that sleeping sickness is caused by the entrance into the blood of a minute parasite, the *Trypanozoma gambiense*, and that this trypanosome is conveyed from the sick to the healthy by means of a particular fly, the *Glossina palpalis*, and by it alone.

(3) The distribution of this fly was then worked out and found to coincide exactly with the distribution of sleeping sickness, a strong proof that this fly is the only carrier.

(4) The distribution of this species of tsetse-fly was found to be a peculiar one. It was only found on the shore of the Lake, or on the banks of open rivers, such as the Nile, where there is plenty of forest shade. This rendered it easy for intelligent persons to escape sleeping sickness, as all that was required was to keep out of the fly area, or if it was necessary to pass through it, to take precautions against being bitten by the fly. It also enabled preventive and stamping-out measures to be organised on a rational basis.

(5) The last Sleeping Sickness Commission continued to work until March, 1906, when one of the members, the late Lieutenant Forbes Tulloch, R.A.M.C., most unfortunately contracted the disease, and this sad event brought the work of the Commission to an abrupt close.

(6) It had been the intention of the Royal Society to keep this scientific Commission constantly employed by sending out fresh workers from time to time, until all the main diseases, both of men and animals, had been described and their distribution mapped out. It was truly said to the Commission the other day by Lord Delamere, that it is only by science that these colonies can progress. In the last Report of the Government Veterinary Bacteriologist, Transvaal, it is stated that the sum of money voted by the Legislative Assembly to his department alone for the current expenditure of the year was £30,934. In the Transvaal this money is considered well spent.

(7) If the programme of the Royal Society had been carried out, no doubt much good would have accrued to the Protectorate. Examples

illustrating this could be multiplied: in 1903 when Mr. Grant brought some 1,500 cattle from Mount Elgon to Jinja, he rested them in a valley swarming with *G. morsitans*, and as a result lost them all from nagana. A little knowledge of the distribution of this deadly fly would have prevented this loss. Again, at the present time, the Uganda Government are losing numbers of their oxen from an unknown disease. If the cause of it could be discovered and its mode of spread traced, this mortality among the stock might be prevented. Thanks to the courtesy of the Principal Medical Officer, Dr. Hodges, who thinks the disease may be caused by *T. dimorphon*, and the Transport Officer, Mr. Russell, the Commission are having the opportunity of seeing examples of this disease. Yet, again, the Commission are informed that from 40 to 60 per cent. of calves die of a disease called "m'kebe." This seems a large mortality, and something might perhaps be done to lessen it. The Commission, thanks to the kindness of the Katikiro and the Sekibobo, will also have an opportunity of seeing this disease.

(8) During the last few years the knowledge of the distribution of the *G. palpalis* and of sleeping sickness in Uganda has been much advanced, and mainly through the energy of the Principal Medical Officer, Dr. Hodges, and Dr. Bagshawe, at present Director of the Sleeping Sickness Bureau in London. It is gratifying to know that nothing has been discovered to shake the conclusions arrived at by the Commission in 1903.

(9) The chief work of the present Commission is to continue the study of sleeping sickness in the Protectorate, and for this reason this Memorandum is being sent to officials, missionaries and others, to invite their aid and criticism. At the same time the Commission is ready to undertake the investigation of any disease, whether of men or animals, which may be brought to their attention.

(10) Since 1903 evidence has been brought forward, especially from the Congo, to the effect that sleeping sickness is spread not only through the agency of *G. palpalis*, but also by other species of tsetse-flies, other biting flies, and even by fleas and such-like insects. Now, if anyone can bring forward any proof of cases of sleeping sickness arising in districts free from *G. palpalis* the Commission would be greatly assisted. The theory held by the Commission is that the tsetse-fly, *G. palpalis*, is the only carrier. Naturally, it is most important to know if other biting insects can also act as carriers.

(11) Again, His Excellency, Professor R. Koch, of Berlin, has advanced the theory that close contact, as, for example, when an infected man returns from the sleeping sickness area to his wife and children living in a fly-free area, is also a means of spreading the disease. The importance of this cannot be exaggerated. The Commission hold that this never occurs, but invite information and criticism.

(12) Another important point which is engaging the attention of the Commission is whether it can be shown that any other animal except

man is capable of acting as a reservoir of the virus. The importance of this is self-evident. For example, the monkey is very susceptible to this disease, and dies in a few months after infection. If the monkeys along the Lake shore are infected, then the removal of the Lake-shore population will not render that area healthy, as the *G. palpalis* will be able to get the virus from the monkey. This also holds good of the hippopotamus. The Commission do not believe that this occurs, but wish to examine the blood of as many monkeys and hippopotami as possible. The Commission would like, therefore, to receive as many living monkeys from the Lake shore as possible, especially from places where sleeping sickness is prevalent. Also, is there any evidence that monkeys have been dying of sleeping sickness? It is reported that the monkeys have disappeared from Buvuma. Is this true? In the event of a hippopotamus being killed on land or shallow water, the heart full of blood might be sent post haste to the Mpumu laboratory. The blood-vessels at the base of the heart should be tied lightly, and the heart wrapped in damp grass or banana leaves to keep it cool.

(3) In tropical countries the chief disseminators of disease are blood-sucking insects. For example, malaria is carried by certain mosquitoes, sleeping sickness by a tsetse-fly, the *G. palpalis*, tick fever by a tick, horse sickness probably by a mosquito, East Coast fever and redwater in cattle by ticks, jaundice in dogs by a tick, and so on. It is therefore very important that the different species of these biting insects should be known and their distribution mapped out. Their habits (such as feeding by day or night), their habitat (such as living in houses, valleys, woods or marshes), &c., should also be studied. The Commission would therefore be greatly obliged if anyone interested in these matters would send in specimens of biting flies, mosquitoes, ticks, fleas, &c. All that is necessary is to kill them, and then place them in a bottle, gourd, or matchbox, addressed to the Sleeping Sickness Laboratory, Mpumu, with an enclosure giving the native name, place of capture, &c. All such specimens will be fully acknowledged in the official Reports of the Commission.

Mpumu, Chagwe, Uganda,
December 12th, 1908.

JOURNAL OF THE ROYAL ARMY MEDICAL CORPS (1913) XXI
pages 561-568

THE TRYPANOSOMES FOUND IN THE BLOOD OF WILD ANIMALS LIVING IN THE SLEEPING-SICKNESS AREA, NYASALAND.[1]

By Surgeon-General Sir DAVID BRUCE, C.B., F.R.S., Majors DAVID HARVEY and A. E. HAMERTON, D.S.O., R.A.M.C.; Dr. J. B. DAVEY Nyasaland Medical Staff;[2] and Lady BRUCE, R.R.C.

Introduction.

The chief object of this Commission in coming to Nyasaland was to inquire into the relation of the African fauna to the maintenance and spread of trypanosome disease.

The Commission arrived at their camp on Kasu Hill on January 12, 1912. As this was the rainy season the low country was covered with dense vegetation and much of it under water. Nothing could therefore be done in the study of the fauna until about the beginning of June, when the dry season was well established.

The camp at Kasu is situated on one of the hills (lat. 13° 40′ S., long. 34° 12′ E.) which rise on the western edge of the flat country adjoining Lake Nyasa. This low-lying, lake coast plain looks quite flat when viewed from the camp, and extends from the lake shore some twenty miles inland. The camp lies about ten miles from the edge of this low country, and, therefore, some thirty miles from the lake. This plain is covered with thorn scrub, except near the lake, where there are large grassy plains, or "dambos," dotted over with palm trees. The thorn scrub is the home of the tsetse-fly and also of numerous wild animals.

When an animal is shot in this fly country by a member of the Commission a small quantity of the blood is taken in a bottle containing citrate of soda solution for inoculation purposes, and a thick and thin film of the blood spread on glass slides for microscopical examination. The blood is then sent to a point on one of the main paths, where a motor-cyclist is waiting to carry it to the camp. When the blood arrives it is at once injected into a goat, a monkey and a dog.

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[1] Reprinted from the *Proceedings of the Royal Society*, B, vol. lxxxvi.

[2] Dr. Davey resigned his membership of the Commission in October, before the completion of the work here recorded.

Wild Animals living in a Fly-area as Hosts or Reservoirs of Trypanosome Disease.

The following table represents the result of the examination of 180 specimens of wild game or other animals shot in this fly-area. In one column is given the number of hours between the taking of the blood and its inoculation, in others the result of the microscopical examination of the thick and thin film, and of the inoculation of the blood. A plus sign means that trypanosomes are present, a minus sign that they are absent, and a blank space (..) that a microscopical specimen was not available for examination, or an animal for inoculation, as the case may be.

TABLE I.—List of Wild Animals living in a Fly-area whose Blood has been examined for Trypanosomes.

Date	Expt. No.	Animal	Age of blood in hours	By microscopical examination		By inoculation		
				Thick	Thin	Goat	Monkey	Dog
1912								
Jan. 20	32	Hartebeeste	..	−	−	−	..	−
,, 20	33	,,	..	..	−	−	..	−
,, 20	34	,,	..	..	−	−	..	−
,, 22	40	,,	..	..	−	−	..	−
,, 22	41	Eland ..	..	..	−	−	..	+
,, 22	44	,, ..	..	..	−	+	..	−
,, 23	62	Sable ..	..	−	−	−	..	−
,, 23	63	,, ..	..	..	..	−	..	−
,, 26	95	Eland ..	..	−	−	−	..	−
Feb. 6	159	Warthog ..	..	..	..	−	..	−
,, 6	160	Sable ..	..	..	−	−	..	−
,, 18	246	Elephant ..	..	..	−	−	..	−
,, 23	283	Eland ..	..	..	−	..	..	..
,, 28	288	Lion ..	..	..	−	−	..	−
May 19	615	Oribi ..	3	−	−	−	..	−
,, 19	616	Waterbuck ..	17	..	+	−	..	..
,, 25	583	Duiker ..	..	..	−	−	−	−
,, 25	584	Warthog ..	..	..	−	−	−	−
,, 26	589	,, ..	..	..	−	..	..	−
,, 26	591	Reedbuck ..	..	..	+	..	..	−
,, 26	593	Duiker ..	..	..	−	..	..	−
June 2	611	Buffalo ..	9	−	−	−	−	−
,, 2	612	,, ..	9	−	−	−	−	−
,, 2	613	,, ..	9	+	−	−	−	−
,, 2	614	,, ..	9	−	−	−	−	−
,, 15	686	Warthog ..	9½	−	−	−	−	−
,, 15	687	Oribi ..	9½	−	−	−	−	−
,, 16	692	Reedbuck ..	8½	−	−	−	−	−
,, 16	695	Sable ..	5	−	−	−	−	−
,, 23	742	Warthog ..	9	−	−	−	−	−
,, 23	742a	,, ..	9	−	−	−	−	−
,, 23	743	Oribi ..	9	+	−	−	−	−
,, 23	743a	,, ..	9	−	−	−	−	−
,, 25	744	Duiker ..	7½	−	−	−	−	−

TABLE I.—*Continued.*

Date	Expt. No.	Animal	Age of blood in hours	By microscopical examination		By inoculation		
				Thick	Thin	Goat	Monkey	Dog
June 27	755	Bushbuck ..	11	−	−	−	−	−
,, 29	768	Hartebeeste	6½	−	−	−	−	−
,, 29	769	Reedbuck ..	5½	−	−	..	−	−
,, 29	780	,, ..	2	−	−	..	−	−
,, 30	783	,, ..	¼	+	+	..	+	+
July 1	777	Hartebeeste	7	..	..	−	−	−
,, 1	778	,,	7	..	..	−	−	−
,, 1	779	,,	7	..	..	+	+	+
,, 2	820	Oribi ..	7¾	..	−	..	..	−
,, 3	801	,, ..	7¾	−	−	−	−	−
,, 3	818	Warthog ..	11¼	−	−	..	−	..
,, 4	813	Hartebeeste	8	−	−	−	−	−
,, 4	814	,,	8	−	−	−	−	−
,, 4	815	,,	8	−	−	−	−	−
,, 4	816	,,	8	−	−	−	−	−
,, 4	817	,,	8	−	−	−	−	−
,, 5	828	Reedbuck ..	..	+	−	..	−	−
,, 6	825	Hartebeeste	8	−	−	..	..	..
,, 6	826	Warthog ..	7¾	+	+	−	−	−
,, 6	827	Oribi ..	7¾	−	−	−	−	−
,, 8	844	Hartebeeste	4¼	−	−	−	−	−
,, 8	863	Oribi ..	1¼	−	−	..	+	−
,, 10	859	Hartebeeste	9¾	−	−	−	−	−
,, 10	860	Oribi ..	5¾	−	+	−	−	−
,, 10	861	Warthog ..	6¾	−	−	−	−	−
,, 10	862	Oribi ..	5¾	−	−	−	−	−
,, 11	866	,, ..	7½	−	−	−	−	−
,, 11	869	Warthog ..	8½	−	−	−	−	−
,, 11	872	,, ..	7½	−	−	−	−	−
,, 11	875	Hartebeeste	5¾	−	−	−	−	−
,, 20	912	Reedbuck ..	7¼	−	−	+	−	−
,, 21	918	Hartebeeste	8	−	−	−	−	−
,, 21	919	Oribi ..	7	−	−	−	−	−
,, 21	920	Warthog ..	5	−	−	−	..	−
,, 21	920a	,, ..	5	−	−	−	−	−
,, 21	920b	,, ..	5	−	−	−	−	−
,, 21	921	Oribi ..	8	−	−	−	−	−
,, 21	923	Warthog ..	10	−	−	−	−	−
,, 21	925	Bushbuck ..	10	−	−	−	−	−
,, 22	927	Hartebeeste	7¾	−	−	−	−	−
,, 22	929	Warthog ..	5¾	−	−	−	−	−
,, 22	931	,, ..	5¾	−	−	−	−	−
,, 22	933	Warthog ..	4¼	+	+	−	−	−
,, 22	935	,, ..	4¼	−	−	−	−	−
,, 23	955	Hyæna ..	8	−	−	+	−	−
,, 23	956	,, ..	8	+	−	−	−	−
,, 23	957	Hartebeeste	5	−	−	+	+	+
,, 23	958	,,	3¼	+	+	−	−	−
,, 25	988	Reedbuck ..	6¾	+	+	+	−	−
,, 26	993	Duiker ..	5½	−	−	−	−	−
,, 27	1000	Hartebeeste	3½	+	−	+	+	+
,, 29	1004	,,	5¼	−	−	−	−	−
,, 29	1007	Duiker ..	4	+	−	−	−	−
,, 30	1010	Hartebeeste	4	−	−	−	−	−

TABLE I.—*Continued.*

Date	Expt. No.	Animal	Age of blood in hours	By microscopical examination		By inoculation		
				Thick	Thin	Goat	Monkey	Dog
July 30	1013	Eland ..	4	+	+	+	+	+
Aug. 1	1017	Oribi ..	8¼	−	−	−	−	−
,, 2	1024	Sable ..	7¼	−	−	−	−	−
,, 2	1027	Duiker ..	5¼	+	−	−	−	−
,, 4	1044	Eland ..	6½	−	−	+	−	−
,, 5	1045	Duiker ..	6¼	−	−	−	−	−
,, 5	1048	Wild cat ..	3	−	−	−	−	−
,, 7	1052	Warthog ..	5¾	−	−	−	−	−
,, 7	1055	Wild cat ..	2¾	−	−	−	−	−
,, 11	1058	Koodoo ..	3½	+	+	−	−	−
,, 11	1061	Waterbuck ..	2¼	+	−	+	−	−
,, 11	1064	Warthog ..	2¾	+	+	−	−	−
,, 12	1067	Hyæna ..	4	−	−	−	−	−
,, 18	1075	Waterbuck ..	5	−	−	−	−	−
,, 18	1078	Bushbuck ..	3	+	+	+	−	−
,, 18	1081	,, ..	3	+	−	−	−	−
,, 18	1084	,, ..	3	+	+	+	+	+
,, 18	1087	,, ..	3	+	+	+	−	−
,, 19	1090	Oribi ..	7	−	−	−	−	−
,, 19	1093	,, ..	7	−	−	−	−	−
,, 19	1096	,, ..	7	−	−	+	−	−
,, 19	1099	,, ..	7	−	−	−	−	−
,, 19	1102	,, ..	7	−	−	−	−	−
,, 21	1136	Warthog ..	5¾	−	−	−	−	−
,, 21	1139	,, ..	5	+	+	+	−	−
,, 21	1142	Hartebeeste	7½	−	−	+	−	+
,, 21	1145	,,	6¾	−	−	−	−	−
,, 22	1150	Reedbuck ..	8½	+	+	+	−	−
,, 22	1153	,, ..	8½	+	−	+	−	−
,, 22	1156	,, ..	7	+	−	+	−	−
,, 22	1159	,, ..	7	−	−	−	−	−
,, 22	1162	,, ..	6	+	−	+	−	−
,, 22	1165	,, ..	6	−	−	−	−	−
,, 23	1168	Warthog ..	7¾	−	−	−	−	−
,, 23	1171	Wild cat ..	6¾	−	−	−	−	−
,, 23	1174	Waterbuck ..	7	−	−	−	−	−
,, 24	1177	,, ..	5	−	−	−	−	−
,, 24	1180	,, ..	5	+	−	+	+	+
,, 24	1183	Warthog ..	7½	−	−	−	−	−
,, 24	1186	,, ..	6	+	−	+	−	−
,, 24	1189	,, ..	6	+	−	−	−	−
,, 24	1192	Oribi	7¼	−	−	−	−	−
,, 24	1195	,, ...	7¼	−	−	−	−	−
,, 24	1198	Porcupine ..	8½	−	−	−	−	−
,, 28	1202	Eland ..	4	+	+	+	..	+
,, 28	1203	Bushbuck ..	5	+	+	−	−	−
,, 28	1205	Eland ..	4	−	−	−	..	−
,, 28	1210	Waterbuck ..	4	+	−	+	+	+
,, 30	1216	Bushbuck ..	8	+	−	−	..	−
Sept. 6	1250	Koodoo ..	2	−	−	−	−	−
,, 6	1254	Oribi ..	6¾	−	−	−	−	−
,, 7	1261	Bushbuck ..	4¼	−	−	+	−	−
,, 7	1264	Waterbuck ..	3¾	+	+	−	+	+
,, 7	1268	Buffalo ..	6¼	−	−	−	−	−

TABLE I.—*Continued.*

Date	Expt. No.	Animal	Age of blood in hours	By microscopical examination		By inoculation		
				Thick	Thin	Goat	Monkey	Dog
Sept. 7	1272	Hartebeeste	5½	−	−	−	−	−
,, 7	1276	Warthog ..	4	−	−	−	−	−
,, 7	1281	Buffalo ..	9	−	−	−	−	−
,, 10	1285	,, ..	5	−	−	−	−	−
,, 10	1289	Eland ..	8½	−	−	−	−	−
,, 10	1293	Warthog ..	12½	−	−	−	−	−
,, 10	1298	Buffalo ..	5	−	−	−	−	−
,, 11	1304	,, ..	3¼	−	−	+	−	−
,, 12	1308	Warthog ..	6	..	..	+	−	−
,, 13	1339	Waterbuck ..	6½	−	−	+	−	−
,, 13	1343	Bushbuck ..	7	−	−	−	−	−
,, 13	1347	Reedbuck ..	6	+	−	−	+	+
,, 13	1351	,, ..	5¾	−	−	−	−	−
,, 14	1355	Hartebeeste	7½	−	−	−	−	−
,, 14	1359	,,	7½	−	−	−	−	−
,, 14	1363	Reedbuck ..	6	−	−	+	−	−
,, 16	1368	Oribi ..	7¼	−	−	−	−	−
,, 16	1372	,, ..	7¼	−	−	−	−	−
,, 16	1376	Elephant ..	20	−	−	−	−	−
,, 17	1380	Koodoo ..	2½	−	−	+	−	−
,, 17	1384	Warthog ..	6½	−	−	−	−	−
,, 18	1388	Waterbuck ..	8	+	+	+	−	−
,, 18	1392	Hartebeeste	5	−	−	−	−	−
,, 18	1396	,,	5	−	−	−	−	−
,, 18	1400	Oribi ..	4½	−	−	−	−	−
,, 20	1406	Waterbuck ..	9	−	−	+	−	−
,, 20	1410	,, ..	9	−	+	−	−	−
,, 20	1414	Warthog ..	6¼	−	−	−	−	−
,, 20	1418	Hartebeeste	..	−	−	−	−	−
,, 20	1422	,,	9	−	−	−	−	−
,, 20	1426	,,	7	−	−	−	−	−
,, 20	1435	Reedbuck ..	9	−	−	−	+	+
,, 20	1439	,, ..	8½	−	−	−	−	−
,, 20	1443	Oribi ..	7¾	−	−	−	−	−
,, 24	1447	Waterbuck ..	14	−	−	−	−	−
,, 25	1453	Hartebeeste	10½	+	−	−	−	+
Oct. 6	1471	Eland ..	2	+	−	+	−	−
Nov. 10	1577	Warthog ..	3½	−	−	−	−	−

Total 180. Infected with pathogenic trypanosomes 57 = 31·7 per cent.

In the above table an account is given of the examination of 180 wild animals shot in the fly-area adjoining the Commission's camp at Kasu. This part of the country is situated in the proclaimed Sleeping-Sickness Area of Nyasaland, which extends from the Chirua River (lat. 13° 20′ S., long. 34° E.) in the north to the Lintipe River (lat. 13° 50′ S., long. 34° 30′ E.) in the south. It is bounded on the east by the Lake and on the west by the foothills. The area is about fifty miles from north to south and twenty-five from east to west. These figures are only approximate, as the

available maps are far from correct. This is the only part of this country in which cases of the human trypanosome disease of Nyasaland, up to the present, have been found. It will be seen, then, that these animals were procured from the very heart of the Sleeping-Sickness Area.

Among the 180 animals, 57 were found to harbour pathogenic trypanosomes—31·7 per cent.

Table II gives the species of trypanosomes found in the 180 animals. Here a difficulty is encountered—the classification. The tendency in this branch of natural history, as in all others, is to multiply species.

In a previous paper[1] the trypanosome causing human trypanosome disease in Nyasaland was called *Trypanosoma rhodesiense*, on account of the presence of posterior-nuclear forms. This trypanosome agreed in all other respects with *T. brucei*, the common trypanosome of wild animals in South Africa, and the cause of the tsetse-fly disease, or nagana. In order to compare the two species of trypanosomes more closely, the Commission procured, by the kindness of Dr. A. Theiler, C.M.G., Pretoria, a strain of nagana from the same spot in Zululand where it was first discovered in 1894. Much to the surprise of the Commission it was found that *T. brucei* has quite as large a proportion of posterior-nuclear forms as *T. rhodesiense*, and that the blunt-ended character is common to both species. The Commission is therefore driven to the conclusion that *T. rhodesiense* is neither more nor less than *T. brucei*, and that the human trypanosome disease of Nyasaland is nagana.

To this it may be objected that nagana has never been known to attack human beings. This has probably been due to faulty diagnosis, cases in man being returned as malaria.

The pathogenic trypanosomes then, found in the blood of wild animals in Nyasaland, up to the present, by the Commission are *T. brucei* (Plimmer and Bradford) vel *rhodesiense* (Stephens and Fantham), *T. pecorum*, *T. simiæ*, and *T. capræ* (Kleine). *T. ingens* is also found, but this trypanosome cannot, with our present knowledge, be considered a pathogenic species to man or domestic animals.

In Table II the plus sign means that the trypanosome named at the top of the column was present in the blood. The other plus signs signify that the trypanosome was found in a thick or thin

[1] *Proc. Roy. Soc.*, 1912, B, vol. lxxxv, p. 423.

TABLE II.—Species of Trypanosomes found in the Blood of Wild Animals living in the Sleeping-Sickness Area, Nyasaland.

Date	Expt. No.	Animal	*T. brucei* vel *rhodesiense*	*T. pecorum*	*T. simiæ*	*T. capræ*	*T. tagens*	Thick film	Thin film	Inoculation
1912										
Jan. 22	41	Eland ..	..	+	..	..	..	..	..	+
,, 22	41	,, ..	..	+	..	..	..	..	..	+
May 19	616	Waterbuck ..	..	..	..	+	..	..	+	..
,, 26	591	Reedbuck ..	..	..	..	+	..	..	+	..
June 2	613	Buffalo ..	..	+	..	..	..	+	..	..
,, 23	743	Oribi.. ..	..	..	..	..	+	+	..	..
,, 30	783	Reedbuck ..	+	..	..	+	..	+	+	+
July 1	779	Hartebeeste	+	..	..	..	..	..	..	+
,, 5	828	Reedbuck ..	..	..	..	+	+	+	..	..
,, 6	826	Warthog ..	..	+	..	..	..	+	+	..
,, 8	863	Oribi.. ..	+	..	..	..	..	..	..	+
,, 10	860	,, ...	..	..	..	+	..	..	+	..
,, 20	912	Reedbuck ..	..	+	..	..	..	..	..	+
,, 22	933	Warthog ..	..	+	..	..	..	+	+	..
,, 23	955	Hyæna ..	..	+	..	..	..	..	..	+
,, 23	956	,, ..	..	+	..	..	..	+	..	..
,, 23	957	Hartebeeste	+	..	..	..	..	..	..	+
,, 23	958	,, ..	+	..	..	..	..	+	+	..
,, 25	988	Reedbuck ..	..	..	..	+	..	+	+	+
,, 27	1,000	Hartebeeste	+	..	..	..	..	+	..	+
,, 29	1,007	Duiker ..	+	..	..	..	..	+	..	..
,, 30	1,013	Eland ..	..	+	..	+	..	+	+	+
Aug. 2	1,027	Duiker ..	..	..	..	..	+	+	..	..
,, 4	1,044	Eland ..	..	+	..	..	..	..	..	+
,, 11	1,058	Koodoo ..	..	+	..	..	..	+	+	..
,, 11	1,061	Waterbuck ..	..	+	..	+	..	+	..	+
,, 11	1,064	Warthog ..	+	..	..	..	..	+	..	..
,, 18	1,078	Bushbuck ..	..	+	..	..	..	+	+	+
,, 18	1,081	,, ..	..	+	..	..	..	+	..	..
,, 18	1,084	,, ..	..	+	..	..	..	+	+	+
,, 18	1,087	,, ..	..	+	..	+	..	+	+	+
,, 19	1,096	Oribi.. ..	..	+	..	..	..	..	..	+
,, 21	1,139	Warthog ..	..	..	+	..	..	+	+	+
,, 21	1,142	Hartebeeste	+	..	..	..	..	..	..	+
,, 22	1,150	Reedbuck ..	..	..	..	+	..	+	+	+
,, 22	1,153	,, ..	..	..	..	+	..	+	..	+
,, 22	1,156	,, ..	..	..	..	+	..	+	..	+
,, 22	1,162	,, ..	..	..	..	+	..	+	..	+
,, 24	1,180	Waterbuck ..	+	..	..	+	..	+	..	+
,, 24	1,186	Warthog ..	..	..	+	..	..	+	..	+
,, 24	1,189	,, ..	..	+	..	..	..	+	..	..
,, 28	1,202	Eland ..	..	+	..	..	..	+	+	+
,, 28	1,203	Bushbuck ..	..	+	..	..	..	+	+	..
,, 28	1,210	Waterbuck ..	+	..	..	+	..	+	..	+
,, 30	1,216	Bushbuck ..	..	+	..	..	..	+	..	..
Sept. 7	1,261	,, ..	..	+	..	..	..	..	..	+
,, 7	1,264	Waterbuck ..	+	..	..	..	..	+	+	+
,, 11	1,304	Buffalo ..	..	+	..	..	..	..	..	+
,, 12	1,308	Warthog ..	..	..	+	..	..	..	..	+
,, 13	1,339	Waterbuck ..	..	..	..	+	..	..	..	+
,, 13	1,347	Reedbuck ..	+	..	..	..	..	+	..	+
,, 14	1,363	,, ..	..	..	..	+	..	..	..	+
,, 17	1,380	Koodoo ..	..	+	..	..	..	..	..	+
,, 18	1,388	Waterbuck ..	..	..	..	+	..	+	+	+
,, 20	1,406	,, ..	..	..	..	+	..	..	..	+
,, 20	1,410	,, ..	..	..	..	+	..	..	+	..
,, 23	1,435	Reedbuck ..	+	..	..	..	..	..	..	+
,, 25	1,453	Hartebeeste	..	+	..	..	..	+	..	+
Oct. 6	1,471	Eland ..	..	+	..	..	..	+	..	+

film or by inoculation of a quantity of blood from the wild animal into healthy experimental animals.

TABLE III.—Species of Trypanosomes found in the Blood of Wild Animals in the Sleeping-Sickness Area, Nyasaland, and the Number of Times each was found.

Number of animals	*T. brucei* vel *rhodesiense*	*T. pecorum*	*T. simiæ*	*T. capræ*	*T. ingens*
180	14	26	3	20	3

In every 100 wild animals living in the Sleeping-Sickness Area, Nyasaland, taken at random, the following numbers may be expected to be found infected with these species of trypanosomes.

TABLE IV.—Percentage of Animals infected by the Different Species of Trypanosomes.

T. brucei vel *rhodesiense*	*T. pecorum*	*T. simiæ*	*T. capræ*	*T. ingens*
7·8	14·4	1·7	11·1	1·7

TABLE V.—The Species of Animals dealt with, the Total Number examined, the Number found Infected, and the Species of Trypanosomes by which they were Infected.

Animal	Total number examined	Number found infected	*T. brucei* vel *rhodesiense*	*T. pecorum*	*T. simiæ*	*T. capræ*	*T. ingens*
Eland ..	10	6	..	6	..	1	..
Sable ..	5	0	..	..	..	..	..
Waterbuck ..	13	9	3	1	..	8	..
Koodoo ..	3	2	..	2	..	..	..
Bushbuck ..	10	7	..	7	..	1	..
Hartebeeste	35	6	5	1	..	..	..
Reedbuck ..	19	12	3	1	..	9	1
Oribi	26	4	1	1	..	1	1
Duiker ..	7	2	1	..	..	..	1
Buffalo ..	9	2	..	2	..	..	..
Lion	1	0	..	..	..	..	..
Hyæna ..	3	2	..	2	..	..	..
Elephant ..	2	0	..	..	..	..	..
Warthog ..	33	7	1	3	3	..	..
Wild cat ..	3	0	..	..	..	..	..
Porcupine ..	1	0	..	..	..	..	..
Total ..	180	59	14	26	3	20	3

The next table gives the percentages of the different trypanosomes occurring in the wild animals. The numbers are too small to be taken literally, but it is interesting to learn that in this fly-district the waterbuck, hartebeeste, reedbuck and duiker are

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MORPHOLOGY OF VARIOUS STRAINS OF THE TRYPANOSOME CAUSING DISEASE IN MAN IN NYASALAND. I.—THE HUMAN STRAIN.[1]

By Surgeon-General Sir DAVID BRUCE, C.B., F.R.S.; Majors DAVID HARVEY and A. E. HAMERTON, D.S.O., R.A.M.C.; and Lady BRUCE, R.R.C.

Introduction.

In order to gain a general idea of this important species of trypanosome, it will be necessary to study as many individual strains as possible. It may be thought unnecessary to describe each strain so much in detail, but without this it will be impossible to get any order out of the chaos which rules at present in the classification of the African species of trypanosomes pathogenic to man and the domestic animals.

Up to the present the Commission have only had an opportunity of working with five human strains. Four of these are from natives infected in the sleeping-sickness area, Nyasaland, the fifth from a European who contracted the disease in Portuguese East Africa. It is intended, in later papers, to describe five strains from wild game and the same number from the tsetse fly, *Glossina morsitans*.

The human strains are named: I, Mkanyanga; II, E——; III, Chituluka; IV, Chipochola; and V, Chibibi.

I.—Morphology of Strain I, Mkanyanga.

This has already been dealt with in a previous paper.[2]

II.—Morphology of Strain II, E——.

The following table gives the average length of this trypanosome as found in goats, sheep, monkeys, dogs and rats, 1,500 trypanosomes in all, and also the length of the longest and shortest :—

Table I.—Measurements of the Length of the Trypanosome of Strain II., E——.

Date	Method of Fixing	Method of Staining	In microns		
			Average length	Maximum length	Minimum length
1912	Osmic acid	Giemsa	22·2	36·0	15·0

[1] Reprinted from the *Proceedings of the Royal Society*, B, vol lxxxvi.

[2] *Proc. Roy. Soc.*, 1912, B, vol. lxxxv, p. 423.

The average length of the trypanosome of Strain II, in different species of animals, is as follows :—

TABLE II.

Species of animal	Number of trypanosomes measured	In microns		
		Average length	Maximum length	Minimum length
Goat	60	20·7	34·0	15·0
Sheep	20	21·3	28·0	18·0
Monkey	160	22·9	36·0	17·0
Dog	260	21·8	31·0	17·0
Rat	1000	23·1	32·0	17·0

TABLE III.—DISTRIBUTION IN RESPECT TO LENGTH OF 1,500 INDIVIDUALS OF THE TRYPANOSOME OF STRAIN II, E——.

	In microns										
	15	16	17	18	19	20	21	22	23	24	25
Total	2	2	12	55	108	159	210	188	215	177	138
Percentage ..	0·2	0·2	0·9	3·0	7·2	10·6	14·0	12·6	14·4	11·8	9·2
	In microns										
	26	27	28	29	30	31	32	33	34	35	36
Total	83	60	34	26	18	8	3	—	1	—	1
Percentage ..	5·6	4·0	2·3	1·8	1·2	0·6	0·2	—	0·1	—	0·1

This curve is made up of measurements from 60 specimens of trypanosomes taken from the goat, 20 from the sheep, 160 from the monkey, 260 from the dog, and 1,000 from the rat.

In a previous paper it was suggested that 1,000 trypanosomes taken at random would be a suitable number to plot a curve from, for purposes of comparison. This is done in Chart 2.

The taking away of 500 rat trypanosomes has changed, to a great extent, the character of the curve. There is no resemblance between this curve and that given on Chart 1 of Strain I, Mkanyanga.

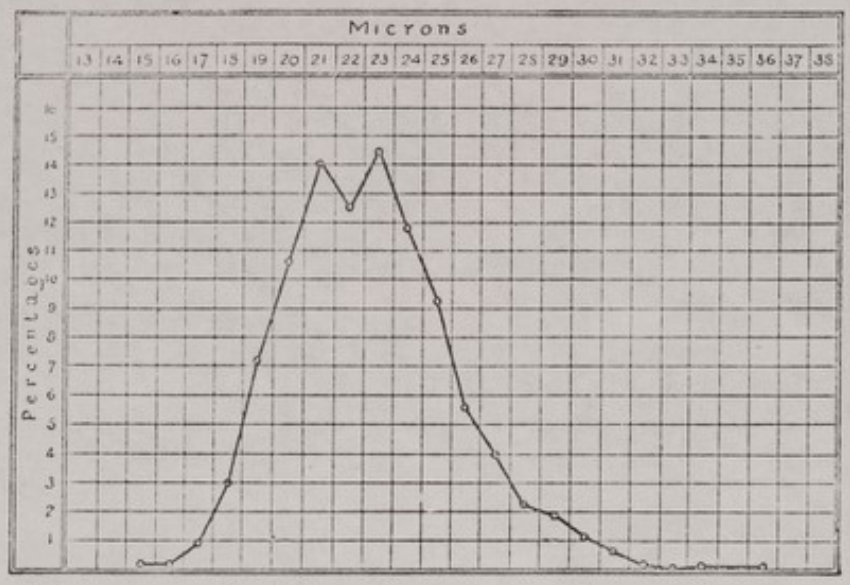


CHART 1.—Curve representing the distribution, by percentages, in respect to length, of 1,500 individuals of the Trypanosome of Strain II, E——.

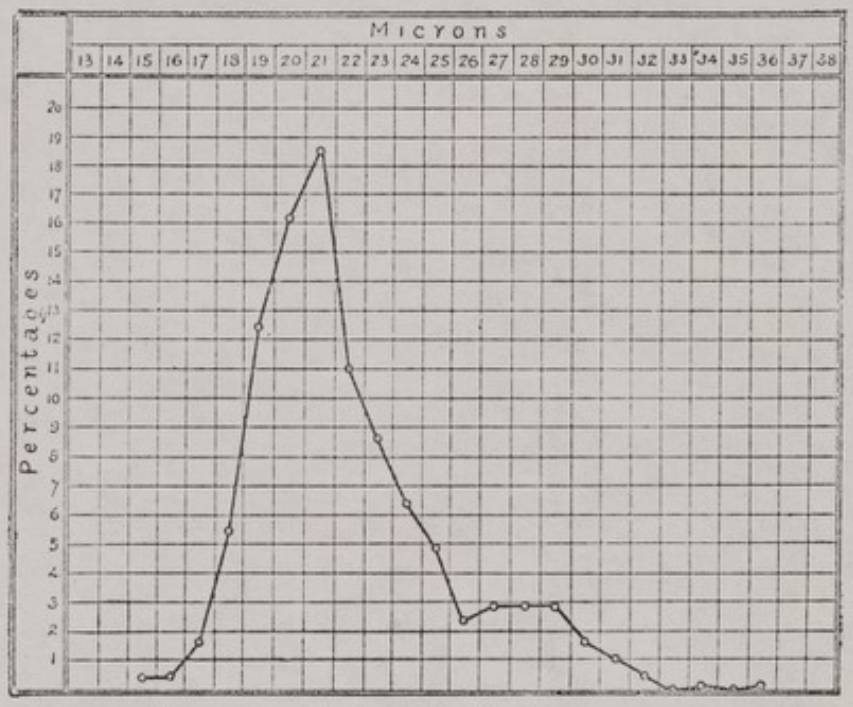


CHART 2.—Curve representing the distribution, by percentages, in respect to length, of 1,000 individuals of the trypanosome of Strain II, E——.

If the two strains, I and II, belong to the same species, then little help can be expected from this system of measurement in classifying trypanosomes.

It has been suggested by Dr. J. W. W. Stephens that the measurements should be made from one animal, and he proposed the tame rat as a suitable species. There seems much to be said in favour of this. Practically, his proposal is that a series of slides should be made with blood taken on ten consecutive days from a single rat, and that 100 trypanosomes should be drawn each day. But it is no light task to draw 1,000 trypanosomes at a magnification of 2,000, and afterwards to measure them. We have therefore made a compromise and measure 60 trypanosomes on nine consecutive days, beginning from the day the parasites first appear in the blood. In order to deal with a round number (500) only 20 are measured on the ninth day.

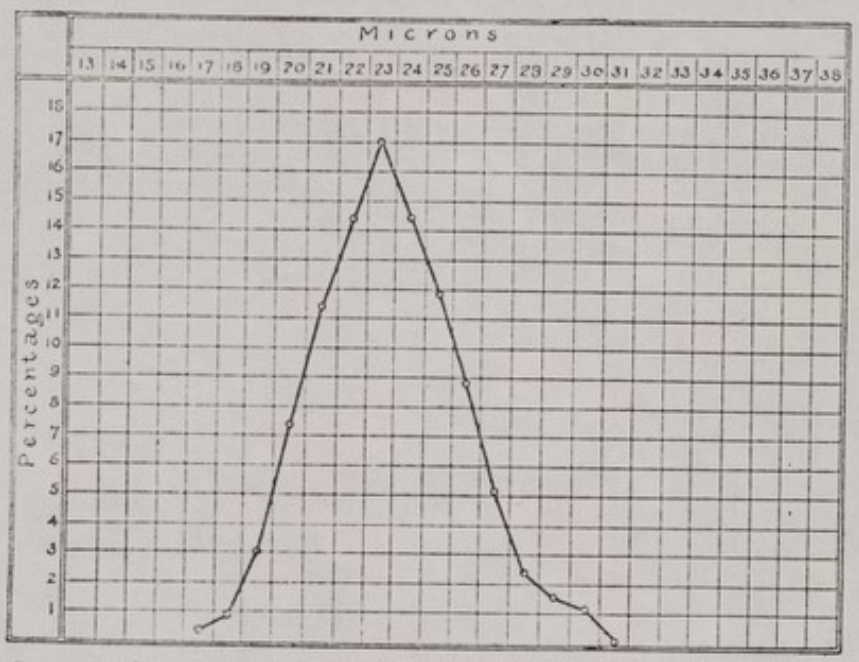


CHART 3.—Curve representing the distribution, by percentages, in respect to length, of 500 individuals of the trypanosome of Strain II, E——, taken on nine consecutive days from Rat 728.

This makes a symmetrical curve, which ascends and descends by fairly regular steps, but with little likeness to Charts 1 and 2.

In an organism low in the scale of nature, such as this, subject to great variation in form, it might be thought that it would not

be likely to behave in any two rats in the same way. The following chart shows that this is not so, but that, on the contrary, the same strain of trypanosome planted in two different animals of the same species grows in a remarkably similar way.

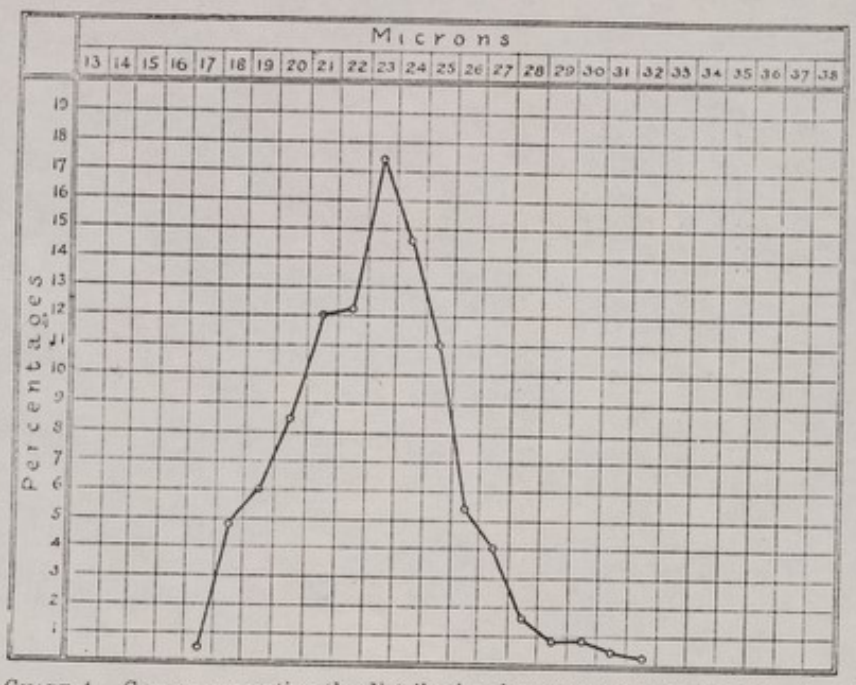


CHART 4.—Curve representing the distribution, by percentages, in respect to length, of 500 individuals of the trypanosome of Strain II, E——, taken on nine consecutive days from Rat 726.

It is remarkable how much alike these last two curves are. If curves made in this way from different strains of one species of trypanosome showed the same degree of similarity, this method would certainly be useful for purposes of classification. But, as we have seen, the curve of Strain II has no resemblance to that of Strain I, and it will be found that each human strain of this species of trypanosome differs, more or less, when subjected to this method of measurement.

As the occurrence of posterior-nuclear forms has been made the distinguishing character between *Trypanosoma brucei*, *gambiense*, and *rhodesiense*, it will be of interest to note the percentage of these forms in the various strains. The method used is to count the number of posterior nuclears in 1,000 short and stumpy forms in ten specimens of a single rat's blood taken, as near as possible, on ten consecutive days.

TABLE IV.—PERCENTAGE OF POSTERIOR-NUCLEAR FORMS FOUND AMONG THE SHORT AND STUMPY VARIETIES OF THE TRYPANOSOME OF STRAIN II, E——

Date	Experiment No.	Animal	Percentage among short and stumpy forms
1912.			
June 25	728	Rat	10
,, 26	728	,,	17
,, 27	728	,,	3
,, 29	728	,,	9
July 1	728	,,	5
,, 2	728	,,	5
,, 3	728	,,	9
,, 4	728	,,	3
,, 5	728	,,	18
,, 6	728	,,	14
		Average ..	9·3

In regard to breadth, shape, contents of cell, nucleus, micronucleus, undulating membrane and flagellum, it is not proposed to describe these characters separately for each strain, as was done in Strain I. Suffice it to say that no difference can be made out in regard to these particulars on comparing the five strains. The same posterior-nuclear and blunt-ended forms are present in all.

III.—MORPHOLOGY OF STRAIN III, CHITULUKA.

The following table gives the average length of this trypanosome as found in the goat, monkey, dog and rat, 1,500 trypanosomes in all, and also the length of the longest and shortest:—

TABLE V.—MEASUREMENTS OF THE LENGTH OF THE TRYPANOSOME OF STRAIN III, CHITULUKA.

Date	Method of fixing	Method of staining	In microns		
			Average length	Maximum length	Minimum length
1912	Osmic acid	Giemsa	26·1	38·0	15·0

The average length of the trypanosome of Strain III, in different species of animals, is as follows:—

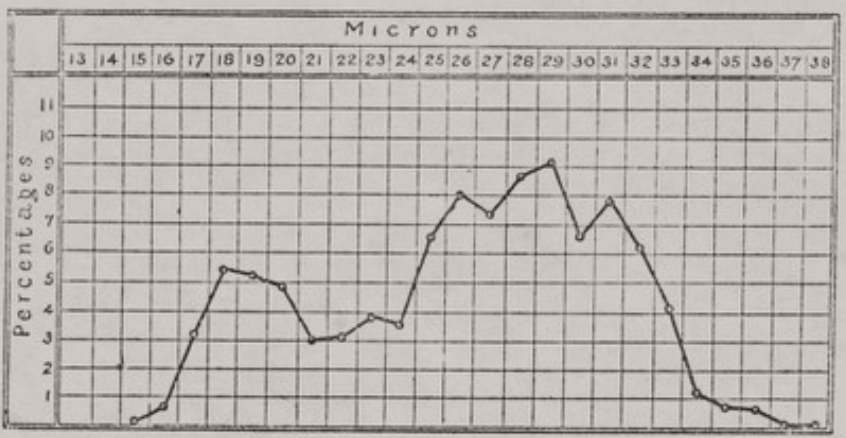
TABLE VI.

Species of animal	Number of trypanosomes measured	In microns		
		Average length	Maximum length	Minimum length
Goat	80	26·9	32·0	16·0
Monkey	160	27·7	36·0	16·0
Dog	260	24·1	35·0	16·0
Rat	1000	26·4	38·0	15·0

TABLE VII.—DISTRIBUTION IN RESPECT TO LENGTH OF 1,500 INDIVIDUALS OF THE TRYPANOSOME OF STRAIN III, CHITULUKA.

	In microns											
	15	16	17	18	19	20	21	22	23	24	25	26
Total ..	1	8	48	81	78	71	44	46	56	53	98	120
Percentage	0·1	0·6	3·2	5·4	5·2	4·8	3·0	3·1	3·8	3·6	6·6	8·0

	In microns											
	27	28	29	30	31	32	33	34	35	36	37	38
Total ..	111	128	138	99	117	91	63	27	11	9	1	1
Percentage	7·4	8·6	9·2	6·6	7·8	6·2	4·2	1·1	0·7	0·6	0·1	0·1



CHAR 5.—Curve representing the distribution, by percentages, in respect to length, of 1,500 individuals of the trypanosome of Strain III, Chituluka.

This curve is made up of measurements from 80 specimens of trypanosomes taken from the goat, 160 from the monkey, 260 from the dog, and 1,000 from the rat. It resembles that of Strain I, and differs absolutely from Strain II.

As in the case of Strain II, E——, a curve is also given of 1,000 individuals of this strain.

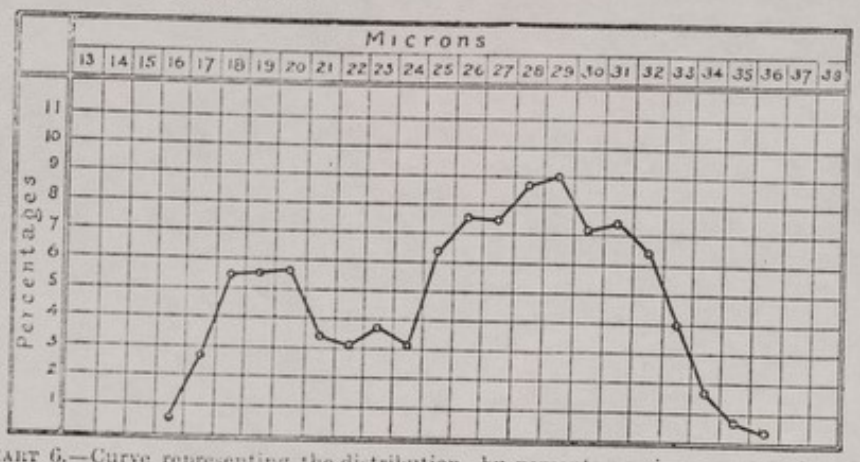


CHART 6.—Curve representing the distribution, by percentages, in respect to length, of 1,000 individuals of the trypanosome of Strain III, Chituluka.

This curve, made up of 1,000 individuals, is very similar to the previous one of 1,500. It is made up of 80 specimens of trypanosomes taken from the goat, 160 from the monkey, 260 from the dog, and 500 from the rat.

The two following curves represent measurements of 500 trypanosomes taken from each of two rats.

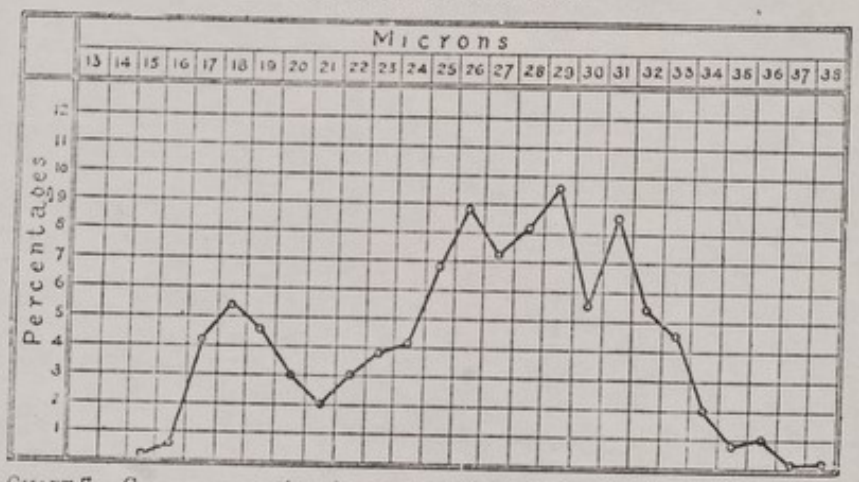


CHART 7.—Curve representing the distribution, by percentages, in respect to length, of 500 individuals of the trypanosome of Strain III, Chituluka, taken on nine consecutive days from Rat 952.

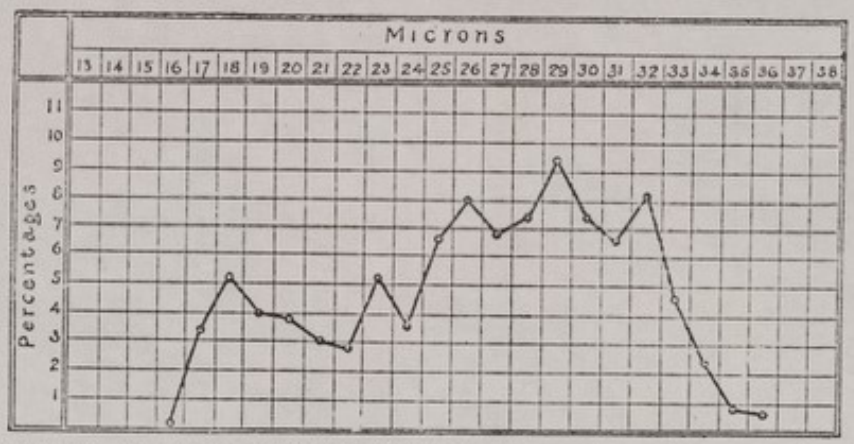


CHART 8.—Curve representing the distribution, by percentages, in respect to length, of 500 individuals of the trypanosome of Strain III, Chituluka, taken on nine consecutive days from Rat 953.

These last two curves from different rats also closely resemble each other. It is curious and striking that the same strain of trypanosome growing in two different animals should show this remarkable similarity.

TABLE VIII.—PERCENTAGE OF POSTERIOR-NUCLEAR FORMS FOUND AMONG THE SHORT AND STUMPY VARIETIES OF THE TRYPANOSOME OF STRAIN III, CHITULUKA.

Date	Experiment No.	Animal	Percentage among short and stumpy forms
1912.			
August 2	953	Rat	4
,, 3	953	,,	6
,, 6	953	,,	3
,, 7	953	,,	8
,, 8	953	,,	6
,, 9	953	,,	13
,, 10	953	,,	32
		Average ..	10·3

IV.—MORPHOLOGY OF STRAIN IV, CHIPOCHOLA.

The following table gives the average length of this trypanosome as found in goats, monkeys, dogs and rats, 1,000 trypanosomes in all, and also the length of the longest and shortest :—

TABLE IX.—MEASUREMENTS OF THE LENGTH OF THE TRYPANOSOME OF STRAIN IV, CHIPOCHOLA.

Date	Method of Fixing	Method of staining	In microns		
			Average length	Maximum length	Minimum length
1912	Osmic acid	Giemsa	22·5	34·0	15·0

The average length of the trypanosome of Strain IV, in different species of animals, is as follows :—

TABLE X.

Species of animal	Number of trypanosomes measured	In microns		
		Average length	Maximum length	Minimum length
Goat	80	20·4	29·0	15·0
Monkey	160	22·0	34·0	16·0
Dog	260	20·9	31·0	15·0
Rat	500	22·5	34·0	15·0

TABLE XI.—DISTRIBUTION IN RESPECT TO LENGTH OF 1,000 INDIVIDUALS OF THE TRYPANOSOME OF STRAIN IV, CHIPOCHOLA.

	In microns									
	15	16	17	18	19	20	21	22	23	24
Total	2	4	32	68	110	101	109	106	95	95
Percentage	0·2	0·4	3·2	6·8	11·0	10·1	10·9	10·6	9·5	9·5

	In microns									
	25	26	27	28	29	30	31	32	33	34
Total	74	64	50	38	26	16	5	3	1	1
Percentage	7·4	6·4	5·0	3·8	2·6	1·6	0·5	0·3	0·1	0·1

CHART 9.—Curve representing the distribution, by percentages, in respect to length, of 1,000 individuals of the trypanosome of Strain II, Chipochola.

This curve is made up of 80 specimens of trypanosomes taken from the goat, 160 from the monkey, 260 from the dog, and 500 from the rat.

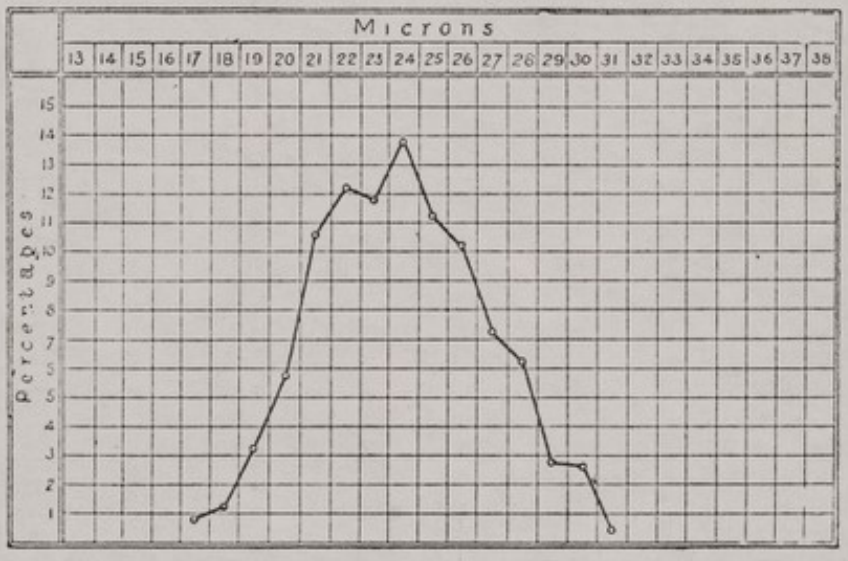


CHART 10.—Curve representing the distribution, by percentages, in respect to length, of 500 individuals of the trypanosome of Strain IV, Chipochola, taken on nine consecutive days from Rat 1337.

TABLE XII.—PERCENTAGE OF POSTERIOR-NUCLEAR FORMS FOUND AMONG THE SHORT AND STUMPY VARIETIES OF THE TRYPANOSOME OF STRAIN IV, CHIPOCHOLA.

Date	Experiment No.	Animal	Percentage among short and stumpy forms
1912.			
Sept. 20	1337	Rat	1
,, 23	1337	,,	1
,, 24	1337	,,	2
,, 25	1337	,,	4
,, 26	1337	,,	0
,, 28	1337	,,	0
,, 29	1337	,,	1
,, 30	1337	,,	14
Oct. 1	1337	,,	5
,, 2	1337	,,	5
		Average ..	3·3

V.—MORPHOLOGY OF STRAIN V, CHIBIBI.

The following table gives the average length of this trypanosome as found in goats, monkeys, dogs and rats, 1,000 in all, and also the length of the longest and shortest :—

TABLE XIII.—MEASUREMENTS OF THE LENGTH OF THE TRYPANOSOME OF STRAIN V, CHIBIBI.

Date	Method of fixing	Method of staining	In microns		
			Average length	Maximum length	Minimum length
1912	Osmic acid	Giemsa	22·4	37·0	15·0

The average length of the trypanosome of Strain V, in different species of animals, is as follows :—

TABLE XIV.

Species of animal	Number of trypanosomes measured	In microns		
		Average length	Maximum length	Minimum length
Goat	80	19·9	31·0	16·0
Monkey	160	21·8	32·0	15·0
Dog	260	20·6	37·0	16·0
Rat	500	24·0	32·0	18·0

TABLE XV.—DISTRIBUTION IN RESPECT TO LENGTH OF 1,000 INDIVIDUALS OF THE TRYPANOSOME OF STRAIN V, CHIBIBI.

	In microns										
	15	16	17	18	19	20	21	22	23	24	25
Total	1	8	20	58	117	122	123	107	93	93	63
Percentage	0·1	0·8	2·0	5·8	11·7	12·2	12·3	10·7	9·3	9·3	6·3

	In microns											
	26	27	28	29	30	31	32	33	34	35	36	37
Total	51	41	43	30	16	10	3	—	—	—	—	1
Percentage	5·1	4·1	4·3	3·0	1·6	1·0	0·3	—	—	—	—	0·1

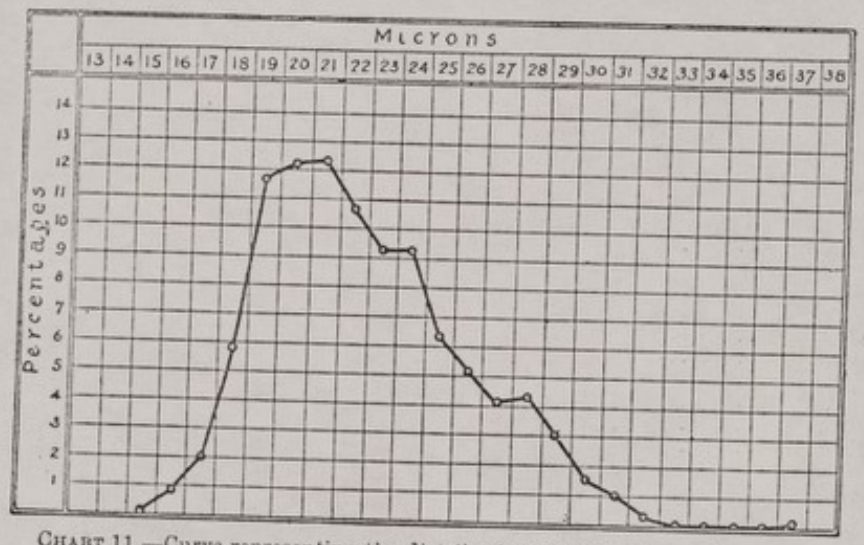


CHART 11.—Curve representing the distribution, by percentages, in respect to length, of 1,000 individuals of the trypanosome of Strain V, Chibibi.

This curve is made up of 80 specimens of trypanosomes taken from the goat, 160 from the monkey, 260 from the dog, and 500 from the rat.

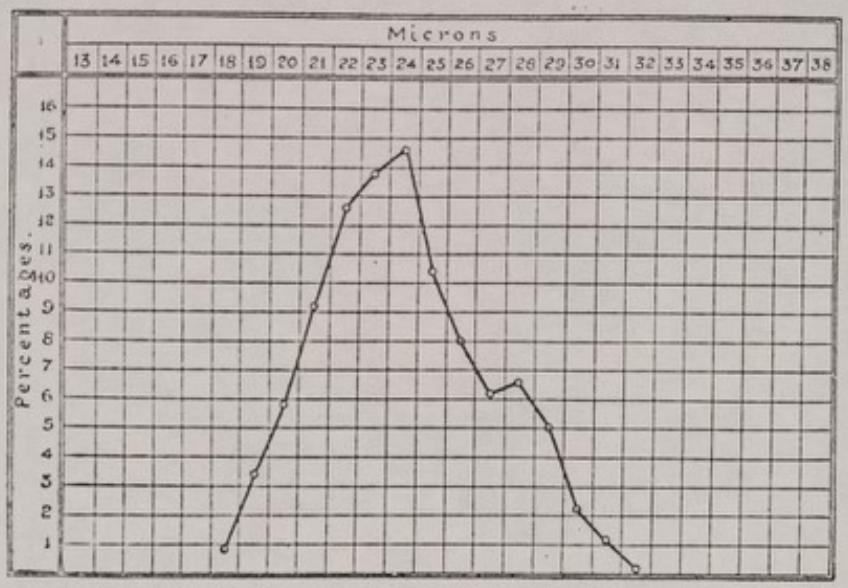


CHART 12.—Curve representing the distribution, by percentages, in respect to length, of 500 individuals of the trypanosome of Strain V, Chibibi, taken on nine consecutive days from Rat 1660.

TABLE XVI.—PERCENTAGE OF POSTERIOR-NUCLEAR FORMS FOUND AMONG THE SHORT AND STUMPY VARIETIES OF THE TRYPANOSOME OF STRAIN V, CHIBIBI.

Date	Experiment No.	Animal	Percentage among short and stumpy forms
1912.			
Dec. 3	1660	Rat	0
,, 4	1660	,,	34
,, 5	1660	,,	2
,, 8	1660	,,	6
,, 9	1660	,,	8
,, 10	1660	,,	23
,, 11	1660	,,	31
,, 12	1660	,,	28
,, 13	1660	,,	27
,, 14	1660	,,	32
		Average	21·1

COMPARISON OF THE HUMAN STRAINS.

The following table gives the average length of this trypanosome in the five human strains under consideration, as found in goats,

sheep, monkeys, dogs and rats, 6,200 trypanosomes in all, and also the length of the longest and shortest :—

TABLE XVII.—MEASUREMENTS OF THE LENGTH OF THE TRYPANOSOMES OF THE FIVE HUMAN STRAINS. THE TRYPANOSOMES HAVE BEEN TAKEN FROM VARIOUS ANIMALS.

Date	Strain	Name	Number of trypanosomes	Animals	In microns		
					Average length	Maximum length	Minimum length
1912	I	Mkanyanga	1220	Various	21·1	36·0	14·0
1912	II	E——	1500	,,	22·2	36·0	15·0
1912	III	Chituluka	1500	,,	26·1	38·0	15·0
1912	IV	Chipochola	1000	,,	22·5	34·0	15·0
1912	V	Chibibi	1000	,,	22·4	37·0	15·0
			6220		23·5	38·0	14·0

It must be acknowledged that, in spite of the fairly large number of trypanosomes measured, there is a marked difference in the average length of the five human strains—from 22·2 to 26·1 microns. Strains II, IV and V are similar, varying only from 22·2 to 22·5.

This difference in average length may be due to slight variations having taken place in the different strains, resulting from the passage through more or less resistant man. There is no evidence that this variation is due to treatment by atoxyl or other drugs. It has been shown that the same strain grown in two animals of the same species gives like results.

TABLE XVIII.—MEASUREMENTS OF THE LENGTH OF THE TRYPANOSOMES OF THE FIVE HUMAN STRAINS. THE TRYPANOSOMES HAVE BEEN TAKEN FROM THE RAT ALONE.

Date	Strain	Name	Number of trypanosomes	Animal	In microns		
					Average length	Maximum length	Minimum length
1912	I	Mkanyanga	600	Rat	25·1	35·0	16·0
1912	II	E——	1000	,,	23·1	32·0	17·0
1912	III	Chituluka	1000	,,	26·4	38·0	15·0
1912	IV	Chipochola	500	,,	22·5	34·0	15·0
1912	V	Chibibi	500	,,	24·0	32·0	18·0
			3600		24·2	38·0	15·0

COMPARISON OF THE CURVES FROM THE FIVE HUMAN STRAINS.

It must also be confessed that, on comparing the five curves one with another, they do not give as much assistance in classifying this species of trypanosome as was hoped. Curves I and III are alike, and coincide with that prepared by Dr. Stephens from the case of Armstrong in Liverpool, whereas Curves II, IV and V approach more to the type described by Kinghorn and Yorke from the Luangwa Valley.

TABLE XIX.—DISTRIBUTION IN RESPECT TO LENGTH OF 6,220 INDIVIDUALS OF THE FIVE HUMAN STRAINS. THE TRYPANOSOMES HAVE BEEN TAKEN AT RANDOM FROM VARIOUS ANIMALS.

	In microns											
	14	15	16	17	18	19	20	21	22	23	24	25
Strains I-V ..	1	10	41	154	325	494	528	577	512	525	511	464
Percentage ..	—	0·2	0·7	2·5	5·3	8·0	8·4	9·3	8·3	8·4	8·3	7·5

	In microns.												
	26	27	28	29	30	31	32	33	34	35	36	37	38
Strains I-V	425	372	347	307	198	167	123	77	36	12	11	2	1
Percentage ..	6.8	6·0	5·6	4·9	3·1	2·7	2·0	1·0	0·6	0·2	0·2	—	—

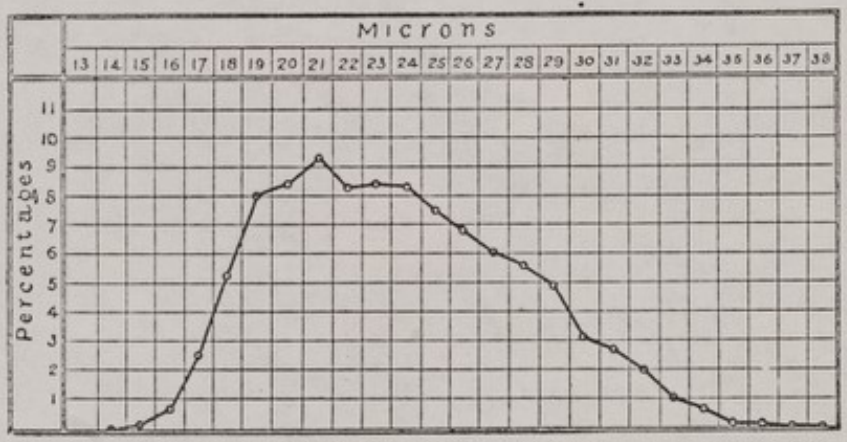


CHART 13.—Curve representing the distribution, by percentages, in respect to length, of 6,220 individuals of the human strain of the trypanosome causing disease in man in Nyasaland. The trypanosomes have been taken from various animals.

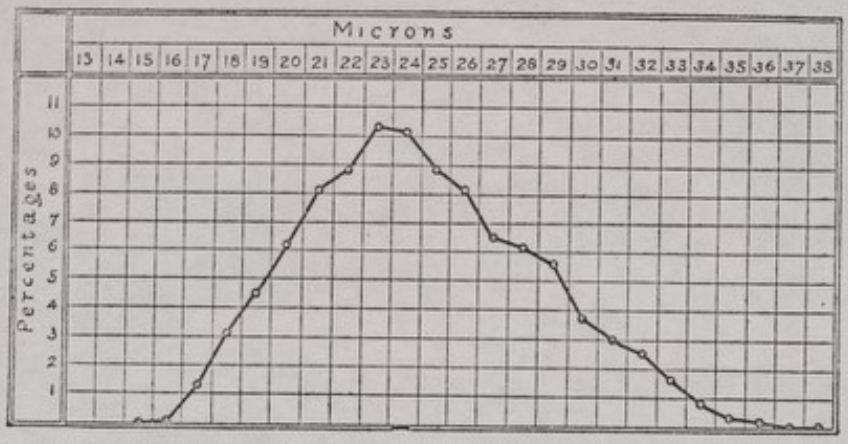


CHART 14.—Curve representing the distribution, by percentages, in respect to length, of 3,600 individuals of the human strain of the trypanosome causing disease in man in Nyasaland, taken from the rat alone.

Curves 13 and 14 will be found of use when the human strain of this species of trypanosome is compared with the wild game and the wild *Glossina morsitans* strains.

TABLE XX. — COMPARISON OF THE PERCENTAGES OF POSTERIOR-NUCLEAR FORMS FOUND AMONG THE SHORT AND STUMPY VARIETIES OF THE TRYPANOSOME OF THE HUMAN STRAIN.

Experiment No.	Strain	Name	Animal	Percentage among short and stumpy forms
—	I	Mkanyanga	Rat	34·1
728	II	E——	,,	9·3
953	III	Chituluka	,,	10·3
1337	IV	Chipochola	,,	3·3
1660	V	Chibibi	,,	32·0
			Average ..	17·8

It is to be noted that in the human strain the percentage of posterior-nuclear forms varies greatly, although the method of enumeration is the same in each case. This presence of posterior-nuclear forms would have been accepted a few months ago as sufficient proof that the species dealt with was *T. rhodesiense*. Since then posterior-nuclear forms have been reported as occurring

in *T. brucei* from Egypt, Uganda and Zululand. In a strain lately obtained by Theiler from the same spot in Zululand where this species was originally discovered in 1894, this percentage rose to the highest yet recorded.

Conclusions.

(1) The five human strains of this trypanosome, isolated from four natives in Nyasaland and one European in Portuguese East Africa, belong to the same species.

(2) This species is *T. rhodesiense* (Stephens and Fantham).

(3) Evidence is accumulating that *T. rhodesiense* and *T. brucei* (Plimmer and Bradford) are identical.

The Croonian Lectures

ON

TRYPANOSOMES

CAUSING DISEASE IN MAN AND DOMESTIC ANIMALS IN CENTRAL AFRICA.

Delivered before the Royal College of Physicians of London on June 17th, 22nd, 24th, and 29th, 1915.

BY SIR DAVID BRUCE, C.B., F.R.S., M.B. EDIN., F.R.C.P. LOND.,
SURGEON-GENERAL, A.M.S.

LECTURE I.

Delivered on June 17th.

MR. PRESIDENT AND GENTLEMEN,—I beg to thank you for the honour you have conferred in electing me Croonian lecturer for the present year. I am afraid the subject I have chosen will be found to be of little or no practical interest to the Fellows of this College, since it deals with a form of tropical disease which is seldom seen in England, and then, as a rule, only in hospitals devoted to the treatment of exotic diseases. The investigations into these diseases were also made from the standpoint of causation and prevention rather than treatment, a circumstance which must further lessen their interest to physicians engaged almost exclusively in the treatment of disease. But this is the subject which for some years has almost exclusively engaged my attention, and on account of the pressure of work caused by the war it would have been difficult or impossible to gather materials on any other subject. Further, I intend to confine myself in these lectures to a consideration of the trypanosomes causing disease in man and domestic animals in Central and Southern Africa, since it is only in Zululand, Uganda, and Nyasaland that I have had the opportunity of studying these parasites in the field and under natural conditions. The conditions, however, which obtain on the East and West Coasts of Africa between 20° N. and 30° S. latitude are much the same as those which are found in the central parts, and it is probable that the same trypanosome species are found throughout. So that in describing the species found in our own colonies it may be assumed that all the important pathological species found in Central Africa are being dealt with, although in other places they may be known by other names.

The central region—the tropical or equatorial—corresponds with the distribution of the tsetse flies, and the trypanosomes causing disease in this region are carried from sick to healthy animals by various species of this genus of flies. In the north of Africa, outside the range of the tsetse flies, two trypanosome diseases are found, one of the horse (dourine) and another of camels (surra), the former conveyed from sick to healthy horses by contagion, the latter almost certainly by large biting flies, the so-called horse flies, or tabanidæ. Now, in order to understand the wide distribution of these hæmatozoa, reference may be made to Fig. 1, a map of the world on which their distribution is shown.

GEOGRAPHICAL DISTRIBUTION.

It will be seen from the accompanying map that these blood parasites are found in most parts of the world, from South America through Africa, Southern Europe and Persia to India, Burma, China, and the Philippines. (Fig. 1.) In Africa is shown a broad equatorial band representing the trypanosome diseases carried by the tsetse flies. In it are represented, for example, the distribution of *Trypanosoma gambiense*, the cause of the ordinary or Congo sleeping sickness, and the distribution of *Trypanosoma brucei*, the cause of nagana in animals, and the Rhodesian and Nyasaland form of sleeping sickness or trypanosome disease in man. Further north out of the tsetse-fly region we have *Trypanosoma equiperdum*, the cause of dourine, which the map shows to be widely distributed in Europe also. *Trypanosoma evansi* or surra, which spreads out of Africa along the camel caravan routes into India and China, is also shown.

In this introduction it is unnecessary for me to give an early account of the history of these parasites, since this has often been done and can be found in most text-books; suffice it to say that the first trypanosomes were discovered some 70 years ago in the blood of fish and frogs. These were of interest to zoologists, but having no obvious bearing on the causation of disease did not attract the attention of medical men. Thirty years afterwards, in 1877, Surgeon Timothy Lewis, of the Army Medical Department, discovered in Bombay the trypanosome of the common rat, which was afterwards named after him—*Trypanosoma lewisi*. Three years later, in 1880, Dr. Evans, Chief of the Veterinary Staff in Madras, discovered what were supposed for a long time to be similar flagellates in the blood of horses suffering from surra. It is from these two discoveries that we must date the beginning of the study of trypanosome diseases.

CLASSIFICATION OF THE AFRICAN TRYPANOSOMES.

After these few introductory remarks, and in order to further clear the ground, allow me before proceeding to describe any of the individual species of African trypanosomes to briefly introduce them and to show into what groups or classification they can be thrown. In classifying them I have striven for simplicity, as it seems better for practical purposes to divide them into a few well-defined groups and species rather than to try with our present incomplete knowledge to subdivide them more minutely.

The three characters mainly relied upon in this classification of trypanosomes are, in the first place, their morphology; secondly, their pathogenic action on animals; and, thirdly, their mode of development in the tsetse flies.

At one time it was hoped that cultivation on artificial media might be used as an aid to classification, but up to the present this hope has been unfulfilled. Other methods, such as cross-inoculation experiments and serum diagnosis, I do not consider of much use in making a simple, workable, practicable classification such as will be found of use for diagnosis in the field. If we admit them into our methods the multiplication of species must proceed to an unmanageable degree.

1. *Morphology.*

To begin with the morphology, and this is of great importance in classification. The trypanosomes are first examined in a fresh living condition to ascertain their general appearance and kind of movement. There is a good deal of difference in the range of movement in different species. Whereas many vibrate about one spot, and show little power of wider movement, others are capable of hurling themselves from one point to another with great power and rapidity. But, of course, it is

after the trypanosomes have been fixed and stained that their characteristics can be made out best. For example, the length and breadth of a fixed and stained trypanosome may be very useful in identifying it, and in addition to the length and breadth, a description of the contents of the cell, the nucleus, micronucleus, undulating membrane, and flagellum, may all help in the differentiation of species.

2. *Susceptibility of Animals.*

The second means at our disposal for the classification or differentiation of trypanosomes—namely, their pathogenic effect on various experimental animals—must be used with caution. For example, it is well known that their passage through a series of animals of the same species usually exalts their virulence towards that animal. For instance, the nagana parasite, after passage through white rats for many generations, kills the rats in as short a time as two days; whereas the naturally wild strain of nagana only kills the same animals on an average in 20 or 30 days. On the other hand, another species of trypanosome in its natural wild state kills monkeys in a few days. But if it is first passed through a goat, and the attempt is made to infect a monkey with the goat's blood, the experiment always fails. Passage through the goat has lowered the virulence of the parasite towards the monkey. But if a trypanosome is caught in its wild state, and straightway put through a series of experimental animals, the result is, in my opinion, of some use in differentiating species. For example, *Trypanosoma brucei* will be found to be much more virulent and kill off more quickly the various laboratory animals than *Trypanosoma gambiense*. Some trypanosomes are deadly to horses and cattle and harmless to other animals, such as dogs, monkeys, and rabbits, while others show a marked preference for some particular species of animal, such as the domestic pig.

3. *The Development in the Invertebrate Host.*

The third character of use in classification is the mode of development in the tsetse fly or invertebrate host. As already mentioned, all the pathogenic trypanosomes of man and his domestic animals found in Africa, with the exception of the two northern species, pass through a specific cycle of development in the tsetse flies, the mode of development in the tsetse flies is different for different species of trypanosomes, and this may be made use of in classification, and in truth is one of the best means at our disposal. It is not known whether the North African species are capable of developing in tsetse flies. It is possible that on account of disuse they have lost the faculty, if they ever had it. It would certainly be an interesting experiment to try to pass them through the "fly."

FIG. 1.

Geographical Distribution of Trypanosome Diseases.

Trypanosome diseases transmitted by tsetse flies.
Congo sleeping sickness.
Nagana.
Mal de Caderas.
Surra.
Dourine.

CLASSIFICATION INTO THREE GROUPS.

With these few preliminary remarks, let me now introduce the chief Central African pathogenic trypanosomes. They may be divided into three groups, and these are set out on the following scheme:—

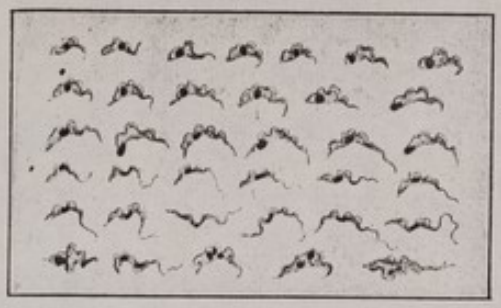
Group A. *Trypanosoma Brucei Group.*
1. Trypanosoma brucei.
2. Trypanosoma gambiense.
3. Trypanosoma evansi.
4. Trypanosoma equiperdum.

Group B. *Trypanosoma Pecorum Group.*
1. Trypanosoma pecorum.
2. Trypanosoma simiæ.

Group C. *Trypanosoma Vivax Group.*
1. Trypanosoma vivax.
2. Trypanosoma capræ.
3. Trypanosoma uniforme.

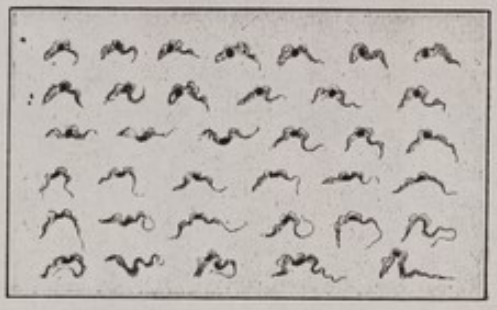
These names probably represent most of the principal pathogenic trypanosomes discovered up

FIG. 2.



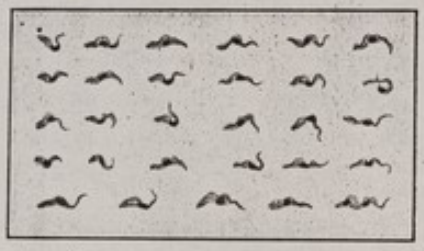
Trypanosoma brucei (Plimmer and Bradford). Zululand, 1913. × about 700.

FIG. 3.



Trypanosoma gambiense (Dutton). Tanganyika, 1913. × about 700.

FIG. 4.

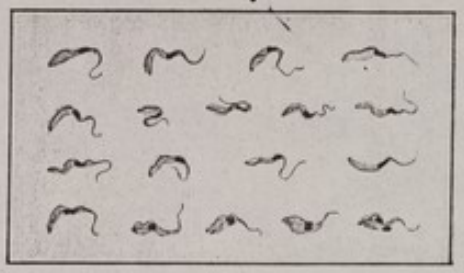


Trypanosoma pecorum. × about 700.

FIG. 5.

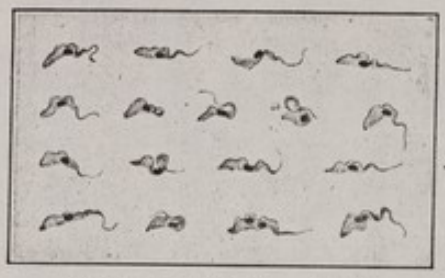
Trypanosoma simiæ. × about 700.

FIG. 6.



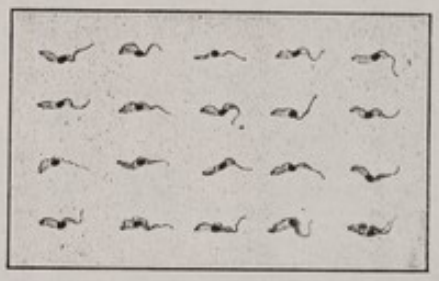
Trypanosoma vivax (Ziemann). × about 700.

FIG. 7.



Trypanosoma capræ (Kleine). × about 700.

FIG. 8.



Trypanosoma uniforme. × about 700.

FIG. 9.

The tsetse fly, life size.

to the present time in Central Africa. For the sake of completeness I have placed the Northern species, *Trypanosoma evansi* and *Trypanosoma equiperdum*, in the first group, as they seem by morphology and their action on animals to belong there. Each group is distinguishable or separable by well-defined characters.

Group A. The Trypanosoma brucei group.—The species forming this group (Figs. 2 and 3) are all more or less polymorphic, varying in size and shape from short and stumpy forms without free flagella to long and slender forms with free flagella. The cytoplasm contains numerous dark-staining granules. The micronucleus or kinetonucleus is small, and is situated as a rule some distance from the posterior extremity. The undulating membrane is well developed and thrown into bold folds.

In regard to their action on animals, the members of this group may be said generally to affect many different species of animals—as, for example, man, horses, cattle, dogs, and most of the smaller experimental animals. The two Central African members of the group, *Trypanosoma brucei* and *Trypanosoma gambiense*, develop in the tsetse flies in the same way. At first the development takes place in the intestine; afterwards the parasites pass into the salivary glands, by way probably of the proboscis, and there complete their development into infective forms. This is the only group in which the salivary glands are invaded. This group can be separated from the other groups by shape alone.

Group B. The Trypanosoma pecorum group.—The trypanosomes are small and monomorphic. The cytoplasm is non-granular. The micronucleus is prominent, subterminal, and often seems to project beyond the margin. The undulating membrane is fairly well developed. (Figs. 4 and 5.)

The cycle of development in the tsetse fly in Group B begins in the intestinal tract; afterwards the flagellates pass forward into the proboscis of the fly, and finally reach the salivary duct or hypopharynx, where they complete their development and become infective. The difference between Group A and Group B is that in the latter the salivary glands are never invaded. There are only two species at present included in this group—*Trypanosoma pecorum* and *Trypanosoma simiæ*. The former gives rise to the most important trypanosome disease of cattle in Africa, while the latter is remarkable for the rapidity with which it kills the domestic pig.

Group C. The Trypanosoma vivax group.—The species making up this group (Figs. 6, 7, 8) are monomorphic, and remarkable for the extreme rapidity of their movements. The posterior extremity is enlarged. The cytoplasm is clear and hyaline. The micronucleus is large and terminal, and the undulating membrane is little developed and simple. This species only affects horses, cattle, goats, and sheep. Monkeys, dogs, rabbits, guinea-pigs, and rats are refractory.

The cycle of development in Group C differs from that in Groups A and B in that it takes place at first only in the labial cavity of the proboscis, and later in the salivary duct or hypopharynx. (Fig. 10.) No part of the cycle takes place in the intestinal tract or in the salivary glands.

These three groups are well marked, and it is fairly easy by microscopic examination alone to name what group a trypanosome belongs to, when seen in the blood of the vertebrate host or even in the tsetse fly.

DESCRIPTION OF THE TSETSE FLIES.

General characters.—The insects (Fig. 9) are dull-coloured, ordinary-looking flies about half an inch in length. The strong proboscis stands out horizontally in front. The wings are long and closed over each other, like the blades of a pair of scissors, when the fly is at rest. The dorsal aspect of the abdomen is marked by five more or less distinct transverse bands.

FIG. 10, A.

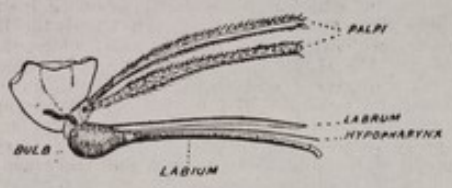


FIG. 10, B.

Mouth parts of tsetse fly. L. Indicates labial cavity.

It is important to understand the structure of the proboscis, as this plays an important part in the development of Groups B and C. In Fig. 10 a side view and a transverse section of the mouth parts are given. In the side view the mouth parts—the labrum, the labium, and the hypopharynx or terminal duct of the salivary glands—are separated. This is done by slipping the point of a fine needle between them at the base and running it towards the tip. This separates the labrum from the labium, and, as a rule, the hypopharynx springs up from the hollow of the labium and appears between the two parts as an extremely delicate transparent tube.

In the transverse section the parts are seen in position, the labrum and labium joined together form a tube through which the blood is drawn in the act of sucking, and known as the labial cavity; and the delicate terminal duct of the salivary glands or hypopharynx lying in the hollow of the labium, and opening near the tip of the proboscis. The salivary glands are long convoluted organs lying chiefly in the abdominal segment of the fly.

When I arrived in Zululand in 1894 there was only one known species of tsetse fly—*Glossina morsitans*. At the present time some 14 or more different species have been named. These are divided into four groups by Austen: The *Glossina palpalis* group; the *Glossina morsitans* group; the *Glossina fusca* group; and the *Glossina brevipalpis* group. For our purpose it will be sufficient to describe the principal species from the first two groups, *Glossina morsitans*, the carrier of *Trypanosoma brucei*, and *Glossina palpalis*, the carrier of *Trypanosoma gambiense*. But I may mention here that probably all the tsetse flies are capable of acting as carriers of all the pathogenic trypanosomes, at least in laboratory experiments. What makes one species of fly the especial carrier of a particular trypanosome is probably bound up in the natural history, the habits, and distribution of the fly.

Habitat.—This is the species made familiar by writings of travellers like Livingstone and hunters like Gordon Cumming. Until a few years ago it was the only species of which the habits had been studied, and when the word tsetse was used it was this species which was meant. Its habitat is the dry, thorny scrub which covers large areas of tropical Africa. (Fig. 11.) It is not found along the banks of lakes or rivers, and, in fact, seems to have a distaste for water. It requires shade, however, and is never found on open plains where it would be exposed to the tropical sun. In the "fly country" there are thickets, undergrowth, and trees which supply the requisite shade.

Habits.—These flies begin to bite soon after sunrise if the day is fine, but usually disappear during the hottest hours, coming out again towards evening when it becomes cooler. About sunset they are often particularly active. Moving objects such as a motor cycle seem to attract them greatly, and the cyclist is often surrounded by a cloud of them attacking him like an angry swarm of bees. Under these circumstances there is often a great disparity in the numbers of the sexes, the males predominating. This is probably due to the males attaching themselves to a moving object in order to mate with the females, which are attracted by the same movement, and come out of their cover to feed. Tsetse flies are very sensitive to weather conditions. If it rains or blows they usually remain hidden. They diminish in numbers during the dry season, and are most numerous towards the end of the rains.

FIG. 11.

Habitat of *Glossina morsitans*.

Food.—In regard to the food of *Glossina morsitans*, in one experiment 500 flies were caught in the sleeping sickness area of Nyasaland, and examined as to the contents of their intestines. It was found that 288 (or 57·6 per cent.) contained mammalian blood in a recognisable state. Measurements of these were made and the small type of blood cell was found to predominate, such as occur in the hartebeeste, waterbuck, and other antelope. In only three cases were nucleated red blood corpuscles found. From this experiment it appears, at least in that district, that the principal food of *Glossina morsitans* is the blood of antelope. Tsetse flies never suck the juices of fruits or vegetables, as is usual in the case of other biting flies such as mosquitoes.

The question is sometimes asked as to how often tsetse flies feed under natural conditions. From experiments with flies in the laboratory it was found that blood is recognisable in stained specimens for two and even three days after a feed, but not beyond the third day. This means, roughly, that half the 500 flies examined had fed within at most three days of their capture; it results that flies feed under natural conditions once in five or six days.

It is rather an interesting point as to whether these flies could maintain an existence on the smaller mammals and birds if the big game disappeared. They are quite ready to feed on the smaller animals, but most of these, such as monkeys, shrews, the mongoose, and rats, are usually too quick and snap up the fly before it has had time to feed. Another curious fact seems to be that when rinderpest sweeps through a country the tsetse flies disappear with the game and only return when the game has again multiplied to a fair extent. The curious point is that by no means all the game is killed off by the rinderpest; there is usually some species left which one would think would suffice to keep numbers of flies in food. It was thought at one time that this mortality among the flies might be due to some poisonous quality in rinderpest blood, but when flies were fed on rinderpest animals nothing untoward happened.

Act of feeding.—In regard to the act of feeding, this is done as a rule very rapidly, the fly fully distending itself in from half a minute to a minute after it has punctured the skin.

Reproduction.—Lastly, we come to the most important function of the tsetse flies, that of reproduction. The genus *glossina* is distinguished from most of the other diptera in being pupiparous. The female produces a single whitish or yellowish-coloured larva about once in ten days. This is retained in the oviduct until it is fully grown. As soon as the larva is born it creeps at once into the soil or into a crack in the earth, or among leaves and débris, and within a few hours has changed into a hard black puparium. As to how long the pupa remains quiescent depends mainly on the temperature. At a temperature of 85° F. the fly will emerge in 23 days, at 70° in 35 days, and at 65° in about 60 days. These larvæ are deposited all over the "fly" country, but there are certain positions and conditions which are favoured. The female usually chooses a spot with plenty of shade. A favourite site for her to take up her abode is on the under-surface of a tree which has fallen, and which remains at places some inches above the ground. Another condition is that the breeding place is near a native path or a game path. This may be to enable the mother to procure her food

easily, or it may be some instinct in favour of the offspring which enables the newly emerged fly to obtain a feed within 24 hours of birth.

Glossina Palpalis.

This is also a widely distributed species. It ranges on the west coast from the Senegal river —16° N. latitude—to Angola. It extends eastwards into the Bahr el Ghazal. The eastern boundary of the species follows the valley of the Nile, the eastern shores of Lake Victoria and Lake Tanganyika. From the south end of the latter lake the boundary follows the frontier between the Congo Free State and Rhodesia in a south-westerly direction to Angola.

Habitat.—This species differs from *Glossina morsitans* in being a lover of water. It frequents the edges of lakes and rivers where there is clear water and plenty of shade; this shade consists of thick jungle with high trees and dense undergrowth, which grows to within a few feet or yards of the water's edge. This tsetse fly is never found on open beaches backed by grass plains, even although there may be some low scrub near the water. It is not found in reed beds or papyrus swamps, and as most of the Uganda river valleys are choked with reeds it follows that the tsetse fly does not ascend these rivers. In short, it is never found away from water, except in cases where it has followed man or animals for a mile or so for the purpose of feeding. In this way it is brought much more in contact with man than *Glossina morsitans*, which is a dweller in desert places, the haunt of wild animals. *Glossina palpalis* is a frequenter of watering places, on lakes and rivers, or water-holes in the bush, where the natives come for water, and where as a rule, on account of the density of the human population, there is little game.

Habits.—*Glossina palpalis* has the same habit of biting by daylight as *Glossina morsitans*. It is not seen until the sun is up. If it is a fine morning they may be active as early as seven or half-past seven. On dark shady spots on the lake shore they do not become troublesome until about ten o'clock when the sun is well up. In cloudy or windy weather few flies are abroad. They have a rapid flight and suddenly and silently flop on to the skin, causing so little sensation that the sharp stab of the proboscis is often the first thing felt. Sometimes they insert the proboscis so painlessly that attention is not drawn to the spot. As a rule little or no irritation follows the bite, no itching or swelling or reddening of the skin. But if there have been many bites about the same place there is often a good deal of swelling, induration, redness, and irritation which last for several days, and as is natural some individuals are much more affected than others.

Feeding.—As in *Glossina morsitans* the time taken by the fly in filling itself with blood is short. Stuhlmann weighed the flies before and after feeding and found that the males took in one and a half times their own weight in blood, and the females sometimes as much as two and a half times.

Food.—Under ordinary circumstances in populous districts it may be assumed that man supplies most of the food of this fly, and it is considered by some that it thrives better on human blood than on any other. In captivity, however, it feeds readily on any warm-blooded animal, especially on birds, and if hungry may even be induced to feed on cold-blooded animals, such as the lizard or frog. But in the absence of man it may be remarked that as this species is a dweller on the banks of rivers and lakes, it comes much more in contact with large birds—cormorants and other water-fowl—and reptiles—crocodiles and monitors—than does *Glossina morsitans*. In Uganda before the natives were removed from the lake shore and islands doubtless they formed the chief supply of blood for the fly. On the other hand, after the natives had been removed inland or in places where there was no native population the fly had to adapt its diet to the available supply. One experiment made by us in Uganda in such a place showed that only 17 per cent. of the flies had fed on mammalian blood and 83 per cent. on avian or reptilian, and as far as could be made out twice as many of the flies had fed on reptiles as on birds. In such places the large lizard or monitor seems to be a favourite dish with this species.

Reproduction.—I need not go fully into the reproduction of *Glossina palpalis* as the process is the same as in *Glossina morsitans*. One point may be mentioned, however, and that is that in Uganda the former has a marked predilection for certain breeding grounds; these are sandy beaches along the lake shore backed by a belt of vegetation. The breeding grounds on Damba Island, for example, where some thousands of pupæ were collected every month for the laboratory, are formed of coarse sand and pebbles. It is 4 or 5 feet above the level of the lake, and the bush comes to within a few yards of the water's edge. The pupæ are found as a rule an inch or two below the surface of the sand at or near the edge of the belt of vegetation. For a long time we failed to find any wild pupæ, although days were spent in turning over soil and decaying vegetable matter in those places where the fly most abounds. At last their breeding haunts were discovered by Captain A. D. Fraser, R.A.M.C., to be in patches of sand at the edge of the lake. After this secret was discovered there was no lack. Our natives found them in large numbers. One day they brought up as many as 7000, and as I had promised a cent for each pupa brought up to the laboratory I had to pay out nearly £5 for them. These wild pupæ proved to be much healthier than those obtained from flies in captivity. The flies bred from pupæ born in the laboratory rarely showed any marked vitality; on the other hand, the flies hatched out from the wild pupæ found on the lake shore were fairly strong and vigorous, and lived in captivity for a couple of months or more. In conducting experiments with flies it is very necessary to work with laboratory bred ones, as the wild flies may be naturally infected with several species of trypanosomes. Numerous experiments went to show that there is no hereditary transmission of trypanosomes in tsetse flies, and there is no reason to believe that flies become infected by contact with infected flies or from fouled cages. Any trypanosomes found in laboratory bred flies may therefore be considered to be derived from the infected animal they were fed upon.

It will be seen from the foregoing that the two principal groups of tsetse flies—the *Glossina morsitans* group and the *Glossina palpalis* group—differ from each other in well-marked characters, the former living in wild, unpopulated districts and trusting to the wild game for their food, the latter along rivers and lakes which are usually thickly populated and trusting to man for a food supply, or in his absence living on the large reptiles, birds, and antelopes which frequent these places.

LENGTH OF LIFE OF TSETSE FLIES.

One word more in regard to the duration of life of tsetse flies. This is an important question, but one difficult to answer. The importance comes in when we have to consider how long a place may remain dangerous from the presence of infected flies. I remember at a meeting of the Royal Society when the question came up that the late Lord Avebury said he did not see any reason why a tsetse fly should not live for years. He had himself known an ant to live in captivity for some 15 years. Carpenter tried to solve the question by marking large numbers in a given spot and finding out how long the marked flies could be recaptured. One male was caught 199 days after it had been marked. Kleine states that he kept a fly in captivity for 227 days. If we put the life of the fly, then, at anything up to a year we may not be far out.

I have now given a sketch of the principal pathogenic trypanosomes in Central Africa, and also of their carriers, the tsetse flies. In my next lecture I shall proceed to describe more in detail the individual species of trypanosomes, beginning with that one which causes nagana.

THE USE OF MAGNESIUM SULPHATE IN THE TREATMENT OF TETANUS:

WITH AN ACCOUNT OF A SIMPLE APPARATUS FOR PHARYNGEAL INSUFFLATION.

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TETANUS, a frequent complication of the wounded in the present war, is a frightful disease. Horrible spasms torture fully conscious victims. Furthermore, it is the spasms which, at least in most cases, cause the fatal issue, by profoundly affecting the functions of respiration and circulation. Accordingly, a treatment which may offer nothing more than relief from these spasms ought to be of considerable importance.

The various experiences accumulated in the last nine years with the use of magnesium sulphate in sporadic cases of tetanus have established beyond a doubt that the spasms of tetanus can be relieved by the use of this remedy to a much greater extent than by any other method of treatment. Furthermore, in many cases of tetanus magnesium sulphate proved to be directly a life-saving remedy. Similar results were obtained with the use of Epsom salts in the extensive experience in the present war. However, by a study of the present numerous brief communications on this subject I became convinced that there is great necessity for a better understanding of the principles underlying this method of treatment, the various methods of administration and their indications, the possible danger due to the use of the magnesium salts, and the means for combating this danger. On the basis of an extensive experimental experience and a study of the clinical literature I formulated definite opinions regarding these various points, which I shall state here as briefly as possible, having in mind exclusively the practical side of our subject.

There are four ways for the administration of magnesium sulphate, each of which has a special action and consequently a special indication. They are: (1) Subcutaneous injection; (2) intramuscular injection, combined with inhalation of ether; (3) intravenous injection; and (4) intraspinal injection. Except for the intravenous injection, the magnesium salt ($MgSO_4 + 7\,H_2O$) shall be given in a 25 per cent. (molecular) solution. In sterilising the solution it must be kept in mind that if evaporation be allowed and not refilled with sterile water, the solution will be much more concentrated and the patient will therefore receive more of the salt. The injections should be made aseptically, or at least antiseptically.

1. *Subcutaneous injections.*—The dose should not be more than 2 c.c. and not less than 1·2 c.c. of the solution (25 per cent.) per kilogramme of body weight, to be injected four times in 24 hours. No massage. Light etherisation or a morphinisation should precede the injection of magnesium.

2. *Intramuscular injection and inhalation of ether.*—It is based upon the finding by Auer and myself that a moderate inhalation of ether increased considerably the efficiency of magnesium salts. Chloroform does not exert such an effect. The patient should be fairly well etherised, and 2 c.c. of a solution of magnesium sulphate (25 per cent.) per kilogramme of body weight be injected into the muscles of the thigh. At the end of the injection the thigh should be massaged and the ether anæsthesia continued lightly for about 20 minutes longer.

3. *Intravenous injections.*—The concentration of the solution should be about 3 per cent. (isotonic), and not more than 5 c.c. per minute should be permitted to run into the vein.

4. *Intraspinal injection.*—The dose to be injected, at the usual place of the lumbar region, should be 1 c.c. (of a 25 per cent. solution) for every 10 kilogrammes of body weight.

Subcutaneous injections exert their effects slowly. They cannot relieve immediately severe or dangerous spasms, but they exert undoubtedly a beneficent effect by cumulative action. Under their influence the spasms gradually become milder and less frequent, and the patient may eventually recover. Subcutaneous injections should be begun as soon as initial symptoms set in (local tetanus, slight trismus, &c.) and be continued throughout the disease. (In very young infants the dose should not exceed 0·8 c.c. per kilogramme of body weight.)

Intramuscular injections plus ether may relieve greatly even severe spasms in less than half an hour, but the beneficial effect is liable to pass off completely after two or three hours. On account of the local reaction which they produce the injections should not be repeated too frequently, and the method ought not to be used as a routine treatment. However, on account of the simplicity of the procedure it may be resorted to in severe spasms when for some reason other methods which are capable of exercising a rapid effect are not practicable.

Intravenous injections are capable of relieving dangerous effects of the spasms (tetanus of the diaphragm, constriction of the larynx) more promptly than any other method of application. But the beneficial effect may completely disappear in less than 30 minutes. Besides, by the use of this method the circulation may become affected also—by the direct action upon the myocardium. The use of this method of injection should therefore be reserved for emergency cases only, when quick action is urgently desired. Pulse and respiration should be guarded during the infusion of the solution; when the pulse shows softness or intermittence, or the respirations show shallowness, the infusion should be at once discontinued. Fortunately the ill-effects, if not permitted to continue too long, disappear quite soon after the infusion is discontinued.

The Croonian Lectures

ON

TRYPANOSOMES

CAUSING DISEASE IN MAN AND DOMESTIC ANIMALS IN CENTRAL AFRICA.

Delivered before the Royal College of Physicians of London on June 17th, 22nd, 24th, and 29th, 1915,

BY SIR DAVID BRUCE, C.B., F.R.S., M.B. EDIN., F.R.C.P. LOND.,

SURGEON-GENERAL, A.M.S.

LECTURE II.[1]

Delivered on June 22nd.

MR. PRESIDENT AND GENTLEMEN,—In my first lecture an attempt was made to introduce the subject—the Trypanosomes causing Disease in Man and Domestic Animals in Central Africa—by a few introductory remarks on trypanosomes generally and their classification, and also by a short description of their carriers the tsetse flies. To-day I propose to deal with one of the species of trypanosomes more in detail, describing its morphology, its pathogenic action on various animals, its carrier—the tsetse fly, *Glossina morsitans*—and the reservoir of the virus, the wild game.

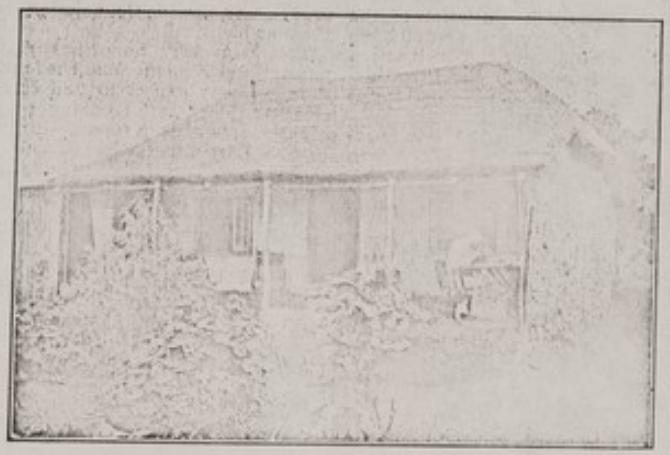
HISTORY OF THE NAGANA PARASITE.

The first species of Group A, as stated in my last lecture, is *Trypanosoma brucei*, and it will be convenient to begin with it, as it is also first chronologically. That is to say, it was the first pathogenic trypanosome discovered in Central or South Africa, and if you will allow a short autobiographical digression, I will relate the circumstances leading up to the discovery.

Shortly after I arrived in South Africa in 1894, the late Sir Walter Hely-Hutchinson, the then Governor of Natal and High Commissioner of Zululand, asked me to go to the north of Zululand in order to report on an outbreak of disease called "nagana," which had broken out among the native cattle. Travelling at that time was no easy matter, as the railway into Zululand had not been constructed. My wife and I left Pietermaritzburg on Oct. 27th, 1894, and travelling by mule-wagon arrived seven days later in Eshowe, the capital of Zululand. There an ox-wagon was provided, and in it we trekked to Ubombo, a magistracy in the north of Zululand and in the centre of the affected district. This was reached after a month's journey on Nov. 24th, 1894. Here is the small wattle-and-daub hut which was provided as a laboratory and for living in. The verandah, as you see, was used as the laboratory. (Fig. 12.) Shortly afterwards some of the affected cattle were brought in by the natives. As I had just come from the Army Medical College, Netley, where I had been teaching bacteriology for five years, it was natural that a bacteriological examination of the blood and organs of the infected cattle should first be made. This proved to be negative.

About this time (1894) the study of the blood had become popular, thanks probably in great measure to Ehrlich, and it was the fashion to make elaborate examinations of the red and white blood corpuscles. To this the discovery of the nagana parasite was probably due. It must be remembered that these parasites are, as a rule, very few and far between in the blood of oxen, and also that our staining methods in those days were rather primitive. After some days of this blood examination it began to be remarked that a curiously shaped object different from anything previously found in blood was sometimes seen lying among the blood corpuscles. At first it was thought to be accidental, due to the carbol-fuchsin stain which was being used, but soon it became evident that it might be a blood parasite. It was then thought that if so it might be motile in the living state. Fresh preparations of blood were made, and after a long search a rapidly moving object was seen lashing about among the red blood corpuscles. At that time I knew nothing about trypanosomes, and at first thought that the wriggling object might possibly be a small filaria. There were few or no allusions to these hæmatozoa in medical literature at that time, but when I returned to Natal and had an opportunity of consulting books, it soon became evident that the rapidly vibrating body was probably a trypanosome.

FIG. 12.



Our hut, Ubombo, Zululand.

But there was as yet no proof that the organisms seen had any causal connexion with the disease. They were possibly harmless blood parasites, and they were so scanty in numbers in the blood of the oxen that this might well be so. This led to trying the effect of injecting the blood of nagana cattle into horses and dogs. In these animals the disease is much more acute than in cattle and the blood swarms with the parasites. In this way it began to be evident that these hæmatozoa had a causal connexion with the disease. At that time, however, there was no suspicion that nagana and tsetse-fly

[1] Lecture I. appeared in THE LANCET of June 26th, p. 1323.

disease were one and the same. It was believed by everybody that the tsetse fly killed horses and cattle by injecting a poison into them. Moreover, these cases of nagana were occurring among native cattle many miles away from the "fly belt." The work was being done on the top of the Lebombo, a range of hills some 2000 feet in height, running north and south, about 50 or 60 miles from the coast. Between the hills and the sea there was a low-lying coast plain, some parts of which are infested with tsetse flies. Now I had read in Livingstone and other African travellers and hunters about the tsetse-fly disease, and was curious to know what it was like. Two young oxen and several dogs were therefore sent down into this "Fly Belt" and herded among the fly for a fortnight. At the end of this time they were brought back to the hill, and it was a great surprise to find the same parasite in their blood as that found in the nagana oxen. In this way the fact gradually unfolded itself that nagana and the "fly disease" of the travellers and hunters were identical. This, then, was the manner in which the discovery of the part played by trypanosomes in tsetse-fly disease was made.

I arrived at Ubombo on Nov. 24th, 1894, and was recalled to duty in Natal two months afterwards on Jan. 26th, 1895. This was done by the military authorities in South Africa, who evidently thought they had not been sufficiently consulted in the matter of this investigation in Zululand. It was a year before the Governor could obtain from England the authority of the Secretary of State so as to enable me to return along the long road and take up the broken investigation. I mention this to show that if it had not been for the energy and determination of the Governor of Natal, the Hon. Sir Walter Hely-Hutchinson, this discovery might have been delayed for years. The initiation of the inquiry into the nature of nagana was wholly due to him. In spite of much difficulty and obstruction he persevered in the furtherance of the investigation, and certainly without his active aid nothing at that time would have been accomplished.

The nagana parasite was sent in the living condition, in 1896, to the Royal Society in London, when it was placed in the hands of Messrs. Kanthack, Durham, and Blandford. Their investigation lasted two years and was published in the Proceedings of the Royal Society in 1898. In that year the trypanosome was handed over to Bradford and Plimmer at the Brown Institution, and described and named by them in a paper written in 1899. At this time the nagana parasite found its way into many laboratories and much of the earlier work on trypanosomes was founded upon it.

The Nagana Parasite and Trypanosoma Rhodesiense.

A new and very important page in the history of this hæmatozoon was turned in February, 1910, when Professor J. W. W. Stephens, of the Liverpool School of Tropical Medicine, while examining in class work a stained specimen of rat's blood, containing what was supposed to be *Trypanosoma gambiense*—that is, ordinary sleeping sickness—noticed a marked peculiarity in the morphology. This made him doubt whether the micro-organism was really *Trypanosoma gambiense* or not. These parasites were obtained from a man named Armstrong, under treatment in Liverpool, who had been infected in North-East Rhodesia in September, 1909. Stephens, in collaboration with Fantham, then studied this organism more closely, and came to the conclusion that it was a different species from *Trypanosoma gambiense*, and called it *Trypanosoma rhodesiense*. In this way, then, came about the separation of the Rhodesian form of sleeping sickness from the old Congo form, and you will agree with me that the greatest credit is due to these gentlemen for being the first to bring this far-reaching and important discovery to light.

In 1911 a Commission was sent to Nyasaland by the Colonial Office, under the direction of the Royal Society, to inquire into this and other questions of a like nature. The Commission came to the same conclusion as Stephens and Fantham, that Nyasaland sleeping sickness and Congo sleeping sickness are separate and distinct diseases. We were, however, soon struck by the fact that although the "Fly Country" of Nyasaland extends almost uninterruptedly into the Zululand "Fly Country," no nagana trypanosomes—the common trypanosome of wild game in this part of Africa—could be found. Everywhere, in the wild tsetse flies and in the wild game, it was always *Trypanosoma rhodesiense*, and this in spite of the fact that nagana was reported from Portuguese East Africa, German East Africa, and, in fact, all round about except Nyasaland. It then began to dawn on the mind of the Commission that perhaps *Trypanosoma rhodesiense* was in reality the old nagana parasite masquerading under a new name. As soon as possible a strain of the latter was procured from Zululand for purposes of comparison, and the Commission, after a good deal of work, came to the conclusion that the nagana parasite and *Trypanosoma rhodesiense* are in reality one and the same. They are identical in morphology, in their action on animals, and in their manner of development in the tsetse fly, and until further proof is brought forward that they are separate species the Commission decided to consider them as identical.

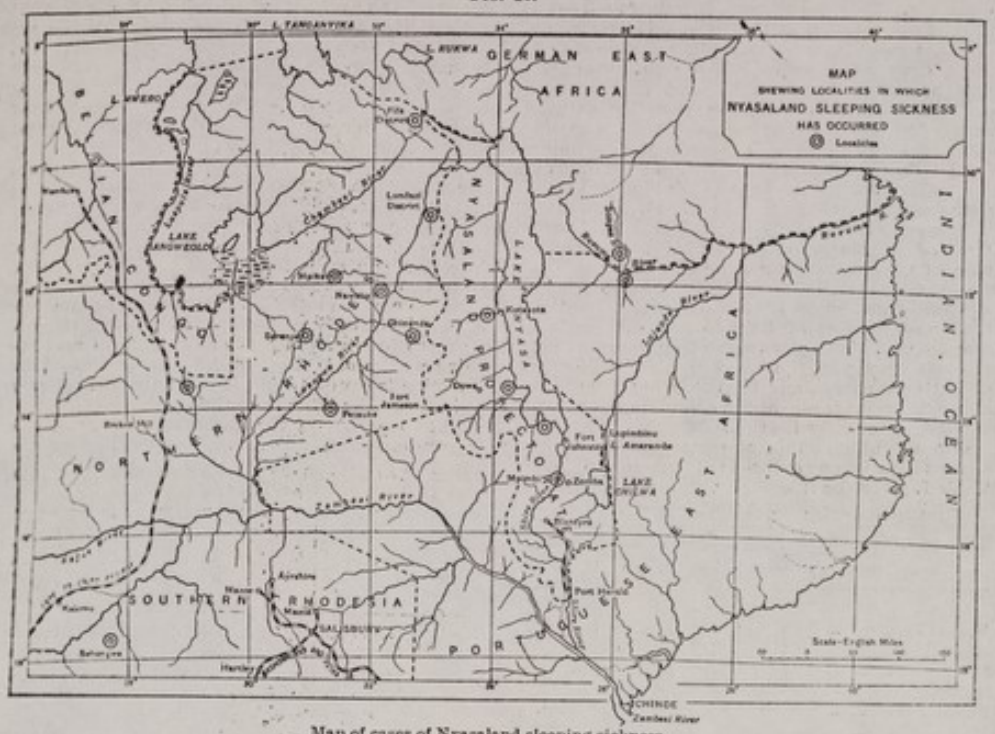
This is a very important matter, because if nagana and *Trypanosoma rhodesiense* are identical then we may expect to find cases of "Nyasaland sleeping sickness" cropping up in all parts of Africa where nagana occurs—in the Sudan, Uganda, British East Africa, North-Eastern Transvaal, and Zululand. If, on the other hand, they are separate species, then cases of this disease would only be expected to occur where *Trypanosoma rhodesiense* is found in addition to nagana. In the past nagana has always been regarded as harmless to man, and certainly no harm seemed to come to those who lived or travelled in the "Fly Country." To this it may be answered that it is only within recent years that microscopical examination of the blood of such cases has been made. Many cases of death occurred among hunters and explorers which were usually put down to malaria, but it is possible some of these may have been due to infection by nagana. This is a question which I will not pursue further; time and further knowledge are wanted before a completely satisfactory answer can be given. But it must be understood that in the following description of *Trypanosoma brucei*, *Trypanosoma rhodesiense* is included.

So much for the history of the nagana parasite. Let us now consider the distribution of this trypanosome in Africa.

GEOGRAPHICAL DISTRIBUTION.

From the map [a map was exhibited representing the distribution of *Trypanosoma brucei* in Africa] it will be seen that *Trypanosoma brucei* and the

FIG. 13.



Map of cases of Nyasaland sleeping sickness.

disease caused by it—nagana—are widely distributed in Africa, extending from the Sudan to Zululand and from the Gambia to Zanzibar; in fact, it is the most widely distributed pathogenic trypanosome in Africa. It may be that in the future strains of nagana in widely separated parts of Africa may be found to differ from each other sufficiently to enable them to be ranked as separate species. As a matter of fact, the nagana of Togoland has lately been named *Trypanosoma togolense* and that of Uganda *Trypanosoma ugandæ*. But until more is known of these varieties I think it better for the sake of simplicity to include them all under one specific term.

On the next map the districts are shown where up to the present cases of this disease in man have been discovered. (Fig. 13.)

MORPHOLOGY.

I shall now go on to describe the morphology of the nagana parasite. Here is a slide (see Fig. 2, Lecture I.) representing the Zululand strain of *Trypanosoma brucei* which we had sent to us in Nyasaland in 1913 from Pretoria in order to compare it with the Nyasaland human strain—the *Trypanosoma rhodesiense* of Stephens and Fantham.

This trypanosome is dimorphic or polymorphic. This merely means that between the shorter and longer forms a greater diversity of shape is found than in the species belonging to the other groups. The short forms are broad and stumpy in appearance and have no free flagellum, whereas the long are much more slender in appearance, and have a well-marked free flagellum. In the living and unstained preparations this dimorphic character can be readily made out, and the parasites are seen to be actively motile, although they do not move far from one place, they have little or no power of translation. The long and slender are very similar in shape and appearance to *Trypanosoma gambiense*, but the short forms have often broader and blunter ends. (Fig. 14.) In well-stained specimens the

FIG. 14.

Trypanosome causing disease in man in Nyasaland.
× about 700.

protoplasm of many of the trypanosomes shows granules, especially in the anterior portion of the cell. The nucleus is oval in the long and slender, and round or oval in the short and stumpy. One peculiarity about the nucleus of this species is that

it is frequently placed far back in the body of the organism. This peculiarity is only found in the short forms, never in the long. The percentage of these so-called posterior nuclear forms is often large, even as high as 50 per cent. The micronucleus is small and round, and situated on an average 2 microns from the posterior extremity in the long and slender forms and 1·4 microns in the short and stumpy. The undulating membrane is well developed and thrown into bold folds and undulations. The flagellum in the long and slender averages 5·8 microns (maximum 11, minimum 2). There is no free flagellum in the short and stumpy forms. [Slides showing various strains of this species were here thrown on the screen.] From these slides it is abundantly evident that the *Trypanosoma brucei* of Zululand, 1894 and 1913, of Nyasaland, and of Uganda are all identical in morphology. This does not, of course, prove that they all belong to the same species. One species of butterfly may mimic the colouring and shape of another. But it is one of the characters upon which we depend for classification.

One useful point in the morphology of these strains has been omitted: I mean the length. Table I. gives the length of various strains of this

TABLE I.—*Showing the Length of Various Strains of* Trypanosoma Brucei.

Source of strain.	Average.	Max.	Min.	Remarks.
	Microns.	Microns.	Microns.	
Human: Nyasaland ...	23·5	38·0	14·0	Various. 6220
,, ,, ...	24·2	38·0	15·0	Rats. 3600
Wild game	22·6	35·0	15·0	,, 2500
Wild *Glossina morsitans*	22·6	35·0	15·0	,, 2500
Zululand, 1913	21·0	35·0	12·0	Various. 1000
,, 1894	22·8	35·0	13·0	,, 200
Uganda, 1909	23·0	34·0	15·0	,, 160

species. From this it will be seen that the measurements of various strains taken from widely separated parts of Africa come out fairly regularly. The human strain is the longest, having an average length of 24·2 microns, whereas the Zululand 1913 strain is the shortest, 21·0 microns. It is rather remarkable that the wild game and the wild *Glossina morsitans* strains should have resulted in exactly the same measurements. The breadth of the long and slender averages 2·76 microns, the intermediate 3·25, and the short and stumpy 3·53.

SUSCEPTIBILITY OF ANIMALS TO TRYPANOSOMA BRUCEI.

Now, gentlemen, having described the morphology of this species, and having shown that the various strains found in Uganda, Nyasaland, and Zululand are absolutely identical in appearance, allow me to pass on to the second part, the pathogenic action of this trypanosome on various animals.

Many mammals, including man, horses, mules, donkeys, oxen, goats, sheep, monkeys, dogs, and many others, are attacked by this parasite. Birds and the cold-blooded vertebrates, such as crocodiles, lizards, and frogs, are quite unaffected by it. A single trypanosome seems to be just as efficacious in setting up infection as a million, and it does not seem to matter whether the kind of trypanosome injected is one of the long and slender forms or one of the short and stumpy. As I mentioned already, passage through one species of animal usually heightens its virulence towards that animal. At the Army Medical College, when the nagana trypanosome begins to kill rats in two or three days, it is usual to pass it a few times through the rabbit, which has the effect of materially lowering its virulence towards the rat and making its passing through the rat less irksome.

In regard to modes of infection, it is extremely easy to infect an animal through the skin; it is usually sufficient to dip a needle in infected blood and merely to scratch the skin of the experimental animals. There is evidence also that infection may take place through the mucous membrane; dogs are sometimes infected in this way through eating infected meat, but it is possible that in these cases there is some scratch or wound of the mouth.

Experiments have been published to show that infection can even take place through unbroken skin, but this must be a rare accident, else why have we escaped infection who have made hundreds of post-mortem examinations on cases of sleeping sickness in man and other animals? In nagana I think we are safe if we lay down as a rule that the infection is conveyed in nature in the vast majority of instances by the bite of the tsetse fly.

But to return to the pathogenic action of this trypanosome on animals. Table II. gives the

TABLE II.—*Giving (a) the Average Duration in Days of the Disease in Various Strains of* Trypanosoma Brucei.

Strain.	Man.	Horse.	Ox.	Goats and sheep.	Monkeys.	Dogs.	Rabbits.	Guinea-pigs.	Rats.
Human	20	—	134	42	26	34	28	67	30
Wild game	—	—	—	46	38	41	—	—	32
Wild *Glossina morsitans*	—	—	Recovered	54	38	29	47	81	26
Zululand, 1913	—	38	310	77	29	18	33	44	27
(b) The Number of Animals Employed.									
Human	?	—	1	?	20	25	7	15	22
Wild game	—	—	—	5	9	13	—	—	6
Wild *Glossina morsitans*	—	—	2	16	14	25	3	10	19
Zululand, 1913	—	3	1	7	8	17	8	10	23

average duration in days of the disease caused by various strains of this trypanosome, also the number of animals employed. From this it will be seen that this disease runs a fairly rapid course in man, killing him as a rule in three or four months. This, as we shall see, is in marked contrast to the much more chronic course of the Congo sleeping sickness caused by *Trypanosoma gambiense*. In horses, donkeys, and mules nagana runs its course on an average of 38 days. No opportunity of studying the disease in horses occurred in Uganda or Nyasaland, as horses are very seldom seen in these countries. In the ox the disease is chronic and a certain proportion recover. In the other animals it may be said broadly that the disease runs a fairly similar course, and that little or no difference in the virulence is seen between the different strains.

Nagana is, as a rule, a fatal disease, and this is shown in Table III. From this table it will be seen that no recoveries have been reported up to the present in man. In oxen 80 per cent. and 83 per cent. of recoveries are noted. The number of animals employed, however, is so small that these figures are not reliable. With the exception of the oxen, almost all the other animals die. Out of 318 employed in these experiments only 3 recovered.

From its action on animals, then, just as from its morphology, it is apparent that *Trypanosoma brucei*

as it occurs in Zululand differs in no way from the Nyasaland strain called by Stephens and Fantham *Trypanosoma rhodesiense*. It is true that cases in man have not been reported from Zululand, nor from the Sudan, Uganda, or British East Africa, but I expect this hiatus will be filled up within the next

TABLE III.—*Showing (a) the Percentages of Recoveries in Various Animals Infected with* Trypanosoma brucei.

Strain.	Man.	Horse.	Ox.	Goats and sheep.	Monkeys.	Dogs.	Rabbits.	Guinea-pigs.	Rats.
Human	0	—	80%	0	0	0	0	0	0
Wild game	—	—	—	0	0	—	—	—	0
Wild *Glossina morsitans*	—	—	100%	6%	7%	4%	0	0	0
Zululand, 1913	—	0	83%	0	0	0	0	0	0
(b) The number of animals employed.									
Human	1	—	5	29	20	25	7	15	21
Wild game	—	—	—	5	9	13	—	—	6
Wild *Glossina morsitans*	—	—	2	17	15	26	3	10	19
Zululand, 1913	—	3	6	4	8	17	8	10	23

few years. It is true that Dr. Taute tried to infect himself with *Trypanosoma brucei* got from the wild game in Portuguese East Africa, and is of opinion that this proves that the trypanosome of man and of wild game are different species; but even this does not disturb my belief that the nagana parasite and that causing disease in man in Nyasaland are one and the same. It is, of course, possible that there may exist in Nyasaland a separate species of trypanosome confined to man, and exactly identical in morphology and action on animals with the trypanosome found in wild game and the wild fly, it may be possible, I say, but it is highly improbable.

THE CARRIER OF TRYPANOSOMA BRUCEI.

Now, having described the morphology of *Trypanosoma brucei* and its action on animals, I come to the question as to how this protozoon is conveyed from the sick to the healthy. In Zululand, when it became apparent that nagana and tsetse-fly disease were identical, experiments were made to find out if the fly was the carrier of the disease or merely a concomitant of the low-lying unhealthy country. It was commonly believed by the Zulus that their cattle contracted the disease by drinking out of the same water-holes as the wild game. Healthy horses, therefore, were sent for a few hours into the "Fly Country," muzzled in such a way that they could neither eat nor drink while there. These contracted the disease. On the other hand, bundles of grass and supplies of water brought from the heart of the "Fly Country," and fed to healthy horses on the top of the hill, failed to infect. But tsetse flies brought up in cages from the low country and placed straightway on healthy animals were found to give rise to the disease. By these and other experiments it was proved beyond question that the tsetse flies *Glossina morsitans* and *pallidipes* were carriers of nagana, and one of the first questions which presents itself is, What proportion of the wild tsetse flies found under natural conditions are infected?

THE INFECTIVITY OF WILD TSETSE FLIES (GLOSSINA MORSITANS).

Moreover, when one is in the "Fly Country," and being bitten by tsetse flies, it is interesting to know how many times you may be bitten without encountering an infected fly.

Methods Employed.

The method employed in Nyasaland in studying the infectivity of the wild flies was as follows. Native boys were employed in catching the flies in the low country, and these were brought up the same day to the camp in small cages by a native cyclist. Each cage was fed on three healthy animals; the first day on a monkey, the second day on a dog, and the third day on a goat. To ensure to some extent that each animal was fed on by every fly, the flies were fed daily for nine days, three times on each animal. It is doubtful, however, even with these precautions, if every fly did feed on all three animals. The number of flies in each case averaged about 60, and as each animal was fed on by three different sets of flies, then each monkey, dog, and goat ran the gauntlet of some 180 flies. If any animal became infected with *Trypanosoma brucei*, it was reckoned that there was only one infective fly in the batch. There may, of course, have been two or more. The method was not a very accurate one, but probably near enough for practical purposes.

I now draw your attention to the result as shown in Table IV. As will be seen from this table, there

TABLE IV.—*Showing the Proportion of Tsetse Flies* (Glossina morsitans) *Naturally Infected with* Trypanosoma brucei *in Nyasaland.*

1912.	No. of flies fed.	Monkey.	Dog.	Goat.	1912.	No. of flies fed.	Monkey.	Dog.	Goat.
Jan. 20th ...	296	—		+	May 14th ...	250	—	—	+
,, 24th ...	370	—		—	,, 17th ...	190		+	—
,, 29th ...	280	—		—	,, 24th ...	113		—	—
Feb. 2nd ...	295	—		—	,, 28th ...	120	—	—	—
,, 8th ...	220	—		—	,, 28th ...	230	—	—	—
,, 13th ...	200	—		—	,, 29th ...	320		+	—
,, 16th ...	195		+	+	,, 29th ...	240	—	—	—
,, 21st ...	170		—	—	,, 29th ...	100		—	—
,, 26th ...	170		—	—	,, 31st ...	175	+	+	—
March 2nd ...	140		—	—	June 2nd ...	300		—	—
,, 9th ...	165		—	—	,, 6th ...	210	—	—	—
,, 14th ...	100		—	—	,, 7th ...	230	+	+	+
,, 17th ...	160		—	—	,, 11th ...	160	—	—	—
,, 22nd ...	205		—	+	,, 18th ...	135	—	—	—
April 3rd ...	135		—	—	,, 25th ...	90	+	+	—
,, 10th ...	275	+	+	—	July 3rd ...	95		—	—
,, 15th ...	330	—	—	—	Sept. 25th ...	70	—		
,, 18th ...	200	—	—	—	,, 27th ...	25	+		
,, 18th ...	180	—	—	—	Oct. 28th ...	87	+	+	+
,, 23rd ...	230	—	—	—	Nov. 5th ...	145		—	—
,, 23rd ...	140	—	—	—	,, 11th ...	150	—	—	—
,, 26th ...	100	—	—	+	,, 18th ...	157	—	—	—
,, 27th ...	260	—	—	—	,, 21st ...	95	—	+	+
May 3rd ...	155	+	—	—	,, 25th ...	180	—	+	+
,, 3rd ...	96	—	—	—	Dec. 3rd ...	180	—	—	—
,, 8th ...	330	+	+	—	,, 6th ...	198	+	+	+
,, 9th ...	120	—	—	—	,, 11th ...	156	—	+	+
,, 13th ...	50	—	+	—	,, 16th ...	113	—	—	—

were 56 experiments, and 10,081 tsetse flies (*Glossina morsitans*) were employed. In the 56 experiments *Trypanosoma brucei* was found 20 times (35·7 per cent.). Nine monkeys, 14 dogs, and 11 goats were infected. This gives a proportion of 1 in 500 or 2 flies per 1000 caught in the sleeping sickness area, Nyasaland, infective with nagana. This is only allowing one infective fly to each series of flies fed on the experimental animals, and is therefore the irreducible minimum.

Months and Seasons.

From these experiments it is also seen that these infective flies occur all the year round, and are just as numerous during one season as another.

To conclude, then, in regard to the natural infectivity of *Glossina morsitans* with this species of trypanosome, it may be said that if a man is bitten by a tsetse fly in the sleeping-sickness area of Nyasaland it is 500 to 1 against his taking the disease, since only 1 in every 500 flies is infective with the specific parasite.

THE CYCLE OF DEVELOPMENT OF TRYPANOSOMA BRUCEI IN GLOSSINA MORSITANS.

I ought now to describe the cycle of development of the nagana parasite in the tsetse fly, but as this development is identically the same as that of *Trypanosoma gambiense* in *Glossina palpalis*, and as the cycle was first worked out by us with the latter, it will be better to defer the description of this cyclical development until we come to discuss *Trypanosoma gambiense*. I shall, therefore, now pass on to consider the reservoir.

Whence does the tsetse fly obtain the nagana virus?

THE RESERVOIR.

In Zululand in 1896, when it became certain that nagana or tsetse-fly disease was conveyed to the animals by the fly, the question arose as to where the fly obtained the virus. In the Zululand "Fly Country" there were no natives, since cattle could not live there, and with the Zulus cattle stand for everything. There were therefore no horses, oxen, goats, or dogs suffering from nagana from which the fly could obtain the parasite. But the place being a Government reserve was swarming with wild animals on which it was evident the fly fed. If you shot one of these animals in the "Fly Country" you would often find many tsetses still feeding on the dead body. This led to the examination of the buffalo, koodoo, wildebeeste, and other wild game found in the district. As soon as an animal was killed a quantity of its blood was sent off by a native runner to the top of the hill, where it was injected into a healthy dog. Smears were also made and examined microscopically. In this way it was proved both by animal experimentation and direct microscopical examination that the blood of many of these wild animals contained the same trypanosome as that which gave rise to nagana, and so the mystery of the reservoir was cleared up.

Since 1896 further observations have been made regarding the presence of these parasites in the blood of wild game in different parts of Africa, on the West Coast, in Uganda, and notably in North-Eastern Rhodesia by Kinghorn and Yorke. In Nyasaland we also examined the wild game with some care, and I shall now proceed to describe the results.

TRYPANOSOMES FOUND IN THE BLOOD OF WILD ANIMALS LIVING IN THE SLEEPING-SICKNESS AREA, NYASALAND.

The method of examining the blood of wild game was much the same as that used in Zululand. When an animal was shot a small quantity of its blood was taken in a sterilised bottle containing citrate of potash to prevent coagulation. Smear preparations were made at the same time. As the animals were often shot 30 or 40 miles away from the camp, a motor cycle was used to get the blood up the hill as quickly as possible. When the blood arrived at the laboratory it was at once injected into a goat, a monkey, and a dog. In this way 180 specimens of blood of wild game living in the fly area were examined, and 57 were found to harbour pathogenic trypanosomes (32 per cent.).

This is, however, probably much below the actual percentage. A wild animal is only examined once, and that often under unfavourable conditions. If it were possible to examine the same animal several times it is probable that many more would be found infected. The parasites come and go in the blood; one day they may be present, the next day absent. The big game live in the "Fly Country" among swarms of infected flies and are constantly liable to infection and reinfection.

The following table (Table V.) represents the number of times *Trypanosoma brucei* was found among the 180 wild animals examined, and the species of game which harboured it. From this it

TABLE V.—*This represents the Number of Times* Trypanosoma brucei *was found among the 180 Wild Animals Examined and the Species of Game which Harboured it.*

Species of animal.	Number examined.	Number infected with *T. brucei*.	Species of animal.	Number examined.	Number infected with *T. brucei*.
Eland ...	10	0	Duiker ...	7	1
Sable	5	0	Buffalo ...	9	0
Waterbuck	13	3	Lion	1	0
Koodoo ...	3	0	Hyæna ...	3	0
Bushbuck...	10	0	Elephant ...	2	0
Hartebeeste	35	5	Warthog ...	33	1
Reedbuck...	19	3	Wild cat ...	3	0
Oribi	25	1	Porcupine...	1	0

will be seen that 14 animals among the 180 harboured the nagana parasite (7·8 per cent.), and that the waterbuck, hartebeeste, reedbuck, and duiker seem to be the most dangerous neighbours to man. 23 per cent. of the waterbuck, 14 per cent. of the hartebeestes, 16 per cent. of the reedbuck, and 14 per cent. of the duiker had *Trypanosoma brucei* in their blood. If, then, my contention that this parasite found in the wild game is the cause of Nyasaland sleeping sickness be proved to be true, then it is abundantly obvious how dangerous these wild animals are to man; and it must be borne in mind that in this Nyasaland fly area *Trypanosoma brucei* is only one of the pathogenic species of trypanosome found in the wild game. Other three species pathogenic to the domestic animals are also found, *Trypanosoma pecorum*, *Trypanosoma simiæ*, and *Trypanosoma capræ*; *Trypanosoma pecorum* in 14·4 per cent., *Trypanosoma simiæ* 1·7 per cent., and *Trypanosoma capræ* in 11·1 per cent. of the wild game examined. Therefore I do not think I was using too strong language when I wrote in a report to the Royal Society: "It is self-evident that these wild animals should not be allowed to live in 'Fly Country' where they constitute a standing danger to the native inhabitants and the domestic animals. It would be as reasonable to allow mad dogs to live and be protected by law in our English towns and villages. Not only should all game laws restricting their destruction in 'Fly Country' be removed, but active measures should be taken for their early and complete blotting out." It must be strictly borne in mind that this only refers to wild animals living in "fly" areas. No pathogenic trypanosomes have up to the present been found by the Commission in the blood of animals living in fly-free areas.

The Croonian Lectures

ON

TRYPANOSOMES

CAUSING DISEASE IN MAN AND DOMESTIC ANIMALS IN CENTRAL AFRICA.

Delivered before the Royal College of Physicians of London on June 17th, 22nd, 24th, and 29th, 1915.

BY SIR DAVID BRUCE, C.B., F.R.S.,
M.B. EDIN., F.R.C.P. LOND.,
SURGEON-GENERAL, A.M.S.

LECTURE III.[1]

Delivered on June 24th.

MR. PRESIDENT AND GENTLEMEN,—In my last lecture I described *Trypanosoma brucei*, the most widely distributed pathogenic trypanosome of Africa, the cause of nagana among the domestic animals, and "Nyasaland sleeping sickness" in man. To-day I propose to take as my subject *Trypanosoma gambiense*, the cause of the notorious "Congo sleeping sickness."

HISTORICAL.

Trypanosoma gambiense was first seen in the blood of an Englishman who had been employed for some six years as master of a Government boat on the river Gambia in West Africa. He was admitted to the Government hospital at Bathurst on May 10th, 1901, 14 years ago. Mr. R. M. Forde, the colonial medical officer in charge, examined his blood and saw actively moving bodies, but was unable to recognise their nature. He therefore asked the late Dr. J. E. Dutton, of the Liverpool School of Tropical Medicine, to come to his help. In the meantime, however, the patient had been invalided to England, where he was treated in a Liverpool hospital for some time. Thinking himself sufficiently recovered to resume duty, he returned to Bathurst in December, 1901, and on the 15th of the same month his blood was submitted to Dr. Dutton for examination. Dr. Dutton saw the parasite, described it, and named it *Trypanosoma gambiense*. But at this time it did not enter into the minds of anyone that this trypanosome was the cause of sleeping sickness. It was looked upon as an almost harmless hæmatozoon, causing no inconvenience to the native and only a slight ephemeral fever, known as trypanosoma fever, to the white man.

At the same time the finding of a parasite of this kind for the first time in the blood of man raised a good deal of interest, and Dr. Dutton and Dr. C. Todd were sent out in the following year to investigate the question further. They arrived at Bathurst on Sept. 2nd, 1902, and proceeded to examine a large number of natives for the presence of trypanosomes in their blood. They examined in all 1,062 natives on the Gambia, and found the parasite only in six cases. They summed up their report by saying that, taking all the facts into consideration, they believe that trypanosoma fever, as it occurred in natives, was a peculiarly mild one, and they suggested the possibility that the natives might bear the same relation to the Europeans as the wild game of Africa to domestic animals in nagana, the tsetse-fly disease. In other words, that the black man was immune to the disease, and merely acted as a reservoir of the virus to the more susceptible white man. For some time, then, the important pathogenic part this trypanosome plays remained unknown, and it was not until 1903, when sleeping sickness was being investigated in Uganda by the Royal Society Commission, that the discovery was made that *Trypanosoma gambiense* was in truth the cause of sleeping sickness.

This, then, is a short account of this hæmatozoon from its discovery in 1901 as a supposed harmless parasite in the blood of natives on the Gambia to its apotheosis as the cause of that interesting and hitherto mysterious disease, sleeping sickness.

GEOGRAPHICAL DISTRIBUTION.

Reference to the map published to illustrate my first lecture will show that this species of trypanosome has a wide distribution in the tropical zone of Africa. It extends on the north from St. Louis at the mouth of the river Senegal to the Bahr-el-Ghazal in the Egyptian Soudan; on the east it reaches to the eastern shore of Victoria Nyanza; and on the south to the southern end of Lake Tanganyika, the river Luapula in North-West Rhodesia, and Donguela in Portuguese West Africa.

MORPHOLOGY.

When in Nyasaland I received from Dr. Kleine, German East Africa, three monkeys infected with *Trypanosoma gambiense*. These animals had been inoculated with blood from natives suffering from "Congo sleeping sickness" on Lake Tanganyika, and it is from these three strains that this description is taken. We sent for these strains because we wished to have an opportunity of comparing *Trypanosoma gambiense* with the trypanosome causing disease in man in Nyasaland side by side and under similar conditions. It presents a strong resemblance to the nagana parasite. There are the same short and stumpy, intermediate, and long and slender forms. In size and general appearance these two species so closely resemble each other that one might easily believe them to be varieties of the same species. The shape of the long and intermediate forms is the same as in the nagana parasite, but among the short there is an absence of the blunt-ended forms, which have been seen to be so marked a feature in the Nyasaland trypanosome. The protoplasm often shows many chromatin granules in its substance. In *Trypanosoma brucei*, among the short and stumpy, there are large numbers of posterior-nuclear forms. In the Tanganyika strains not a single example of this peculiarity was seen. The micronucleus is small and round, and situated on an average 1·1 microns from the posterior extremity in the short, 1·3 in the intermediate, and 1·8 in the long forms. The undulating membrane, as in the other members of this group, is well developed, and thrown into bold folds and undulations. The flagellum in the long and intermedinte forms is free. There is no free flagellum in the short forms. In regard to length, there is practically no difference between the two species as will be seen from Table VI.

Trypanosoma gambiense is therefore very similar in size and shape to *Trypanosoma brucei*, but it would appear to be possible to distinguish them by the presence of the blunt-ended, posterior-nucleated forms which are so common in the blood of animals infected by the nagana parasite and quite absent in animals infected by the other. But as these posterior-nucleated forms are absent or scarce in the blood of man, this method of diagnosis

[1] Lectures I. and II. were published in THE LANCET of June 26th and July 3rd (p. 1) respectively.

requires the inoculation of experimental animals and the study of many preparations of their blood. It would appear to be impossible at present to distinguish between the two species by the microscopical examination of preparations made from the blood of man alone.

TABLE VI.—*Showing Length of* Trypanosoma Gambiense *Compared with* Trypanosoma Brucei, *Zululand, 1913.*

Strain.	Average.	Maximum.	Minimum.
	Microns.	Microns.	Microns.
T. gambiense, Uganda	22·1	33·0	13·0
,, ,, Tanganyika I. ...	22·7	34·0	15·0
,, ,, ,, II. ...	25·8	36·0	16·0
,, ,, ,, III. ...	21·3	34·0	16·0
T. brucei, Zululand, 1913	21·0	35·0	12·0

The average breadth of *Trypanosoma gambiense* is 2·31 microns; its maximum breadth being 4·75, and its minimum 1·25 microns.

SUSCEPTIBILITY OF ANIMALS TO TRYPANOSOMA GAMBIENSE.

I now pass to the pathogenic action of this species on various animals. In this it differs markedly from the nagana parasite, which is essentially a trypanosome of the lower animals, seldom attacking man; whereas the reverse is true of the species under consideration, which under natural conditions is almost wholly confined to man. When *Trypanosoma gambiense* is taken directly from a patient suffering from sleeping sickness there is often a good deal of difficulty in passing it on to the lower animals—that is to say, it is difficult to infect experimental animals by the inoculation of infected human blood. This is very different from the behaviour of *Trypanosoma brucei*, which infects most animals with the greatest readiness.

[To illustrate this Sir David Bruce gave tables on the screen showing the result of inoculating various animals with the three Tanganyika strains. From these tables it was manifest that a marked difference existed between *Trypanosoma gambiense* and *Trypanosoma brucei* in regard to their virulence towards animals.]

It is almost impossible at first to give this disease to goats, monkeys, dogs, and guinea-pigs. The rat is the animal which is least refractory. However, after the trypanosome has become accustomed by several passages through a particular kind of animal its virulence for this species is heightened. It must also be noted that there is reputed to be a good deal of difference in the virulence of different strains. This difference in regard to virulence between the two species is shown in Table VII.

TABLE VII.—*Showing the Average Duration in Days of the Disease caused by* Trypanosoma Gambiense, *Tanganyika, compared with that caused by* Trypanosoma Brucei, *Zululand.*

—	Monkey.	Dog.	Guinea-pig.	White rat.
Trypanosoma gambiense ...	159	96	264	137
Trypanosoma brucei	26	34	67	30

The disease in animals caused by *Trypanosoma gambiense* is thus much more chronic than that caused by *Trypanosoma brucei*, and this character, combined with the morphology already described, affords the surest and safest means of separating these species.

GLOSSINA PALPALIS THE CARRIER OF TRYPANOSOMA GAMBIENSE.

As we have already seen, the carrier of *Trypanosoma gambiense* is the tsetse fly, *Glossina palpalis*, whose habitat is the wooded shores of lakes and rivers. When the Royal Society's Commission in 1903 had convinced itself that in all probability a trypanosome was the cause of sleeping sickness, naturally on the analogy of the old nagana work, a tsetse fly was looked for. It is a curious fact that at that time the presence of tsetse flies on the Lake Victoria was unsuspected. I have already described the habits of this species of fly, and shown how very numerous it is in Uganda, swarming on the lake shore in such numbers that our native boys, who collected about 500 daily for months together from one or two spots, did not seem to make any impression on the supply.

Infectivity of Wild Glossina Palpalis.

Some of these flies were found to be naturally infected with *Trypanosoma gambiense*, and I shall therefore in the first place consider the natural infection which exists among the wild *Glossina palpalis*. It will be remembered that the proportion of tsetse flies in Nyasaland infected with Nyasaland sleeping sickness was 1 in 500. It will be interesting, then, to compare the infectivity of the wild tsetse flies in Uganda. It must be granted that although the shores of Victoria Nyanza and the banks of the Nile and other rivers swarmed with these tsetse flies before 1898, it was only about the time that they became infected with sleeping sickness. Before this time sleeping sickness was unknown in Uganda. It seems probable that the disease was introduced by Emin Pasha's men, who were brought into the country from the Belgian Congo some little time before.

I am sorry that the same method of examination was not used in Uganda as in Nyasaland. In Nyasaland the flies were fed on three different species of animals for nine days. In Uganda the flies were caught on the lake shore, and when brought up to the laboratory were only fed on one species of animal, the monkey. In 1903 at Entebbe, the Government cantonment, the tsetse flies had plenty of opportunity of becoming infected, since they were caught in the vicinity of the hut-tax labourers' camp. These men came in thousands to Entebbe to work for Government for one month in lieu of paying hut-tax. They lived in rudely built grass huts near the lake shore, and on examination of their blood some 30 per cent. of them were found to harbour the parasite. In 1903, while these highly infected labourers were living on the lake shore, the proportion of infective flies was found to be as high as 11·2 per 1000. The Government removed the hut-tax labourers from the vicinity of the lake, which became deserted, and a year afterwards the proportion of infected flies fell to 1·2 per 1000. When the Commission returned to Uganda in 1908 and took up camp at Mpumu at the north end of Lake Victoria we found the lake-shore flies in the vicinity still infective, although the population had been removed early that year. The examination of 7200 flies gave a proportion of 1 per 1000. But we had given the Government to understand that as soon as the natives were removed the flies would become harmless. It was therefore important to find out how long the lake-shore flies remained infective, and why they remained infective. For this purpose they were

ARRIER OF TRYPANOSOMA
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examined every year until 1912, and the result is given in Table VIII.

TABLE VIII.—*Showing the Results of Yearly Examinations of wild* Glossina Palpalis *from 1903 to 1912 inclusive.*

Year	Locality.	Number of flies examined.	Number of flies infective.	Proportion of infective flies per 1000.	Remarks.
1903	Entebbe.	?	?	11·2	—
1904	"	?	?	1·2	—
1908	Mpumu.	7,200	11	1·8	1 in 654
1909	"	18,691	7	0·4	1 in 2,670
1910	"	27,179	4	0·14	1 in 6,795
1911	"	23,899	1	0·04	1 in 23,899
1912	"	28,279	4	0·14	1 in 7,070

From the foregoing table it will be seen that although there had been a steady decrease in the proportion of infective flies, a few remained and these showed no sign of disappearing. The mistake made by the Commission was first in believing that the transmission of the *Trypanosoma gambiense* was mechanical, and that a fly lost its power of infection within three days after feeding on an infected animal; and, secondly, in believing that man was the sole reservoir of the virus. It was found that a fly may remain infective for several months, and that man is by no means the only source of the virus.

This prolonged infectivity which some flies possess is due to the fact that in these the trypanosomes do not die off, but proceed to further multiplication, and I must now describe the cycle of development which the parasite passes through in the fly, from its ingestion with the blood, until its appearance in the salivary glands of the fly in an infective form. When dealing with *Trypanosoma brucei* I mentioned that its development in the fly is identical with what takes place in the case of *Trypanosoma gambiense*, and that it would be more convenient to describe the cycle at this point. I did not describe the development of the nagana parasite in *Glossina morsitans*, as one description will suffice for both species.

THE CYCLE OF DEVELOPMENT OF TRYPANOSOMA GAMBIENSE IN GLOSSINA PALPALIS.

Let me again briefly rehearse the historical facts. Koch and Stuhlmann in German East Africa described developing forms in glossina but did not succeed in infecting healthy animals by the injection of these forms. It is to Kleine that the honour is due of being the first to show that a tsetse fly could convey the infection some 50 days after the fly had fed on an infected animal, and when we come to consider the difficulties of this observation we must feel that he deserves the very highest credit for making this important advance in our knowledge of trypanosome diseases. He used the tsetse fly *Glossina palpalis* and the nagana trypanosome in his first successful experiment, which was carried out at the end of 1908. A few months later, in March, 1909, we had our first successful experiment in Uganda with *Trypanosoma gambiense* and *Glossina palpalis*, and I think it will be best to introduce the subject by a description of this first experiment. (See Table IX.)

On March 5th, 1909, 60 *Glossina palpalis* were placed in two cages, 30 in each. The flies were fed on two infected monkeys for two days. They were then starved for 72 hours to get rid of the danger of mechanical transference. The following five days they were fed on a healthy monkey, and every successive period of five days or thereabouts on a fresh healthy monkey, up to 86 days, when the experiment came to an end. The result was that the first two monkeys remained healthy, and all the following monkeys up to 75 days became infected with sleeping sickness. If five days be deducted for the incubation period, then the flies became infected 20 days after their first feed on the infected animal. There is some evidence that among the 60 flies only one was infective. Fifty-four days after the beginning of the experiment each cage was placed on a separate monkey. Up to that time both cages of flies had been fed on the same animal. Cage A contained after 54 days 11 flies; Cage B 4 flies. Cage A continued to infect monkeys for 21 days more, making a total of 75 days. Cage B did not infect. Again, as was natural, the flies gradually died off during the experiment, and as each fly died it was carefully dissected and examined for trypanosomes. Not a single trypanosome of any kind whatever was seen in any dissected fly up to 75 days, when a fly died in Cage A, and this fly on examination was found to be swarming with trypanosomes. After the death of this fly Cage A ceased to be infective, and when the experiment was stopped the remaining flies were killed off and dissected, but among them not a sign of a trypanosome could be seen. In the same way the flies in the non-infective Cage B were examined with a similar negative result.

TABLE IX.—*Development of* Trypanosoma Gambiense *in* Glossina Palpalis.

Day of experiment.	Procedure with 60 flies: A, cage with 30 flies; B, cage with 30 flies.	Result.	
		Positive.	Negative.
0 to 2	Flies fed on infected monkey.		
2 „ 3	Flies starved 72 hours.		
4 „ 8	Flies fed on Monkey 579.		—
9 „ 13	„ „ 651.		—
14 „ 18	„ „ 652.	+	
19 „ 23	„ „ 653.	+	
24 „ 28	„ „ 654.	+	
29 „ 33	„ „ 655.	+	
34 „ 38	„ „ 672.	+	
39 „ 41	„ „ 722.	+	
42 „ 43	Starved for 72 hours.		
44 „ 51	Fed on Monkey 727.	+	
52 „ 53	Starved for 76 hours.		
54 „ 58	Cage A, fed on Monkey 735.	+	
54 „ 58	Cage B, fed on Monkey 736.		—
59 „ 60	Starved for 74 hours.		
61 „ 65	Cage A, fed on Monkey 749.	+	
61 „ 65	Cage B, fed on Monkey 748.		—
66 „ 67	Starved for 72 hours.		
68 „ 72	Cage A, fed on Monkey 765.	+	
68 „ 72	Cage B, fed on Monkey 764.		—
73 „ 74	Starved for 72 hours.		
75 „ 79	Cage A, fed on Monkey 848.		—
80 „ 81	Starved for 72 hours.		
82 „ 86	Cage A, fed on Monkey 911.		—
87	Experiment stopped.		

This was a most interesting and successful experiment. It was evident that a single infective fly did all the mischief, and by good luck this fly was detected. Not only did one fly do all the mischief, but judging from the incubation periods it would appear that in all probability it infected each animal on the first day it bit it, showing how dangerous such an infective fly is. When this fly came to be dissected the gut was found to be crammed with innumerable trypanosomes, and in addition the salivary glands contained large numbers.

This is the first record of these parasites being found in the salivary glands, and it led up to the discovery that the invasion of the salivary glands is an integral part in the cycle of development of this group—Group A—of trypanosomes. After this numerous experiments were made on the same lines, and with several species of trypanosomes.

The Development of Trypanosoma Gambiense *in Laboratory-bred* Glossina Palpalis.

Let us now enter more fully into the development of *Trypanosoma gambiense* in *Glossina palpalis*, and first let us consider what proportion of laboratory-bred flies become infective when fed on an infected animal.

[Here the lecturer threw on to the screen a table giving the result in one series of experiments.]

In 42 experiments performed to ascertain what proportion of laboratory-fed flies become infective when fed on an infected animal, only 8 gave a positive result; as many as 34 were negative. In the 8 positive experiments 371 flies were used, an average of 46; in the 34 negative experiments 1323, an average of 40. The shortest time which elapsed before a laboratory-bred fly became infective with *Trypanosoma gambiense* was 27 days, the longest 53 days, and the average 36 days. In the 42 experiments 1694 laboratory-bred flies in all were used. If we consider that in each of the 8 positive experiments only 1 fly became infective, then only 8 flies in 1698, or 1 in 212 (0·5 per cent.) became infective. This is a very small proportion, and helps to account for the fact that 15 years elapsed before this cycle of development was discovered. This development of the trypanosome in the fly is somewhat similar to what occurs in the test-tube in artificial cultivation. A thousand tubes are inoculated, let us say, with *Trypanosoma brucei*; the trypanosomes all appear to die off, but 20 days later a peculiarly resistant individual is found in one tube of the thousand, which has adapted itself to the new environment, and soon multiplies into myriads.

But although it is evident that in these 42 experiments only 8 or 10 flies became infective, a larger number were found in which development had proceeded to some extent—that is to say, the flies had become infected but not infective.

TABLE X.—*Number of Flies found Infected with* Trypanosoma Gambiense *in the Experiments with Laboratory-bred Flies.*

Experiment.	No. of flies used.	Experiment (positive or negative).	No. of infected flies found.	Result of injection of infected flies.	Remarks.
975	16	+	0	Positive.	12 remaining flies pooled.
1289	22	—	2	Negative.	
1452	90	—	1	,,	
1549	50	+	4	Positive.	
1566	35	+	9	Negative.	1 fly injected.
1602	50	+	5	Positive.	
1651	60	+	4		Flies not injected.
1672	28	—	2	Negative.	
1680	45	—	1	,,	
1693	50	—	2	,,	
1706	60	—	4	,,	
1712	50	+	1	,,	
1760	60	+	1	,,	
1769	60	—	2	Positive.	
1801	70	—	1		Fly not injected.

As each fly died it was dissected. In all 39 flies were found with trypanosomes in the alimentary tract—that is to say, about 2 per cent. We may therefore summarise this series of experiments by saying that 0·5 per cent. become infective and 2 per cent. infected. It must be noted, however, that a good deal of difference exists in different series of experiments, the proportion of infected flies rising sometimes to 8 or 10 per cent.

The Cycle of Development of Trypanosoma Gambiense *in* Glossina Palpalis.

To find out what occurs after a trypanosome has been swallowed by a tsetse fly, we fed laboratory-bred tsetse flies on an animal whose blood contained numerous trypanosomes, and at the end of various times killed the flies and dissected them. This was done for periods of one day, two days, three days, and so on for 56 days.

The flies were examined first in the fresh condition when the trypanosomes could easily be seen by their movement; afterwards stained specimens made for more minute investigation were examined day after day, and coloured drawings, at a magnification of 2000 diameters, made of all the different forms met with. The drawings of the trypanosomes found in the fore-gut, mid-gut, hind-gut, proctodæum, and salivary glands were kept separate, so that a series of drawings of trypanosomes taken from any one part, from the first day of infection to the fifty-sixth day, could be compared. More than 600 drawings were made in this way, so that it seems impossible that any important form could have been left out.

General Consideration Regarding the Development of the Trypanosomes in the Fly.

For the first three or four days after flies have had a feed of infected blood trypanosomes are found in them all. These are those originally ingested with the blood, and at the end of six or seven days when the process of digestion has been completed they are found to have disappeared from most of the flies—that is to say, it is only in a certain percentage that further development takes place. In one series we saw that this was as low as 2 per cent.; in another it rose to 8 per cent. In other words, in some 95 per cent. of flies which imbibe infected blood the trypanosomes simply degenerate and die out within the first few days. In some 5 per cent., on the other hand, the trypanosomes find conditions more favourable for development and increase, filling the whole of the fore-gut, mid-gut, and hind-gut with countless swarms of multiplication forms. How long this infection of the fly continues is not absolutely known. It is considered probable that in many cases it continues for the rest of the fly's life. In one case a fly was found to retain its infectivity for 96 days, but in a few cases there was evidence that an infective fly might in its lifetime lose its infectivity and become harmless.

Types of Trypanosoma Gambiense *found in the Alimentary Canal of the Fly.*

It would serve no good purpose to describe separately, day by day, the variously shaped trypanosomes found in the different parts of the alimentary canal, since the different forms or shapes run into each other in such a way as to make any classification of them seem impossible. The results with regard to the number of trypanosomes found in the different parts of the alimentary canal were as follows:—

The proboscis.—In our experience *Trypanosoma gambiense* is never found in the proboscis of the fly, except immediately after an infected feed, when for a short time blood containing trypanosomes may be seen in the lumen of the proboscis.

Proventriculus.—This part of the alimentary canal is sometimes found empty when the remainder of the gut is swarming.

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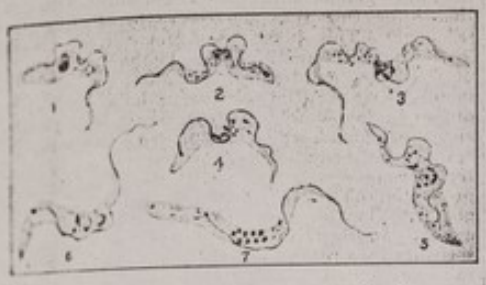
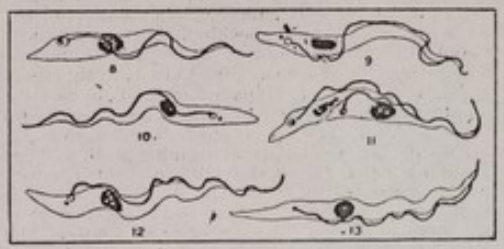


1-3.—Normal blood parasites (*Trypanosoma gambiense*).
4.—24 hours after ingestion by the fly.
5 and 6.—48 hours after ingestion by the fly.
7.—96 hours after ingestion by the fly.
1-7 represent the trypanosomes as they appear in the intestine of *Glossina palpalis* during the first few days.
1-3 are ordinary blood forms, as seen immediately after the fly has fed, and before any change has taken place.
4-7 represent the process of degeneration which takes place during the first four days. The body swells up, the nucleus breaks up, and the cytoplasm becomes vacuolated.

FIG. 16.

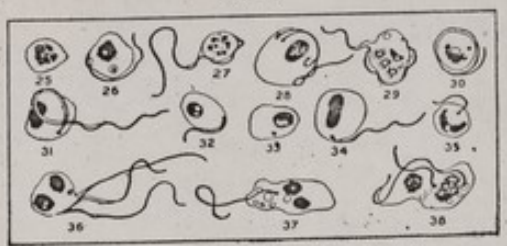


8.—*Trypanosoma gambiense* from fore-gut, 8 days after infected feed.
9.—*T. gambiense* from proventriculus, 14 days after infected feed.
10.—*T. gambiense* from fore-gut, 18 days after infected feed.
11.—*T. gambiense* from mid-gut, 25 days after infected feed.
12.—*T. gambiense* from mid-gut, 34 days after infected feed.
13.—*T. gambiense* from fore-gut, 44 days after infected feed.

FIG. 17.

Part of a mass of *Trypanosoma gambiense* from the mid-gut.

FIG. 18.

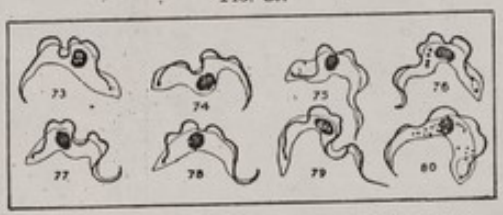


25.—*T. gambiense* from mid-gut, 8 days after infected feed.
26.—*T. gambiense* from fore-gut, 11 days after infected feed.
27 and 28.—*T. gambiense* from mid-gut, 16 and 17 days after infected feed.
29, 30, and 31.—*T. gambiense* from fore-gut, 17 and 18 days after infected feed.
32.—*T. gambiense* from hind-gut, 20 days after infected feed.
33 and 34.—*T. gambiense* from fore-gut, 24 days after infected feed.
35, 36, and 37.—*T. gambiense* from mid-gut, 24, 44, and 46 days after infected feed.
38.—*T. gambiense* from fore-gut, 46 days after infected feed.

FIG. 19.

45, 46, and 47.—*T. gambiense* from hind-gut, 10 days after infected feed.
48.—*T. gambiense* from fore-gut, 17 days after infected feed.
49.—*T. gambiense* from proventriculus, 30 days after infected feed.
50.—*T. gambiense* from mid-gut, 46 days after infected feed.
45-50 represent some of the more exaggerated types of degenerative forms. As will be seen from the drawings, they are huge, misshaped masses of protoplasm, multinucleated and, as a rule, multiflagellated.

FIG. 20.



73.—*T. gambiense* from salivary glands, 34 days after infected feed.
74.—*T. gambiense* from salivary glands, 42 days after infected feed.
75.—*T. gambiense* from salivary glands, 43 days after infected feed.
76, 77, and 78.—*T. gambiense* from salivary glands, 46 days after infected feed.
79 and 80.—*T. gambiense* from salivary glands, 56 days after infected feed.

When alluding, generally, in a previous part of this paper to the types of *Trypanosoma gambiense* found in the salivary glands, it was said that in the salivary glands, and here alone, the trypanosomes are found to revert to the normal type found in the blood. 73-80 illustrate this reversion. By comparing them with 1, 2, and 3 (Fig. 15), which represent normal blood trypanosomes, it will be seen that they are very similar to the short and stumpy form found in the blood.

Fore-, mid-, and hind-gut.—It is here that the greatest development of the trypanosomes is found. Among the extraordinary numbers and diversity of type it is difficult or impossible to find one's way. Generally speaking, the trypanosomes found during the first few days are merely degenerated blood forms. (Fig. 15.) After this there appears a type of trypanosome which remains dominant throughout the whole developmental period. (Fig. 16.) This is a long, moderately broad form, the protoplasm staining well, without granules or vacuoles, having an oval compact nucleus situated in the centre of the body, a small round micronucleus lying at some distance from the elongated snout-like posterior extremity. The undulating membrane is narrow and simple, and the flagellum proceeds little, if at all, beyond the protoplasm of the cell. The flagellum also appears very frequently to arise from a pink-coloured body situated near the micronucleus, an appearance never seen in the normal blood trypanosomes. This seems to be the normal developing type in the intestine of the fly. It is seen in all parts of the intestine and at all times. It forms masses of innumerable individuals alike in size and shape. (Fig. 17.) When a fresh supply of blood is taken by the fly, this type can be imagined to multiply with extraordinary rapidity. When the blood-supply runs low then this type can also be imagined as degenerating and disappearing just as rapidly. The host of divers forms which thus arise beggars description. Some are round or oval in shape, 3 or 4 microns in diameter, with or without flagellum, and from this simple form all shapes and sizes can be seen up to the huge shapeless mass of protoplasm, multi-nucleated and multi-flagellated. (Figs. 18 and 19.)

TABLE XI.—*To show Correlation between the Invasion of the Salivary Glands of* Glossina Palpalis *by* Trypanosoma Gambiense *and Infection by the Bite of the Fly.*

Experiment No.	No. of days after infective feed.	Bites of fly infective or non-infective.	Salivary glands.	Remarks.
1910	1	—	—	
1910	2	—	—	
1910	3	—	—	
1910	4	—	—	
1910	5	—	—	
1910	6	—	—	
1910	7	—	—	
1894	8	—	—	
1894	9	—	—	
2236	10	—	—	
1894	11	—	—	
1871	14	—	—	
1693	15	—	—	
1945	17	—	—	
1945	18	—	—	
1945	20	—	—	
1718	25	—	+	Blood-type not present.
1602	28	+	+	Blood-type present.
1801	30	—	—	
1945	31	—	—	
1760	34	+	+	" "
1769	36	—	—	
1712	42	+	+	" "
2034	43	+	+	" "
1549	44	+	+	" "
2034	44	+	+	" "
1706	51	—	—	
1566	53	+	+	" "
1651	56	+	+	" "

Salivary glands.—Trypanosomes did not appear in these glands until the twenty-fifth day, but that after this time they were usually present. (Fig. 20.) This invasion of the salivary glands is the most interesting phase in the development of Group A, and brings to mind the development of the malarial parasite in the mosquito. It differs in this, however, that whereas in the latter spores are found, which pass to the salivary glands across the body cavity, in the tsetse fly the trypanosomes apparently find their way by the proboscis and salivary duct or hypopharynx to the glands. They have never been found in the body cavity. Another curious fact is that as soon as the trypanosomes reach the salivary glands they revert to their original blood form and become infective. What causes or leads up to this reversion to the blood type in the salivary glands is quite unknown, but, as we shall see, the *Glossina palpalis* does not become infective until this invasion of the salivary glands has taken place. (See Table XI.)

From Table XI. it is seen that the salivary glands first became invaded 25 days after the infecting feed. In this case the monkey did not become infected. This may have been due to an accident, such as this particular fly not biting the monkey, or the invasion of the salivary glands only taking place after the fly had bitten, or to the fact that the blood-type of trypanosome was not present. With this exception all the other experiments, 12 in number, confirm the hypothesis that the fly does not become infective until the salivary glands are invaded.

Another point which comes out with striking clearness from this table is that in all the salivary glands from flies which gave a positive result trypanosomes similar to the short blood-type were invariably present. In this way it was gradually worked out and the discovery made that before *Glossina palpalis* and *Glossina morsitans* become infective with *Trypanosoma gambiense* or *Trypanosoma brucei* an invasion of the salivary glands and a reversion to the blood-type must take place.

Experiments to Ascertain if Trypanosoma Gambiense during its Development within Glossina Palpalis is Infective.

In Zululand it was observed, and at the time it seemed to be an astonishing fact, that when tsetse flies a short time after feeding on infected animals were chopped up and injected under the skin of healthy dogs no infection of nagana took place. It seemed strange that a fly, swollen out with blood in which numberless active trypanosomes could be seen under the microscope, if injected under the skin of a susceptible animal, should not give rise to the disease. As I left Zululand at this time I was unable to follow this observation up. But in Uganda I carried out experiments on the same lines with *Trypanosoma gambiense* and *Glossina palpalis*.

If tsetse flies (*Glossina palpalis*) are fed upon an animal whose blood contains trypanosomes the parasites can be seen living and moving in the contents of the intestines of all the flies for a few days, and in a small percentage (2 to 8 per cent.) of the flies active trypanosomes may continue to be found swarming in their intestines on any day between the seventh and fiftieth day, or even longer.

A series of experiments was undertaken in Uganda to ascertain if *Trypanosoma gambiense*

retained its power of causing sleeping sickness when inoculated subcutaneously into monkeys during its period of multiplication within the fly, especially during the interval of some 20 or 30 days in which the bites of infected flies had been proved to be harmless. The flies were fed upon a monkey whose blood contained many trypanosomes. After a predetermined time had elapsed the wings and legs of the infected flies were cut off, and the bodies were either chopped up or brayed in a mortar with saline solution. In most instances the gut was proved by microscopical examination to be heavily infected with trypanosomes before the whole chopped-up fly or flies were placed under the skin of the experimental animal. Of 29 experiments carried out with *Glossina palpalis* and *Trypanosoma gambiense*, 18 gave a positive result; they were almost uniformly successful up to 18 hours after the infected feed.

Further experiments proved that this parasite only retains its virulence for a period of about 18 hours after it has been swallowed by the tsetse fly. It then loses its power of infecting animals for a period of some 22 days. This means that during their period of development in the tsetse fly the trypanosomes lose their virulence and do not regain it until the developmental cycle is completed.

Summary.

Trypanosomes taken into the alimentary canal of tsetse flies retain their shape and infectivity for some 18 hours. They then degenerate and lose their power of infection, and as a rule have disappeared altogether from the majority of the flies by the fifth or sixth day. In a small percentage of flies, male as well as female, the trypanosomes maintain their position, they continue to multiply, and in a short time swarm in the alimentary canal of the fly. These multiplication forms bear little or no resemblance to the original trypanosomes. After some 20 days the developing flagellates find their way into the salivary glands, resume their original blood form, and regain their infectivity.

THE RESERVOIR OF TRYPANOSOMA GAMBIENSE (CONGO SLEEPING SICKNESS).

We have seen that in *Trypanosoma brucei*, the cause of "Nyasaland sleeping sickness," the reservoir of the virus was undoubtedly the wild game, and that in all probability man played a very small part, if any, in its spread. I have already described *Trypanosoma brucei* as essentially a parasite of animals, and *Trypanosoma gambiense* as a parasite of man. In Uganda cases of sleeping sickness were limited to the edge of the lake and the islands; I say *were* because the epidemic has died out. There was formerly a great deal of trade intercourse between the islands and the mainland. Under the shade of the trees, on the shore of the lake, the natives met, and here the fly was thickest. Now, we know that in the sleeping sickness area in Uganda anything from 20 to 50 per cent. of the lake shore population had sleeping sickness trypanosomes in their blood, and it therefore appeared extremely probable that the fly conveyed the virus from native to native.

We believed at first in 1903 that man was the only reservoir of practical account, and that if he was removed from the fly area the fly would soon—within a few days—become non-infective. When we returned to Uganda in 1908 we were much surprised to find the fly still infective, although the native population had been removed from the lake shore for some months. It was evident, therefore, that the fly had some other reservoir from which to draw the virus, and experiments were instituted to throw light on this. The cattle were first examined. These animals, as we have seen, are practically immune to sleeping sickness—that is to say, they show no signs of illness, but it was possible the trypanosome might live in their blood and be capable of infecting flies without affecting the health of the cattle.

Cattle as a Reservoir.

On Sept. 9th, 1909, an ox was inoculated with a quantity of blood containing large numbers of the parasites. The blood of the ox was examined daily, and 18 days after the injection was found to contain the trypanosome. Its identity was established by injecting a healthy monkey with some blood from this ox. The monkey showed *Trypanosoma gambiense* in its blood on the sixth day. Cattle are therefore capable of being infected with sleeping sickness by the injection of infected blood, although they show no signs of illness. Cattle were also infected by the bites of artificially infected flies. Next, freshly caught flies brought up to the laboratory from the lake shore were fed on healthy cattle. In the first experiment 2195 freshly caught flies were fed on an ox during 16 days, when the animal was found to be infected. In the second 1370 flies, and in the third 459 gave a positive result.

The next question to be asked was, Is it possible to infect tsetse flies by feeding them on these infected cattle, and afterwards to transmit the disease by means of these flies to healthy animals? Five experiments were carried out. Two of them were positive. It was therefore proved that laboratory-bred flies can be infected by feeding them on infected cattle, and afterwards the disease can be transmitted to healthy animals by means of these flies.

Finally, it had to be ascertained whether it was possible to find in the sleeping sickness area cattle which had been naturally infected. Seventeen cattle from various sources were examined with this point in view. Most of them came from places where the tsetse flies were numerous. In one out of the 17 the parasite was found. This ox came from the island of Kome in Lake Victoria where sleeping sickness was prevalent and where tsetse flies abound. A small quantity of its blood injected into a healthy monkey gave rise to sleeping sickness in the monkey and showed that *Trypanosoma gambiense* was really being dealt with.

The conclusion to the whole matter, then, was that in addition to man cattle may act as a reservoir of the virus of sleeping sickness.

Antelope as a Reservoir.

We next turned our attention to antelope. At this time, the beginning of 1910, man and his domestic animals had been removed from the lake shore of the mainland for some two years, and from the islands since the previous September. The effect of this depopulation had been to make an area along the northern shore of the lake virtually a game reserve, in which water-buck, bush-buck, reed-buck, Speke's tragelaphus, hippopotami, wild pig, and other game abound. Before this time we had a strong preconceived idea that cattle and antelope

were immune to sleeping sickness, and these preconceived ideas are stubborn things. But after the cattle experiments we set ourselves to ask the same questions regarding antelope. Eleven antelope in all were employed in this experiment—4 bush-buck, 6 reed-buck, and 1 water-buck. A cage of flies which was known to contain an infective fly or flies was fed on each animal daily for several days. Table XII. gives the results.

TABLE XII.—*Development of* Glossina Palpalis *in Antelope.*

No. of experiment.	Species of antelope.	No. of days infected flies fed.	No. of days before trypanosomes appeared.	Result. Positive.	Result. Negative.	Remarks.
2338	Bush-buck.	5	—	+		Trypanosomes never seen.
2357	Reed-buck.	12	25	+		
2359	,,	6	11	+		
2371	Bush-buck.	8	12	+		
2372	,,	6	8	+		
2378	Water-buck	8	—	+		Trypanosomes never seen.
2427	Reed-buck.	6	7	+		
2428	Bush-buck.	13	—	+		Trypanosomes never seen.
2429	Reed-buck.	8	9	+		
2431	,,	6	10	+		
2445	,,	7	8	+		

These experiments prove that antelope may readily be infected with sleeping sickness by the bites of infective flies.

The next question was, Can these infected antelope transmit the infection to clean laboratory-bred flies, and if these flies become infected can they transmit the virus to susceptible animals? Clean laboratory-bred *Glossina palpalis* were fed for several days on an infected antelope. After an interval of starvation of 24 hours or more the flies were transferred to healthy animals and fed daily. When the healthy animal showed *Trypanosoma gambiense* in its blood the experiment was stopped and the surviving flies were dissected as soon as possible. The result of 24 experiments carried out on these lines is given in Table XIII.

TABLE XIII.—*Result of Feeding Laboratory-bred Flies on Antelope Infected with Sleeping Sickness.*

No. of clean flies used.	Species of antelope flies fed on.	No. of days flies fed on antelope.	No. of days before flies became infective.	Result.	Remarks.
160	Bush-buck 2338.	12	29	+	Buck 2338 never showed *T. gambiense* in blood. In spite of this flies fed on it became infected 55 days after the buck's infection.
100	,,	8	28	+	
70	,,	6	29	+	
100	,,	8	39	+	
100	Reed-buck 2357.	7	41	+	Buck 2357 showed *T. gambiense* in its blood for 5 days only.
100	,,	8			
100	,,	5			
200	Reed-buck 2359.	6	44	+	Buck 2359 showed *T. gambiense* in its blood for 7 days only.
50	Bush-buck 2371.	6		—	Buck 2371 showed *T. gambiense* in its blood for 3 days only.
60	,,	6	29	+	
100	Bush-buck 2372.	8		—	Buck 2372 showed *T. gambiense* in its blood for 2 days only.
95	Water-buck 2378.	6	30	+	Buck 2378 never showed *T. gambiense* in its blood.
60	,,	6		—	
50	,,	4		—	
110	Reed-buck 2427.	6	24	+	Buck 2427 showed *T. gambiense* in its blood for 4 days only.
60	,,	4	33	+	
109	,,	6	30	+	
50	Bush-buck 2428.	7	28	+	Buck 2428 never showed *T. gambiense* in its blood.
50	Reed-buck 2429.	4	27	+	Buck 2429 showed *T. gambiense* in its blood for 3 days only.
100	,,	6	49	+	
55	Reed-buck 2431.	3	28	+	Buck 2431 showed *T. gambiense* in its blood for 4 days only. In spite of this, flies fed on it became infected 81 days after its infection.
90	,,	6	36	+	
100	,,	5	43	+	
50	Reed-buck 2445.	4		—	Buck 2445 showed *T. gambiense* in its blood for 6 days only.

The most significant of these experiments is the one in which it is shown that 55 days after the last feed of the infected flies on bush-buck 2328 the blood of the buck was still capable of infecting clean laboratory-bred flies, although *Trypanosoma gambiense* had been so scarce in the blood that they had never been seen microscopically.

These experiments show that antelope of the water-buck and bush-buck species, when infected with the trypanosome of sleeping sickness, can transmit the infection to clean laboratory-bred *Glossina palpalis*. The infected antelope's blood was in one case capable of giving rise to infection for at least 81 days, and in another for at least 55 days. These experiments further show that the flies when infected are capable of transmitting the disease to susceptible animals.

From these experiments on antelope the curious fact seems to emerge that a higher proportion of flies become infected by feeding on infected antelope in whose blood the parasites are scanty than, for example, on infected monkeys, whose blood swarms. Another curious fact is that even when trypanosomes were never found by microscopical examination in the blood of an antelope, flies fed on the antelope became infected. It would almost lead one to believe that the trypanosomes exist in the blood of these animals in some other less easily recognisable form than the ordinary adult trypanosome form.

The next thing we set ourselves to do was to find out if the antelope living in the fly area are naturally infected with sleeping sickness. Positive evidence on this point would naturally complete the chain of evidence proving that antelope living in the fly area may act as a reservoir of the virus of sleeping sickness. So far it had only been proved that they were potential hosts. The easiest method by which it could be proved that they are naturally infected would be the old one of shooting the animals and at once sending samples of their blood into some healthy area where the blood could be injected into healthy susceptible animals. But those who know the local conditions in Uganda will recognise the difficulty of doing this. The cover is so thick at the edge of the lake that it is exceedingly difficult to see the game, the sun is almost unbearably hot, the country very difficult, and the exposure to the bites of the fly very great. It may be said at once that we were only able to shoot five antelope on the lake shore. The blood of these when injected into susceptible animals gave negative results. A large drive was being organised which might have thrown the desired light on this subject, but unfortunately the Commission was obliged to leave the country before the drive could take place. It was therefore perforce left to a later worker to solve this difficult problem.

In 1911 Mr. H. L. Duke took the question up. Four years had now elapsed since the lake shore was depopulated, and two years since the islands had been emptied of their population. He chose the uninhabited island of Damba for the experiment. This he did because the Commission

had shown in 1910 that the flies on the island were still infective, and again the same result was obtained in May, 1911, by Dr. G. D. H. Carpenter. With the exception of certain patches of papyrus, practically the whole shore-line of the island swarms to a greater or less extent with fly. At one part there is the famous fly-beach from which for several years some thousands of pupæ have been brought monthly to the sleeping sickness camp at Mpumu. The only species of antelope found on the islands of Lake Victoria is the sitatunga (*Tragelaphus spekei*), a species of bush-buck adapted for living in marshes. Mr. Duke shot four sitatunga on the island of Damba, and from these *Trypanosoma gambiense* was obtained. I cannot say whether all four antelope harboured the parasite, because the blood of the first two was injected into one monkey and the blood of the last two into another. Both monkeys showed the *Trypanosoma gambiense*. Mr. Duke examined these trypanosomes with meticulous care in order to exclude any possible source of fallacy, and there cannot be any reasonable doubt that the sitatunga on Damba Island were acting at that time as a reservoir of this parasite.

Another proof that the trypanosome found in the sitatunga was really *Trypanosoma gambiense* has lately been given by Mr. Duke. He states that two of the fly boys who have during the last three years worked with Dr. Carpenter on the islands have developed sleeping sickness of the Uganda type, and trypanosomes have been demonstrated in their glands. These boys have only been exposed to the bite of *Glossina palpalis*, as they had for 18 and 30 months respectively resided on the lake shore and islands, where there are no other species of tsetse fly. This shows conclusively that *Trypanosoma gambiense* still exists in these lake shore and island flies, five years after the removal of the population, and is another striking proof that the antelope are acting as a reservoir. Taking everything into consideration, then, we may look on it as proved that the antelope on the shores of Lake Victoria act as a reservoir of the virus of sleeping sickness, and that this accounts for the fact that the flies have retained their infectivity in spite of the removal of the native population from the lake shore and the islands.

The prophecy of the Commission that the fly would become harmless shortly after the natives were removed from the lake shore has unfortunately proved wrong, and before the islands are repopulated some other measure will have to be taken to get rid of the fly danger.

DONATIONS AND BEQUESTS.—The late Mr. William Balls, of Tynemouth, left by will £1000 to the Tynemouth Victoria Jubilee Infirmary.—By the will of the late Mr William Hurst, of Wakefield, the testator left £1000 to the Clayton Hospital at Wakefield.—By will the late Mr. Archibald Anderson, of London and Bournemouth, has left £1000 each to the Hospital for Paralysis and Epilepsy, Queen-square, W.C., and the London Homœopathic Hospital.—The Chelsea Hospital for Women has received a further sum of £1000 from the executors of the T. S. Whitaker estate towards the rebuilding fund.

DEATH OF MR. R. D. G. HALL, LITTLEHAMPTON.—The death occurred at Bexhill, on June 27th, of Mr. Robert Donnerville Grant Hall, who had resided at Littlehampton for 40 years. He became M.R.C.S. Eng. in 1878, and as a ship's surgeon had travelled nearly all over the world. At one time he was private surgeon to H.H. Maharajah of Dhar. Mr Hall was 58 years of age.

LOSS OF PERSONALITY FROM "SHELL SHOCK."

BY ANTHONY FEILING, M.D. CANTAB., M.R.C.P. LOND.,

TEMPORARY ASSISTANT PHYSICIAN AND CASUALTY PHYSICIAN TO ST. BARTHOLOMEW'S HOSPITAL; ASSISTANT PHYSICIAN TO THE METROPOLITAN HOSPITAL AND THE HOSPITAL FOR EPILEPSY AND PARALYSIS, MAIDA VALE.

THE present campaign in Flanders has made such unexampled demands on the nervous system of the soldier that we are not surprised to meet with many cases of neurasthenia, hysteria, and various disturbances of the special sense organs. Numerous cases of blindness, deafness, dumbness, and loss of memory have already been reported, as well as the more common cases of functional paralysis of a limb or limbs, and all have aroused considerable interest and discussion as to their nature and appropriate treatment. The majority of cases of loss of memory hitherto recorded have been generally of a more or less transitory nature; moreover, the period of time covered by the amnesia has been, as a rule, only that just before, during, and immediately following the trauma, whether such were physical or mental, or both.

The case which I wish to record here is one of exceptional interest. It amounts, in fact, to a complete dissociation or obliteration of personality. The term "double personality" is hardly applicable, as will appear from subsequent remarks. It may be regarded as a case of loss of memory or amnesia of such a degree that all conscious memories of the patient's life, as well as the countless memories forming his knowledge of letters, objects, and life in general were completely suppressed. In order to follow the case more clearly and the better to appreciate the interesting problem presented by the patient it will perhaps be best to take the case exactly as it appeared to my observation.

The patient, aged 24, a bandsman in the 2nd Battalion Wiltshire Regiment, was admitted to the Hospital for Epilepsy and Paralysis, Maida Vale, on Jan. 21st, 1915, under the care of Dr. H. Campbell Thomson, who later kindly transferred him to my charge. From information supplied it appeared that the history was as follows. On an uncertain date—some time at the end of October, 1914—the patient was buried in a trench near Ypres. He was rescued and eventually transferred to the 2nd Western General Hospital, Manchester. Major Wilson has kindly supplied me with the following note as to his condition at that time:—"He speaks quite sensibly, understands, and remembers anything which took place since he was buried, but as regards matter previous to that his mind was blank. He was admitted to this hospital on Oct. 31st, 1914. He did not know his own father or relatives. He was quite able to speak while here, but was slightly deaf. This defect disappeared."

On physical examination he appeared perfectly healthy. The only abnormality observed was a certain nervous twitching of the eyelids and facial muscles. When questioned he gave the following peculiar account of himself. "I came to myself in a strange place which I was told was Manchester. I could not remember anything at all. I think I could speak all right." Attention was good; he was polite, and seemed to try to answer before saying "I can't remember." There was no defect of speech. He could read and write quite well; he

The Croonian Lectures
ON
TRYPANOSOMES
CAUSING DISEASE IN MAN AND DOMESTIC ANIMALS IN CENTRAL AFRICA.

Delivered before the Royal College of Physicians of London on June 17th, 22nd, 24th, and 29th, 1915,

By Sir DAVID BRUCE, C.B., F.R.S.,
M.B. Edin., F.R.C.P. Lond.,
SURGEON-GENERAL, A.M.S.

LECTURE IV.[1]

Delivered on June 29th.

MR. PRESIDENT AND GENTLEMEN,—In this concluding lecture I intend to sketch briefly the outstanding features of the trypanosomes belonging to Groups B and C.

So far as we are aware, none of these trypanosomes attack man. They are therefore of less importance to us than the two species already described.

B.—THE TRYPANOSOMA PECORUM GROUP.

I.—TRYPANOSOMA PECORUM.

The first of this small group, which only consists of two species, is *Trypanosoma pecorum*. It is probably the most important trypanosome disease of domestic animals in Central Africa.

Morphology.

(See Lecture I.) shows the general appearance of this trypanosome. It is the smallest of the African pathogenic trypanosomes, varying from 15 to 18 microns in length, with an average of 16 microns. Its breadth averages 1·96 microns. The species is monomorphic, and short and stout forms. The contents of the cell are generally vacuolated. The nucleus is oval in shape and situated about the middle of the body. The micronucleus is small and round and situated near to, but not at, the posterior extremity, and often appears to project beyond the edge of the trypanosome. The undulating membrane is simple but well developed, and there is no free flagellum. There ought to be no difficulty in recognising this species from morphology alone. If one or two have been drawn and measured the average length will separate it from its neighbour *Trypanosoma nanum*. Another small trypanosome, *Trypanosoma pecorum* differs in shape and in having a free flagellum.

Animals Susceptible to Trypanosoma Pecorum.

With regard to the animals attacked by this trypanosome. This is essentially a disease of the horse, donkeys, oxen, goats, sheep, and pigs, sometimes. One peculiarity about *Trypanosoma pecorum* is, that it readily loses its virulence for certain animals by passage through certain other animals. For example, if this species—which is 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 former animals. This has given rise to the erroneous belief that a species, *Trypanosoma nanum*, exists. *Trypanosoma nanum* is in truth nothing but a strain of *Trypanosoma pecorum*, which has lost its virulence for the other animals by its passage through the goat or allied species. (Table XIV.)

TABLE XIV.—*The Average Duration of Life, in Days, of Various Animals Infected by* Trypanosoma Pecorum.

—	Donkey.	Cattle.	Goat.	Pig.	Monkey.	Dog.	Guinea-pig.	White rat.
Average duration in days	87	121	55	21	129	48	41	33
Number of animals employed ...	1	4	59	1	11	57	5	10

The Percentages of Recoveries in Various Animals from Trypanosoma Pecorum *Infection.*

Percentages...	80	35	12	0	0	1	0	0
Number of animals employed ...	5	17	70	1	11	63	5	10

This trypanosome does not seem to be very fatal to horses, mules, or donkeys. In Nyasaland there was no opportunity of testing it on horses, but out of five donkeys four recovered. Two-thirds of the cattle, and seven-eighths of the goats succumbed.

The Carrier of Trypanosoma Pecorum.

The chief carrier of *Trypanosoma pecorum* is *Glossina morsitans*. I am not aware of this trypanosome ever having been found in nature in *Glossina palpalis*. In Uganda, where we made many feeding experiments with the wild *Glossina palpalis*, in not a single instance did a *Trypanosoma pecorum* infection take place. In Nyasaland, on the other hand, this parasite was the commonest of the trypanosomes with which *Glossina morsitans* was infected, as the following table will show (Table XV.).

TABLE XV.—*The Proportion of Tsetse Flies* (Glossina Morsitans) *Naturally Infective with* Trypanosoma Pecorum, *in Nyasaland.*

1912.	No. of flies fed.	Monkey.	Dog.	Goat.	1912.	No. of flies fed.	Monkey.	Dog.	Goat.
Jan. 20th ...	296	—		—	May 14th ...	250	—	+	+
,, 24th ...	370	—		+	,, 17th ...	190		+	—
,, 29th ...	280	—		+	,, 24th ...	113		+	+
Feb. 2nd ...	295	—		+	,, 29th ...	120	—	+	+
,, 9th ...	220	—		+	,, 29th ...	230	—	+	+
,, 13th ...	200	+		—	,, 29th ...	320		+	+
,, 16th ...	195		—	—	,, 29th ...	240	+	+	+
,, 21st ...	170		—	—	,, 29th ...	100		+	+
,, 26th ...	170		—	—	,, 31st ...	175	—	+	+
March 2nd ...	140		—	—	June 2nd ...	300		+	—
,, 9th ...	165		+	—	,, 6th ...	210	+	+	+
,, 14th ...	100		—	—	,, 7th ...	230	—	+	+
,, 17th ...	160		+	+	,, 11th ...	160	—	+	+
,, 22nd ...	205		+	+	,, 18th ...	135	—	+	+
April 3rd ...	135		+	+	,, 25th ...	90	—	—	+
,, 10th ...	215	—	+	—	July 3rd ...	95		+	+
,, 15th ...	330	—	+	+	Sept 25th ...	70	+		
,, 18th ...	200	—	+	+	,, 27th ...	25	—		
,, 18th ...	180	—	+	—	Oct. 29th ...	87	—	—	+
,, 23rd ...	230	—	+	—	Nov. 5th ...	145		—	—
,, 23rd ...	140	+	+	+	,, 11th ...	150	—	+	+
,, 26th ...	100	—	+	+	,, 18th ...	157	—	+	—
,, 27th ...	260	—	+	+	,, 21st ...	95	—	—	—
May 3rd ...	155	+	+	—	,, 25th ...	180	—	—	+
,, 3rd ...	96	—	+	+	Dec. 3rd ...	180	+	+	+
,, 8th ...	330	—	—	+	,, 6th ...	198	+	—	—
,, 9th ...	120	—	+	+	,, 11th ...	156	—	—	+
,, 13th ...	60	—	—	—	,, 16th ...	113	+	+	+

[1] I., II., and III. were published in THE LANCET of June 12th, July 3rd (p. 1), and July 10th (p. 55) respectively.

It will be seen from this table that there were 56 experiments, and 10,081 tsetse flies (*Glossina morsitans*) were employed. In the 56 experiments *Trypanosoma pecorum* was found 46 times, more than twice as often as *Trypanosoma brucei*. Nine monkeys, 34 dogs, and 35 goats were infected. This gives a proportion of 4·6 per 1000 flies infected with *Trypanosoma pecorum*. It is therefore abundantly evident that *Glossina morsitans* is a carrier of this trypanosoma under natural conditions. But when once this disease has infected a herd there is some circumstantial evidence available to show that the infection may be spread by means of the ordinary cattle or buffalo flies, the *Tabanidæ*. The ordinary horse-fly of England belongs to this genus, and it is a matter of common experience that these flies give a severe bite or stab, as a rule drawing blood.

The *Tabanidæ* are in their habits and distribution quite different from the tsetse flies. At a particular place for the greater part of the year they may be absent or rare, but at certain times they suddenly appear in enormous numbers, only to disappear again in a few weeks. When swarming in this way they are a veritable pest to cattle. The flies feed mostly at the hottest time of the day, and the cattle, to protect themselves, crowd together so as to expose as small a surface of their bodies as possible. If there are any infected animals in the herd the conditions could not be more favourable for mechanical transmission. The infected animals are close beside the healthy, and the flies pass from one to another almost instantaneously.

In Uganda we had an opportunity of studying a sudden epidemic of this disease in a herd of milch cattle. In the course of two months 34 of the cows died out of a herd of 300. The evidence was all against this epidemic having been caused by tsetse flies. For four months we had as many as 100 fly boys scouring the district for biting flies, but not a single tsetse fly was captured. We therefore came to the conclusion that one or more infected animals having got accidentally into the herd, the infection was spread by one of these swarms of *Tabanidæ*. As soon as the affected animals were removed from the herd the epidemic ceased.

Another example of the same kind occurred among our experimental cattle at Mpumu in Uganda. The *Tabanidæ* which had been rare suddenly appeared in swarms. They were first seen in the valley to the west of the hill in September, 1909, and a month later in the valley to the east. Soon after this the cattle, which had shown no signs of disease during the previous year, were found to be suffering from *Trypanosoma pecorum*. Those which grazed in the valley to the west were first affected, and afterwards those which grazed to the east of the hill. Another writer, George E. Owen, has come to the same conclusion. He states that between 1908 and 1913 some 2500 to 3000 head of cattle died from trypanosome disease in the Barotse Reserve of Northern Rhodesia, though this district is free from *Glossina morsitans*. The mortality began each year in February and practically ceased after June. December and March are the months when flies are most numerous. In 1912 Mr. Owen was sent to investigate and was able to keep a herd of 800 without loss through 1913. The animals were carefully watched for six months during the season when the flies were scarce and all the infected or suspected cattle removed before the flies a became numerous. It may therefore, I think, be cluded with a fair degree of certainty that the panosome disease caused by *Trypanosoma pecor* can be carried from sick to healthy animal biting flies other than *Glossinæ*. What hap probably is this. One or more oxen previ exposed to the bites of tsetses are introduced the herd living in a tsetse-free district, and these few infected animals the disease is spre the *Tabanidæ*. I must apologise for discussing point at such a length, but it is an important and shows how necessary it is that cattle ow living outside tsetse areas should keep strict w on their herds in order to prevent the presen trypanosome-infected cattle among them. should include a microscope in their outfit.

The Cycle of Development of Trypanosoma Pec *in* Glossina Morsitans.

This trypanosome belongs to Group B, in w development takes place first in the gut and passes forward into the labial cavity of the boscis, and finally reaches the salivary duc hypopharynx where the trypanosomes rever the original blood form and become infec There is no infection of the salivary gl (Table XVI.)

TABLE XVI.—*The Development of* Trypanosoma Pecor Glossina Morsitans (*Laboratory-bred Flies*).

Date.	Experiment.	No. of flies used.	Experiment positive or negative.	No. of infected flies found.	No. of days before flies became infective.	Mea temper
1912.						
May 16th ...		22	+	4	53	69° F.
July 2nd ...	524	20	+	2	37	65° F.
1913.						
Jan. 3rd ...	1732	60	—	0	—	84° F.
,, 7th ...	1737	40	+	3	19	84° F.
Feb. 10th ...	1853	25	+	5	24	84° F.
,, 24th ...	1950	33	+	6	21	84° F.
April 29th ...	2115	40	—	4	—	84° F.

Seven experiments were carried out laboratory-bred flies. Five were positive an negative. 240 flies were used and 24 in flies found (10 per cent.). The first two e ments were carried out at the ordinary tempe of the laboratory; in the others the flies kept in the incubator. It would appear these five positive experiments that a per from 19 to 53 days may elapse before the of development of *Trypanosoma pecoru Glossina morsitans* is complete and the fly be infective.

Result of the Dissection of the Infected Fl

Table XVII. gives the result of the dis of the 20 infected flies found in the p experiments. The second column give number of days between the first feed of t and its death and dissection. In experime and 524 there was no separate examination hypopharynx; it is included in the gener proboscis. It was only when the importance hypopharynx became evident that an exam of the separate parts of the proboscis was ma not a single fly was any invasion of the s glands noted, but it will be seen that in

experiment trypanosomes are found in the
rynx.

XVII.—*Result of the Dissection of Infected Flies. Laboratory-bred Flies. Positive Experiments.*)

	Proboscis.		Proventriculus	Crop.	Fore-gut.	Mid-gut.	Hind-gut.	Salivary glands.
	–		–	–	+	+	+	–
	–		–	–	++	++	++	–
	–		–	–	++	++	++	–
	++		++	++	++	++	++	–
	–		–	–	–	++	++	–
	+		+	–	++	++	++	–
	Labial cavity.	Hypopharynx.						
	++	++	++	++	++	++	++	–
	+	–	+	–	++	++	+	–
	++	++	++	–	++	++	++	–
	++	++	++	–	++	++	++	–
	–	–	–	–	+	++	+	–
	+	–	+	–	++	++	++	–
	++	++	+	–	++	++	++	–
	++	++	+	–	++	++	++	–
	–	–	+	–	++	++	++	–
	++	++	–	–	++	++	++	–
	–	–	–	–	–	+	–	–
	++	++	+	–	++	++	++	–
	++	++	+	–	++	++	++	–
	++	++	++	–	++	++	++	–

h for the positive experiments, let us see
the result of the dissection of the infected
the negative experiments. (Table XVIII.)
of the infected flies had the development
the hypopharynx, and consequently none
s had become infective.

VIII.—*Result of the Dissection of the Infected Flies. aboratory-bred Flies. Negative Experiments.*)

	Proboscis.		Proventriculus.	Crop.	Fore-gut.	Mid-gut.	Hind-gut.	Salivary glands.
	Labial cavity.	Hypopharynx.						
	–	–	–	–	–	+	–	–
	–	–	–	–	–	++	–	–
	+	–	+	–	+	++	++	–
	–	–	+	–	+	++	+	–

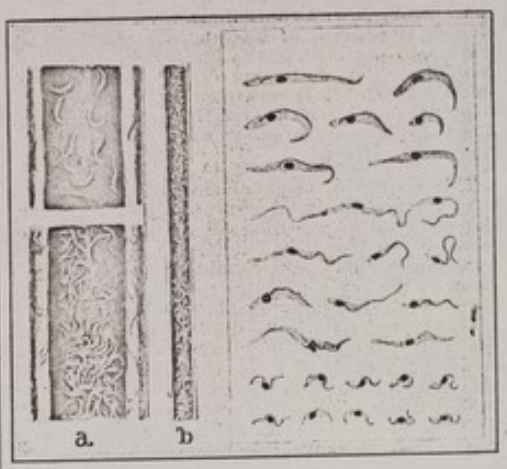
From a consideration of these tables it will be
that in *Trypanosoma pecorum* the develop-
takes place at first in the intestine, then
forward into the labial cavity, and finally
the hypopharynx, and there is completed.

The Type of Trypanosomes found in the Infected Flies.

Fig. 21 represents the developmental forms of
pecorum found in the labial cavity of
wardiana. In regard to the forms found
the intestine, it may be said that these are
distinguishable from the developmental forms of
pathogenic trypanosomes. The first seven
represent early forms in the labial cavity.
were seen adhering singly by their flagella to
the labrum.

The next group contains the ordinary forms
clinging by their flagellar ends to the
It will be seen that they have assumed the
stage, a stage which seems to be a *sine*
in the final stages of the cycle of develop-
of all the pathogenic trypanosomes, and the
of which is still obscure. The small
forms are from the hypopharynx of dead
flies, and also from living infective flies
induced to salivate on a cover-glass. They represent the final stage in the cycle of development and are the only infective forms. On the same figure are seen drawings, at a magnification of a little over 500 diameters, of the labrum and hypopharynx of a fly

FIG. 21.



Developmental forms of *Trypanosoma pecorum* found in the labial cavity and hypopharynx of infected flies. a, Labrum. b, Hypopharynx.

infected with this trypanosome. While the labial cavity is seen to contain clusters of large ribbon-like trypanosomes, the hypopharynx is swarming with the small infective forms. From these drawings the ease and facility with which a tsetse fly can infect an animal will be readily understood.

Another way of showing how easy it is for a fly to infect an animal is to induce an infected fly to salivate on a cover-glass. If a hungry fly is placed on a large cover-glass which covers a man's finger the fly will attempt to bite through the glass, and in doing so will smear it with its saliva. If this is then stained and examined under a microscope thousands of trypanosomes will be seen.

TABLE XIX.—*The Species of Animals dealt with, the Total Number Examined, the Number found Infected, and the Species of Trypanosome by which they were Infected.*

Animal.	Total No. examined.	No. found infected.	Tryp. brucei.	Tryp. pecorum.	Tryp. simiæ.	Tryp. capræ.	Tryp. ingens.
Eland	10	6	0	6	0	1	0
Sable	5	0	0	0	0	0	0
Water-buck...	13	9	3	1	0	8	0
Koodoo	3	2	0	2	0	0	0
Bush-buck	10	7	0	7	0	1	0
Hartebeeste	35	6	5	1	0	0	0
Reed-buck	19	12	3	1	0	9	1
Oribi	26	4	1	1	0	1	1
Duiker	7	2	1	0	0	0	1
Buffalo	9	2	0	2	0	0	0
Lion	1	0	0	0	0	0	0
Hyæna	3	2	0	2	0	0	0
Elephant	2	0	0	0	0	0	0
Warthog	35	7	1	3	3	0	0
Wild cat	3	0	0	0	0	0	0
Porcupine	1	0	0	0	0	0	0
Total	180	59	14	28	3	20	3

The Reservoir of Trypanosoma Pecorum.

Table XIX. represents the number of times *Trypanosoma pecorum* was found among the 180 wild animals examined in Nyasaland and the species of game which harboured it. It will be seen that 26 animals among the 180 harboured this parasite (14·4 per cent.), and the eland, the koodoo, the bush-buck, and the buffalo were the greatest sinners, 60 per cent. of the eland, 66 per cent. of the koodoo, 70 per cent. of the bush-buck, and 22 per cent. of the buffalo having *Trypanosoma pecorum* in their blood. It is rather curious that *Trypanosoma pecorum* has picked out the animals in whose blood *Trypanosoma brucei* was absent.

II.—TRYPANOSOMA SIMIÆ.

This species of trypanosome is remarkable for the virulence it displays towards the monkey 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 it affects goats and sheep, although oxen and antelope escape.

Trypanosoma simiæ is similar to *Trypanosoma pecorum* in the rapidity with which its virulence becomes modified. If a cage containing wild tsetse flies (*Glossina morsitans*) infected with this parasite is placed on a monkey or a goat, both animals take the disease, and the monkey in such an acute form that the average duration of disease is only a few days. But if the attempt is made to pass this species of trypanosome from an infected goat to a healthy monkey by the inoculation of the goat's blood the experiment usually fails, showing that a short sojourn in the blood of the goat has almost nullified the virulence of the parasite for the monkey.

Another interesting point in regard to this species is, that as far as is known, the warthog is the only animal among the wild game which harbours it. It is probable that it will also be found in the blood of the bush-pig, but that has not been done yet.

Morphology.

Trypanosoma simiæ is longer than *Trypanosoma pecorum*. It is monomorphic, varying from 14 to 24 microns in length, with an average of 18 microns. The trypanosomes are fairly uniform in shape; the body is elongated, undulating, and frequently extends in a straight line; the contents of the cell are clear and free from granules; the nucleus is oval and situated about the middle of the body; the micronucleus is small and round, situated almost invariably about 1½ microns from the posterior extremity; and the undulating membrane is well developed and thrown into bold undulations.

It is difficult to say whether this species has a free flagellum or not. By careful staining and good illumination it would seem in most cases as if the undulating membrane extended to the tip of the flagellum. In some preparations, however, the last two or three microns of the flagella appear to be free. (See Lecture I., Fig. 5.)

Animals Susceptible to Trypanosoma Simiæ.

Table XX. shows the average duration of life in various animals infected by *Trypanosoma simiæ* (mixed infections are not included), also the percentages of recoveries from the disease. It will be seen that the ox, antelope, baboon, dog, rabbit, guinea-pig, and rat are refractory.

In the whole range of the trypanosome diseases of animals there is surely nothing so striking as the rapidly fatal action of *Trypanosoma simiæ* on the domestic pig. In nine experiments the a duration was only 5·3 days. This not from th of the appearance of the trypanosome in the

TABLE XX.—*The Average Duration of Life in Various infected by* Trypanosoma Simiæ, *Nyasaland.* (*Mi tions not included.*)

—	Ox.	Antelope.	Goat and sheep.	Pig.	Baboon.	Monkey.	Dog.	Rabbit.
Average duration in days	R.	R.	46·6	5·3	R.	10·8	R.	R.
No. of animals employed	4	5	5	9	3	24	21	1

The Percentages of Recoveries in Various Animals from T soma Simiæ Infection. (*Mixed infections inclu*

Percentages	R.	R.	37·5	0·0	R.	14·3	R.	R.
No. of animals employed	4	5	32	13	3	35	21	1

R. = Refractory.

but from the date of the infection. Furth rapid action is not the result of an exalta virulence by numerous passages through t but natural to the trypanosome.

The Carrier of Trypanosoma Simiæ.

The carrier of *Trypanosoma simiæ* in Ny is *Glossina morsitans*. Table XXI. gives t

TABLE XXI.—*The Proportion of Tsetse Flies* Morsitans) *Naturally Infective with* Trypanosom *in Nyasaland.*

1912.	No. of flies fed.	Monkey.	Dog.	Goat.	1912.	No. of flies fed.	Monkey.
Jan. 20th ...	296	+		—	May 14th ...	250	+
,, 24th ...	370	+		—	,, 17th ...	190	
,, 29th ...	280	+		+	,, 24th ...	113	
Feb. 2nd ...	295	+		+	,, 29th ...	120	-
,, 9th ...	220	+		+	,, 29th ...	330	-
,, 13th ...	200	+		—	,, 29th ...	320	
,, 16th ...	195		—	—	,, 29th ...	240	-
,, 21st ...	170		—	—	,, 29th ...	100	
,, 26th ...	170		—	+	,, 31st ...	175	+
March 2nd ...	140		—	—	June 2nd ...	300	
,, 9th ...	165		—	—	,, 6th ...	210	-
,, 14th ...	100		—	—	,, 7th ...	230	-
,, 17th ...	160		—	—	,, 11th ...	160	-
,, 22nd ...	205		—	+	,, 18th ...	135	-
April 3rd ...	135		—	—	,, 25th ...	90	-
,, 10th ...	275	+	—	—	July 3rd ...	95	
,, 15th ...	330	+	—	+	Sept. 25th ...	70	-
,, 18th ...	200	+	—	—	,, 27th ...	25	-
,, 18th ...	180	+	—	+	Oct. 29th ...	87	-
,, 23rd ...	230	+	—	—	Nov. 5th ...	145	
,, 23rd ...	140	—	—	—	,, 11th ...	150	-
,, 26th ...	100	+	—	+	,, 18th ...	157	-
,, 27th ...	260	+	—	—	,, 21st ...	95	
May 3rd ...	155	+	—	—	,, 25th ...	130	-
,, 3rd ...	95	—	—	—	Dec. 3rd ...	130	-
,, 8th ...	330	+	—	—	,, 6th ...	190	-
,, 9th ...	120	+	—	—	,, 11th ...	156	-
,, 13th ...	50	—	—	+	,, 16th ...	115	-

portion of flies naturally infected with thi There were 56 experiments and 10,081 t were employed. In the 56 experiments *soma simiæ* was found 34 times (60·7 p Twenty-six monkeys and 17 goats were

gives a proportion of 3·4 per 1000 flies infected with *Trypanosoma simiæ*. It must be remembered that warthogs were numerous in the sleeping sickness area, Nyasaland, which accounts for the high proportion of infected flies.

The Cycle of Development of Trypanosoma Simiæ *in* Glossina Morsitans.

This species belongs to Group B and the cycle of development is similar to that which has already been described as occurring in *Trypanosoma*

The Reservoir of Trypanosoma Simiæ.

The number of times *Trypanosoma simiæ* was found among the 180 wild animals examined in Nyasaland and the species of game which harboured it are given in Table XIX. It will be seen that only 3 animals among the 180 harboured this parasite (1·7 per cent.). This is, of course, due to the fact that it is only the warthog among the wild game which acts as a reservoir. Thirty warthogs were examined and 3 were found to be infected (10 per cent.).

C.—THE TRYPANOSOMA VIVAX GROUP.

The three species forming this group have a close family resemblance, and but for size might be included in one species.

I.—TRYPANOSOMA VIVAX.

This is the cause of one of the most important cattle diseases in Uganda. We did not meet with it in Nyasaland, where its place seems to be taken by *Trypanosoma capræ*. It is, however, widely distributed in Central Africa. It has been reported from Senegal and the Sudan in the north to Zululand in the south. It is easily recognised on account of its extreme activity during life, its characteristic morphology in stained specimens, and the fact that it only affects horses, cattle, goats, and sheep, while monkeys, dogs, rabbits, guinea-pigs, rats, and mice are refractory. In Uganda the tsetse flies on the lake shore were found to be infected with it, and it was also found in the blood of a bush-buck shot at the same place at which the flies were collected. (See Lecture I., Fig. 6.)

II.—TRYPANOSOMA UNIFORME.

This trypanosome resembles *Trypanosoma vivax* very closely except that it is smaller. Up to the present it has only been found in Uganda. Its carrier there is *Glossina palpalis*, and its reservoir the wild game on the lake shore. (See Lecture I., Fig. 5.)

III.—TRYPANOSOMA CAPRÆ.

This species has only been reported up to the present from Lake Tanganyika and Nyasaland. It, like the other two species belonging to this group, only affects cattle, sheep, and goats. Monkeys, dogs, and smaller experimental animals are immune.

Morphology.

The general appearance of this parasite is shown in Fig. 7, Lecture I. During life, like the other members of the group, it is characterised by its extreme mobility. It is a monomorphic species varying from 18 to 32 microns in length, the greatest number of individuals being 25 microns long. Measured across the broadest part *Trypanosoma capræ* averages three microns in breadth (maximum, 4·5 microns, minimum 1·75). It differs from *Trypanosoma vivax* in that it is more heavily built and altogether has a larger and clumsier appearance. The posterior half is swollen and its end is bluntly angular or rounded; the anterior extremity is narrower and pointed; the contents of the cell are clear, with a delicate alveolar structure, and free from vacuoles and granules; the nucleus is oval, compact, and lying about the middle of the body; the micronucleus is large and round, situated, as a rule, close to the posterior extremity; and the undulating membrane is more developed than in *Trypanosoma vivax*, and is thrown into bolder folds and undulations. There is a well-marked free flagellum which averages 6·5 microns in length (maximum 9·4 microns, minimum 4).

Susceptibility of Animals to Trypanosoma Capræ.

Table XXII. gives the average duration of the disease and the percentages of recoveries in various experimental animals:—

TABLE XXII.—*The Average Duration of Life in Various Animals Infected by* Trypanosoma Capræ, *Nyasaland.*

—	Ox.	Goat.	Sheep.	Monkey.	Dog.	Guinea-pig.	Rat.
Average duration in days	—	56·5	115·3	R.	R.	R.	2
Number of animals employed... ...	—	19	3	12	12	2	2

The Percentage of Recoveries in Various Animals from Trypanosoma Capræ *Infection.*

Percentages	100	32·2	25	R.	R.	R.	R.
Number of animals employed... ...	2	28	4	12	12	2	2

R. = Refractory.

The Carrier of Trypanosoma Capræ.

The carrier of *Trypanosoma capræ* in Nyasaland is *Glossina morsitans*. Table XXIII. shows the

TABLE XXIII.—*The Proportion of Tsetse Flies* (Glossina Morsitans) *Naturally Infective with* Trypanosoma Capræ *in Nyasaland.*

1912.	No. of flies fed.	Monkey.	Dog.	Goat.	1912.	No. of flies fed.	Monkey.	Dog.	Goat.
Jan. 20th ...	296	—		—	May 14th ...	250	—	—	+
,, 24th ...	370	—		+	,, 17th ...	190		—	+
,, 29th ...	280	—		—	,, 24th ...	113		—	+
Feb. 2nd ...	295	—		+	,, 28th ...	120	—	—	—
,, 9th ...	220	—		+	,, 29th ...	230	—	—	—
,, 13th ...	200	—		+	,, 29th ...	320		—	+
,, 16th ...	195		—	—	,, 29th ...	240	—	—	+
,, 21st ...	170		—	—	,, 29th ...	100		—	+
,, 26th ...	170		—	—	,, 31st ...	175	—	—	—
March 2nd ...	140		—	+	June 2nd ...	300		—	+
,, 9th ...	165		—	+	,, 6th ...	210	—	—	+
,, 14th ...	100		—	+	,, 7th ...	230		—	—
,, 17th ...	160		—	—	,, 11th ...	160	—	—	+
,, 23nd ...	205		—	+	,, 18th ...	135	—	—	—
April 3rd ...	135		—	—	,, 25th ...	90	—	—	+
,, 10th ...	275	—	—	+	July 3rd ...	95		—	—
,, 15th ...	330	—	—	+	Sept. 25th ...	70	—		
,, 18th ...	200	—	—	+	,, 27th ...	25	—		
,, 18th ...	180	—	—	—	Oct. 29th ...	87	—	—	+
,, 23rd ...	230	—	—	+	Nov. 5th ...	145		—	+
,, 23rd ...	140	—	—	+	,, 11th ...	150	—	—	+
,, 26th ...	100	—	—	—	,, 18th ...	157	—	—	+
,, 27th ...	280	—	—	+	,, 21st ...	95	—	—	—
May 3rd ...	155	—	—	+	,, 28th ...	180	—	—	—
,, 3rd ...	96	—	—	—	Dec. 3rd ...	180	—	—	+
,, 8th ...	330	—	—	+	,, 6th ...	198	—	—	+
,, 9th ...	120	—	—	+	,, 11th ...	156	—	—	—
,, 13th ...	50	—	—	+	,, 16th ...	113	—	—	+

proportion of tsetse flies naturally infected with this parasite in Nyasaland. In 56 experiments, in which 10,081 tsetse flies were used, *Trypanosoma capræ* was found 35 times (62·5 per cent.). Since this species is not pathogenic to the monkey or dog, of course it was found only in the experimental goats. This gives a proportion of 3·5 per 1000 flies infected with *Trypanosoma capræ*.

The Cycle of Development of Trypanosoma Capræ *in* Glossina Morsitans.

Trypanosoma capræ belongs to the *Vivax* group, in which the development of the trypanosome is restricted to the proboscis. Six experiments were made with laboratory-bred flies; five were positive and one negative. (See Table XXIV.) 170 labora-

TABLE XXIV.—*The Development of* Trypanosoma Capræ *in* Glossina Morsitans. (*Laboratory-bred Flies.*)

Date.	Experiment.	No. of flies used.	Experiment positive or negative.	No. of infected flies found.	No. of days before flies became infective.	Mean temperature.
1912.						
April 16th	444	12	+	1	16	71° F. (22·1° C.)
June 3rd	617	33	—	0	—	65° F. (18·3° C.)
,, 3rd	1215	22	+	1	21	65° F. (18·3° C.)
1913.						
Jan. 18th	1777	35	+	11	19	84° F. (28·8° C.)
,, 22nd	1784	35	+	20	19	84° F. (28·8° C.)
April 1st	2046	33	+	13	20	84° F. (28·8° C.)

tory-bred flies were used, and 46 infected flies were found (27·1 per cent). The first three experiments were carried out at the ordinary temperature of the laboratory; in the last three the cages containing the flies were kept in an incubator. It is difficult to understand the difference in the number of infected flies found. In Experiments 444 and 1215 only 8 and 5 per cent. respectively of the flies became infected, whereas in the last three experiments an average of more than 40 per cent. was found. The flies in the second group were kept, it is true, at a temperature similar to that which they would find in summer in their native haunts in the low country, while the first three experiments were done in winter and at the ordinary temperature of the laboratory. This would, no doubt, explain the difference to some extent. Again, goats and sheep infected with *Trypanosoma capræ* are unsatisfactory animals to feed flies upon. One day the trypanosomes are present in small numbers in the blood; the next day it may be impossible to find any; very seldom are they in large numbers. It is possible, then, that flies may feed on an infected goat or sheep without taking in a single trypanosome. It would appear from the five positive experiments that an average period of 19 days elapses before the cycle of development of this parasite is complete in *Glossina morsitans* and the fly becomes infective. Now 46 infected flies were found among 170 used, and the next table gives the results of the dissection of these flies.

It will be seen from Table XXV. that it was not until the last experiment that the labial cavity and hypopharynx were examined separately. In the previous experiments the presence or absence of trypanosomes in the proboscis as a whole was noted. In the first two experiments only a single infected fly was found in each. In Experiment 1777, 11, and in 1784 as many as 20 were found. In regard to the number of trypanosomes in the labial cavity this may vary greatly. Sometimes the lumen of the tube will be seen to be densely crowded; at other times a single colony will be seen. For example, in Experiment 1 first infected fly, dissected on the twenty- is noted to have had the lumen of the p swarming with clusters of torpedo-shaped fl

TABLE XXV.—*Result of the Dissection of the Infe (Laboratory-bred Flies. Positive Experiment*

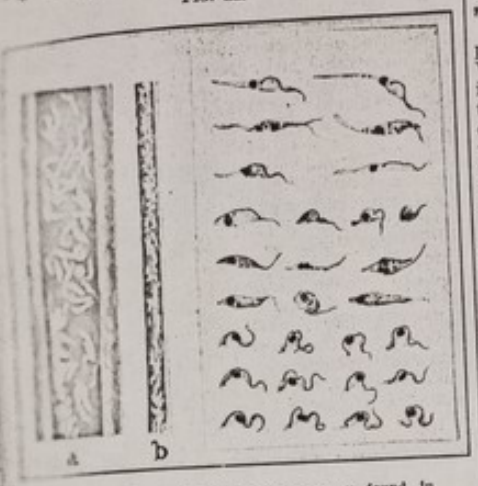
Experiment.	Time, days.	Proboscis.		Proventriculus.	Crop.	Foregut.	Mid-gut.
		Labial cavity.	Hypopharynx.				
444	25	+		—	—	—	—
1215	32	+		—	—	—	—
1777	21	+		—	—	—	—
,,	26	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
1784	19	+		—	—	—	—
,,	21	+		—	—	—	—
,,	23	+		—	—	—	—
,,	24	+		—	—	—	—
,,	29	+		—	—	—	—
,,	29	+		—	—	—	—
,,	29	+		—	—	—	—
,,	29	+		—	—	—	—
,,	29	+		—	—	—	—
,,	29	+		—	—	—	—
,,	29	+		—	—	—	—
,,	29	+		—	—	—	—
,,	29	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
,,	30	+		—	—	—	—
2046	23	+	+	—	—	—	—
,,	23	+	—	—	—	—	—
,,	24	+	++	—	—	—	—
,,	26	++	++	—	—	—	—
,,	28	+		—	—	—	—
,,	28	+		—	—	—	—
,,	29	++	++	—	—	—	—
,,	29	+	++	—	—	—	—
,,	29	+	++	—	—	—	—
,,	29	+	++	—	—	—	—
,,	29	++	++	—	—	—	—
,,	29	++	+	—	—	—	—
,,	30	+	++	—	—	—	—

attached to the labrum by their flagellar e few swimming free. In the seventh infecte dissected on the thirtieth day, only three co are noted. In the same way at one time the pharynx may contain few; at another time seen to be densely packed with swarms of ac moving trypanosomes. In unstained specimen difference in size and shape between the try somes in the labial cavity and those in the pharynx is quite manifest. From this tabl broad facts stand out boldly that in this ge trypanosomes the development is confined t labial cavity and hypopharynx and does not place in any other part of the fly.

The Type of Trypanosomes Found in the Infected Flies.

An attempt was made by the Commission to study the development of *Trypanosoma capræ* in *Glossina* [illegible] in the earliest stages. This can only be done if a large number of laboratory-bred flies are available, and this was not the case in Nyasaland. Fig. 22 represents some of the developmental

FIG. 22.



Developmental forms of *Trypanosoma capræ* found in the buccal cavity and hypopharynx of infected flies. *a*, Labrum. *b*, Hypopharynx.

forms found in the labial cavity and hypopharynx of infected flies. It will be seen that most of the trypanosomes found attached to the labrum are epimastigotal in type, with well-defined nuclei, micronuclei, and free flagella. Some are ribbon-shaped, others have elongated posterior extremities, and [illegible] others are torpedo-shaped. The last three forms are from the hypopharynx, and have been obtained as a rule by causing the fly to salivate on the cover glass. They represent the final stage in the cycle of development—the reversion to the infective or blood form. They are rather smaller than those found in the blood of the vertebrate host, but resemble them closely in every other way.

The Reservoir of Trypanosoma Capræ.

Among the 180 wild animals examined in Nyasaland 20 harboured *Trypanosoma capræ* (11·1 per cent.), 41 per cent. of the water-buck and 47 per cent. of the reed-buck acted as reservoirs. (See Table XIX.)

CONCLUSION.

This concludes the Croonian Lectures on the Trypanosomes Causing Disease in Man and Domestic Animals in Central Africa. These lectures deal with but a small part of the subject, which has in the course of the last 20 years grown to huge proportions. Nothing has been said about medicinal treatment, and even measures of prevention have been left a good deal to the imagination. Taking a look back over the whole field the outstanding features may seem to be, first, that some order is beginning to emerge in what was lately chaos in regard to the classification of the pathogenic trypanosomes. They may all now be referred to three groups and nine species.

In regard to the transference of the virus from man to healthy animals by the fly, this has been made clearer and easier of comprehension by the discovery of the part which the salivary glands and hypopharynx play in the various modes of development which the trypanosomes undergo in the fly. It results that it would almost appear impossible for an infective fly to pierce even momentarily the skin of a healthy susceptible animal without causing infection.

Another important feature is the proof brought forward that *Trypanosoma brucei* and *Trypanosoma rhodesiense* are the same.

Finally, in regard to the prevention of these trypanosome diseases of man and domestic animals. We have seen that the wild game in the fly country is heavily infected. It is impossible to doubt that they are the reservoir and source of many of these diseases. There can be little doubt that if the wild game were driven out of the fly country trypanosome diseases such as those caused by *Trypanosoma brucei* and *Trypanosoma pecorum* would disappear.

In regard to the measures of prevention against the most important of all the trypanosome diseases —Congo sleeping sickness—it has been shown by experience that the removal of the natives from the fly area is a simple and efficacious way of stopping an epidemic. In these sparsely inhabited countries, where spare land and food are easily obtained, there is, as a rule, no difficulty in effecting this migration. If it is desired to go a step further and render the sleeping-sickness area inhabitable, then clearing and cultivation must be resorted to. By these means, in all probability, *Glossina palpalis* will be driven away, and with it the disease.

BREAST FEEDING:

SOME FUNCTIONAL REQUIREMENTS OF THE GLAND AND OF THE INFANT.

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THE high position reached by obstetrical science has been influenced in a great measure by the urgent and dramatic nature of the difficulties and disasters of childbirth. To this no doubt is due much of the accuracy with which their causes have been elucidated and the treatment prescribed. The study of infant feeding has possibly suffered by virtue of its problems coming as a kind of anti-climax. At least it would seem that knowledge in matters pertaining to early infancy has hardly proceeded at the same rate, for tradition still influences a larger share of therapeutics here than is tolerated ih obstetrics. Purgation has not yet been dethroned from its position of sinister importance; dentition is still held responsible for a multitude of ailments with which it can have but the faintest connexion; and the early failure of lactation has come to be almost tacitly accepted as an inevitable pitfall in the path of infant welfare. If it should appear paradoxical to associate tradition with this last example in face of all the modern improvements in artificial feeding, all the great chemical and industrial activity with which its elaboration has been associated, it must also be remembered that it is the lack of accurate knowledge of the subject of lactation that has given bottle feeding its chief impetus. Without this its present high standard of development could hardly have been reached. Once the negative character of this structure is appreciated there appears to be room for doubt whether the underlying physiological principles are such as they are represented to be.