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CATTLE TRYPANOSOMIASIS IN THE
CONGO FREE STATE

CATTLE TRYPANOSOMIASIS IN THE CONGO FREE STATE*

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I. INTRODUCTION

When Europeans first came to the Congo there were practically no cattle in the greater part of the central area of what is now the Free State. Since their advent cattle have constantly been imported from neighbouring African colonies.†

They have been sent to many posts in different parts of the Congo with varying success. As a rule, it is said that cattle tend to do best in plain country where there are no buffaloes.

* Much of the information contained in this paper was communicated in 1904 to the Government of the Congo Free State in unpublished reports.

† The natives in the highlands about Lake Kivu possess large herds of cattle. As a rule the Kivu cattle (Fig. 3) are rather small and have long, upstanding, slightly-curved horns (*Bos aegyptiacus*?). Some of them are of the humped zebu type. The cattle in the parts of the Congo visited by the expedition¹ generally approximate to the European type. Tsetse flies are said not to be present in the Kivu district. Game is plentiful. The mortality among cattle taken from Lake Kivu to other districts is very great. From herds of 20, only two or three have remained on arriving at Kasongo! It was found that more cattle died in herds which travelled only every third day than in those driven hard. The cause of the mortality is therefore probably not fatigue and lack of food, but disease. Seventy-five head of cattle taken North from Rutshuru did well until the forest was entered. They then commenced to die, and at Mawambi all were dead.

II. EXAMINATION OF CATTLE

We examined the cattle of only a few of the more important herds ; those existing at the remaining places visited are only briefly considered, while herds unvisited are not mentioned.

At ZAMBIE there is a herd of about 190 cattle, all in excellent condition ; in 1904 there were 52 births, and no deaths from disease. Those in charge recognise no disease resembling trypanosomiasis.

At the neighbouring island of MATEBA there is a herd of about 5,000 (?) cattle ; said to be in perfect condition. The original animals at both Zambie and Mateba were imported from Portuguese West Africa (San Paul de Loanda, etc.), Walfish Bay, the Canary Islands, and occasionally from Europe. Both places are on low-lying grass plains, and tsetse flies, although probably present, were not seen (October, 1903), and big game was practically absent. Living animals are regularly sent from St. Paul de Loanda, from Mateba and from posts in the Lower Congo to Leopoldville for food ; two said to come from Mateba (?) were found to be infected with trypanosomes on their arrival at Leopoldville.

The LEOPOLDVILLE herd, kept only for food purposes, is heavily infected ^{2, 3}.

At YUMBIE cattle have been present since 1896, but they have died as fast as they reproduced and the herd has not increased. The principal cause of death is "colic" (?). This disease is probably trypanosomiasis (see below). When we saw the herd in July, 1904, the twelve animals present, with one or two exceptions, seemed in fair condition. In June, 1905, the ten animals then composing the herd were seen by Broden.⁴ They were all in wretched condition and three of them had trypanosomes in the peripheral blood. In September, 1904, six heifers arrived from Dolo (near Leopoldville). From October to June, 1905, there were eight deaths ; all probably from trypanosomiasis.

Yumbie is placed on a high grassy plain with neighbouring forest. *Glossina palpalis* and *fusca* (?) are present. Large game is plentiful.

Six young cattle were brought to BASOKO from Nouvelle Anvers in 1898. The herd now numbers eight (only two deaths from accidents have occurred) ; they all seem to be in excellent condition. The herd grazes in cultivated ground surrounded by thick forest. *Glossina palpalis* present, but rare ; big game not plentiful.

LISENGI. No deaths recorded; cattle present for six years. They graze in uncultivated coffee plantations surrounded by forest. No buffaloes, many antelopes present. *Glossina palpalis* not seen, probably present.

At KIRUNDU there were a few miserable-looking trypanosome-infected cattle, in the hands of the natives.

EALA, August, 1904. Before reaching Eala a report was received from the Veterinary Surgeon resident there, M. Bertolotti, in which he described an obscure disease affecting the cattle under his care. The symptoms resembled those of trypanosomiasis, and on examination we succeeded in finding the parasites in one cow (Fig. 1) in which the disease was well advanced (no trypanosomes were found by a single centrifugalisation of the blood of five other animals chosen from the herd for their lack of condition). The extent of the disease at Eala is shown by the following review of the cattle records.

There is at present a herd of 43 cattle at Eala. These represent the remnants and product of 51 cattle sent here from the Lower Congo in May, 1901, one bull and ten cows (of these only two cows are still alive), and from April to May in 1902, five bulls and thirty-five cows (of these one bull and 26 cows are still alive).

The great mortality amongst these animals has been almost exclusively due to trypanosomiasis.* Calves born at Eala (and at Nouvelle Anvers) have suffered specially from this disease; of 36 born at Eala only 14 are living (for example, of 15 bull calves born between August, 1902, and January, 1904, 12 were dead in August, 1904, of trypanosomiasis). Some of the young animals born here which are still alive are undersized and obviously ill-developed.

Histories of the Infected Animals

Cow No. 10.—Brought to Eala from the Lower Congo in 1902. July 23, 1904: Is at present extremely thin and scarcely able to move (Fig. 1). Superficial glands are enlarged (M. Bertolotti regards this as one of the most constant symptoms of the disease; diarrhoea is also a usual symptom). Blood centrifugalised; no trypanosomes seen. August 5, 1904: Animal still thinner; hardly able to stand because of weakness; but still has appetite and munches grass. No oedemas or petechial haemorrhages observed. Blood centrifugalised and prescapular gland punctured; trypanosomes found by both methods. The animal was killed by injecting air into jugular vein and an autopsy was made at once.

* Clinical diagnosis; the parasites were not observed in affected animals until July, 1904.

Autopsy.—Animal is very thin; muscles pale. Organs all normal, spleen not enlarged. Superficial lymphatic glands twice as large as normal, watery, not congested. Deep glands all much enlarged, about half of them (especially in abdomen) much congested—almost haemorrhagic. Examination for trypanosomes: Trypanosomes were found in the blood (20 to a coverslip preparation) only after centrifugalisation (five coverslip preparations of uncentrifuged blood were examined without result). They were also seen (three to a coverslip) in a preparation of gland juice obtained from the prescapular gland by a hypodermic syringe before the animal was dead; none were seen, however, in nine preparations of the juice of glands from various parts of the body made within one to two hours of the animal's death. Many parasites were found in the deposit obtained by centrifuging slightly turbid fluid from the pleural (60 c.cm. present), the peritoneal (500 c.cm.) and the pericardial (35 c.cm.) cavities. It was noted that the trypanosomes seen in these fluids were almost invariably attached to a white cell. Forty-five c.cm. of cerebro-spinal fluid taken immediately after death was centrifuged and most carefully examined. It contained no trypanosomes and no red or white cells, but it was made slightly opalescent by a peculiar flocculent material present in small quantities.

FIG. 1.—Cow, No. 10, at Eala. August 23, 1904

Inoculations.—Two rats (Exp. 137, 138) each received 4 c.cm. of blood from this cow intraperitoneally on July 23. Neither had become infected* on August

* The blood of all the experimental animals mentioned in this paper was examined, almost daily, in three-quarter inch square fresh coverslip preparations until either the animal became infected or the experiment was discontinued.

3rd, so they were then both re-inoculated intraperitoneally, one with 5 c.cm. and the other with 3 c.cm. of a mixture of gland juice, from the same cow, and sodium citrate solution showing one trypanosome to five fields.

A guinea-pig (Exp. 142) was at the same time inoculated intraperitoneally with 4 c.cm. of the same fluid. All three animals were carefully examined; none ever became infected.

The herd at Eala grazes on low-lying land surrounded by forest. *Glossina palpalis*¹ exists in small numbers (July, 1904). Big game is scarce.

NOUVELLE ANVERS, August 15th, 1904. At Nouvelle Anvers five of the thinnest of the 34 cattle present were examined; two had trypanosomiasis. The first cattle were brought here in 1896. From then to 1900, 16 head (thirteen cows, three bulls) were imported from the Lower Congo (two from the Canary Islands). Since 1898, 48 calves have been born; ten have died (one from the results of abortion, nine from fever and unrecognised diseases), and several have been sent to other posts. Of the original animals twelve are dead (one slaughtered, 11 of insufficiently described diseases).*

It is most important to note that seven of these animals came from Stanley Pool (Kinchassa), and all the animals sent from Kinchassa to Nouvelle Anvers have died in from one to four years after their arrival. At present there is only one animal (Bull 18, arrived March, 1904), from Stanley Pool (Leopoldville) and it has trypanosomiasis; Dr. Broden has shown trypanosomiasis to be common among cattle near Leopoldville.

Though it cannot definitely be said that the animals from Stanley Pool did not contract trypanosomiasis at Nouvelle Anvers, it is quite possible that they may have been infected with trypanosomes before their arrival there. If this is the case the herd has contained infected animals since 1899 at least. Its losses since then have certainly been heavy, but the percentage of mortality is smaller and the disease seems less virulent than at Eala. For instance, one cow born at Nouvelle Anvers in 1896 and another brought there from the Canaries in the same year are still alive and well.

STEER 17.—Born here December, 1902. In fair condition; supposed to be healthy; lymphatic glands slightly enlarged.† Fairly numerous trypanosomes seen in blood and gland juice.

*When the cause of death is ill-defined, it is usually because the animal has gradually wasted and died. Such cases are usually ones of trypanosomiasis.

†One of the animals in which a most careful examination failed to reveal trypanosomes also had slightly enlarged glands.

BULL 18.—Age, two (?) years. Imported from Leopoldville, March, 1904. In good condition; supposed healthy; lymphatic glands slightly enlarged. Fairly numerous trypanosomes seen in blood and prescapular gland juice.

Inoculations.—Rat (Exp. 145) inoculated Aug. 15 intraperitoneally with 2 c.cm. of blood from this animal; did not become infected.

Monkey (*Cercopithecus schmidtii*) (Exp. 143) received 8 c.cm. of blood intraperitoneally, August 15, 1904. Trypanosomes appeared in its blood September 22. They soon disappeared, and were only occasionally seen during 1904. During 1905 the monkey seemed quite well, and trypanosomes were not seen in its blood, which was examined at intervals. On January 1, 1906, it was very ill, weak, dull and apathetic. A single degenerated (?) trypanosome was seen in two coverslip preparations. Animal died next day; immediate cause of death was miliary tuberclosis.

A rabbit (Exp. 144) received 3 c.cm. of blood intraperitoneally; never became infected; under observation for six months.

The herd at Nouvelle Anvers grazes for the most part on cultivated land. Big game is not very abundant, but biting flies of several sorts (*Glossina palpalis*, *Stomoxys* and *tabanids*) are present.

ROME, September 12th, 1904. One or two animals now present have been here since 1897, but the great majority of the cattle¹⁹ have been brought here since the end of 1902. Most of them are of Lake Kivu stock and came here by way of Nyangwe. A few head came from the Nile. Only nine deaths have occurred since March, 1903; all were cattle which had arrived in poor condition two or three months previously. It therefore appears that this herd does not lose so many animals from disease (trypanosomiasis ?) as do those at Eala and Nouvelle Anvers. For example none of the calves born here (first in 1899) have died. We were shown ten animals that had been kept apart from the herd of 25 head because of their lack of condition. Six of them (arrived at Rome, July, 1904) were examined.* Four had trypanosomiasis; three of these were decidedly thin and had enlarged lymphatic glands, the fourth had no big glands and was comparatively well-fleshed. All had temperatures of over 101·2°F. All four infected were of Kivu stock; two had come from Stanley Falls and the other two were from Nyangwe.

Three rats (Exp. 138a, 149, 151) inoculated intraperitoneally with blood from Cow No. 2 became infected in three, six and eight days and died in 18, 23 and 21 days.

* In July, 1905, one of these animals was still living and seemed perfectly well; the other three had been slaughtered.

Two guinea-pigs (Exp. 148, 152) inoculated in the same way, one from one of the above rats, the other from the cow, showed parasites in twelve and fifteen days and died in 18 and 23 days of ruptured spleens (much enlarged and friable), in one case after slight violence.

A rabbit (Exp. 147), weight 5 lb., became infected in nine days. Parasites were at first numerous; they then became scanty and were only seen from time to time until January, 1905. None were seen after this. Death from pneumonia October 21, 1905. Spleen not enlarged, firm ($5 \times .8 \times .6$ cm.), capsule thickened. None of glands much enlarged. Animal very fat.

Monkey (*Cercopithecus* ?) (Exp. 146), weight $5\frac{1}{2}$ lb. Inoculated September 13, 1904, with blood from one of the rats; showed trypanosomes in its blood three and six days later and never again. Death from pneumonia December 16, 1905. Spleen slightly enlarged ($5 \times 3 \times 1.5$ cm.), firm; glands not enlarged; animal fat.

The herd grazes on high, wooded, cultivated grounds. Small antelopes are not uncommon. *Glossina palpalis* is rare.

LOKANDU, October 21st, 1904. Sixteen head of cattle present. In January, 1902, there were 23; since then 13 have been sent away (nine to Romee) and three have died. In only two of the deaths were symptoms resembling trypanosomiasis present.

We examined eight heads; five had trypanosomiasis. Three, all infected, of those examined were calves born here. All were thin, had dry noses, much-enlarged glands (to 3 by 4 by 10 cm.) and slight temperatures (101.5°F.).

In two of them there were distinct patches of oedema in the loose skin of the throat. Five of those examined were adult cows imported from Nyangwe or Kasongo. All were in fair condition; only one had enlarged glands. This one, and one other in whom there was no glandular enlargement, had trypanosomiasis. The one with enlarged glands had a temperature of 106.8°F. Trypanosomes were seen in small numbers in the blood of only three of these five infected animals. They were seen in much larger numbers in the gland juice in each case.

Inoculations.—A guinea-pig (Exp. 153) was inoculated intraperitoneally on October 22, 1904, with 7 c.cm. of blood, from one of the calves, containing three trypanosomes to a coverslip preparation. It was examined carefully until January, 1905, but trypanosomes were never seen.

These cattle had scanty pasture, in coffee plantations surrounded by forest. Antelopes and *Glossina palpalis* not uncommon.

SENDWE, November 5th, 1904. Four head of cattle were sent here from Kasongo in 1900. The two bulls imported died soon after their arrival, so the remaining animals were sent away to Matampas.

In May, 1904, eight head passed through on their way to Romee. Two died here; only four reached Romee alive (we examined none of them for trypanosomes). In May, 1904, ten heifers on their way to Romee arrived here by Kasongo from Lake Kivu. They were not in good condition; but this was at the time explained by a two months' stay at Kibombo—poor pasture. A month after arrival they commenced to die, and in three months five were dead. All had the same symptoms, "gradual wasting and loss of vigour." The remaining animals seemed in fair condition, but all of the four examined had enlarged glands (see Fig. 2) and temperatures (to 104.4°F.). Three of them had trypanosomiasis. Some of them were later sent to Lokandu.

FIG. 2.—CALF at Sendwe; to show enlarged gland.

The pasture at Sendwe is poor; *Glossina palpalis* and big game are plentiful.

NYANGWE, November 14th, 1904. A herd, now numbering about 60 head, has been here since the end of the Arab war (1894). It is

largely made up of captured cattle, the majority of which probably came from the neighbourhood of Lake Kivu. The cattle are at present in splendid condition. Since 1900, 45 calves have been born. During the same period there have been only five deaths, none of them from any disease resembling trypanosomiasis.

The country surrounding Nyangwe is high, grassy plain. The herd never grazes further than one and a half miles from the post and never goes near a swampy area towards the South. The country about Nyangwe is thickly populated and extensively cultivated. There is, therefore, little large game in the neighbourhood. Tsetse flies were not seen anywhere about the post nor on the plains where the cattle graze. They were seen, however, along the river bank a mile and a half further South.

The blood of 20 cattle chosen because they were less plump than the remainder of the herd was examined; gland puncture was done in 17 in which the glands were sufficiently large. Trypanosomes were not found.

KASONGO, November 25th, 1904—April 27th, 1905. There is a herd here of about 260 cattle. Many of them were collected by the Arabs; additions have been made by the whites. The animals reproduce well and the herd has been largely increased by local births; deaths from diseases are very rare. Its original members were probably largely from Lake Kivu. Some probably came from the Eastern and Southern shores of Lake Tanganyika. Very few, if any, were ever brought directly from Katanga, far to the South, or from Lusambo, in the West.

One hundred of the cattle were examined for trypanosomiasis during our stay at Kasongo, five were found to be infected. All five were found in the first twenty-two examined. This is noteworthy, since the thinnest animals were taken first. All the animals were examined in the same way and each was gone over but once. Preparations of gland juice and blood were examined and the temperature was taken in each case.

The infected animals were kept under observation for several months. The rareness with which parasites were seen in them during this period (see charts) strongly indicates that many cases remained undetected by our examinations, and therefore that the proportion of cattle infected is much more than five per cent.

ZILANI No. 8 (Nov. 15, 1904).—A young cow, born at Kasongo. She is rather thin and the natives say she is ill; but there is no oedema, staring of the coat, &c. Largest prescapular gland 12×5 cm., largest femoral gland 9×3 cm. Trypanosomes were found in gland juice, not in blood (see Chart I). Inoculations (see below, page 243).

MOIUMA No. 33 (Nov. 25, 1904).—A young cow, born at Kasongo. Apparently quite healthy. Prescapular gland 12×5 cm., soft; femoral 6×3 cm. Trypanosomes present in blood and gland juice. The course of the disease is given by Chart II up to February 8. From then to April 19 (observations ceased) the temperature varied, without any sudden changes, between 101° F. and 104° F. Blood and gland juice were examined at intervals; parasites were seen during this period by gland puncture, only on March 16.

Inoculations.—Monkey (*Cercopithecus schmidtii*) (Exp. 175), January 11, 1905. Inoculated intraperitoneally with 18 c.cm. blood showing one trypanosome to cover; under observation until February 8 (when inoculated with spirochaetes); never infected.

KEOWKOSIKO No. 60 (Nov. 25, 1904).—Cow, born here. It is in fair condition, perhaps slightly thin. Prescapular gland measures 10×5 cm., femoral 8×2 cm.; both are soft. Chart III shows the course of the disease up to February 17. From then to March 9 the temperature continued in the same way and parasites were only seen on March 8, 9, 10. The temperature became irregular and rose constantly until 105° F. was touched on March 22 (no trypanosomes in blood). The temperature then became lower and no parasites were seen in blood or gland juice up to April 18, when they were in the blood in small numbers. Observations ceased.

LIBOKO No. 29 (Nov. 30, 1904).—Fair condition; glands slightly enlarged. Trypanosomes present in gland juice, absent from the blood. As is seen by Chart IV, the parasites were never again seen in this animal.

YOLO No. 9 (Dec. 1, 1904, Fig. 3).—A steer, adult, born at Nyangwe, has been here for three years. Prescapular gland is 15×5 cm.* and soft; femoral is 10×2 cm., soft and moveable. Trypanosomes were seen in gland juice and not in the blood. The course of the disease up to April 14, when the animal was killed for the autopsy, is indicated on Chart V.

Autopsy.—The animal was killed by injecting air into the jugular vein. The examination was commenced immediately after death. No subcutaneous fat or oedemas; muscles dark. Abdomen contained 400 c.cm. clear fluid; mesenteric vessels very turgid, omentum and retroperitoneal tissues oedematous. Thorax: pleurae contained no fluid, pericardium 300 c.cm. Between diaphragm and base of pericardium there was a layer of oedematous tissue 1 cm. in thickness. The fat about base of heart and along its vessels was brownish-canary-yellow in colour and was very oedematous, as was also the connective tissue of the posterior mediastinum. None of the organs showed any striking macroscopic change (spleen weight $1\frac{1}{2}$ lb., substance firm). Marrow of long bones yellow. *Lymphatic glands:* Just before death the prescapular gland was excised. It was surrounded by a capsule of oedematous connective tissue .75 cm. thick; it measured 11×6 cm. All the glands were enlarged and all were firm but distinctly "watery," so that the fluid followed the knife. The larger glands in all parts of the body were pale with darker cortex. Some of the smaller ones (1.5×1 cm.) along the small intestine, at the base of the mesentery (2×3 cm.) and about the bronchi and trachea (1.5×1 cm.) were congested or haemorrhagic. Immediately after death lumbar

* The measurements given for these glands are of course estimates, and include the capsule. This gland when excised on April 14, 1905, actually measured 11×6 cm.

puncture was done at about the sixth vertebra with a four-inch needle. About 4 c.cm. of clear fluid was obtained. Fresh preparations of the following organ juices and body fluids were examined, juice from the prescapular, mesenteric and tracheal glands, liver, spleen, marrow from long and short bones, blood, pericardial and cerebro-spinal fluid. Parasites were only seen in the gland preparations.

Inoculations.—Dog* (Exp. 227), April 13, 1905. Inoculated intraperitoneally with about 150 c.cm. of defibrinated blood from the jugular vein. Died December 12, 1905; no autopsy. No trypanosomes seen.

Dog (Exp. 229), April 13, 1905. Inoculated as above with 92 c.cm. of blood. No trypanosomes seen until December 1, 1905, when killed because of mange.

Dog (Exp. 229), April 13, 1905. Inoculated as above with 150 c.cm. blood. Killed because of mange, December 1, 1905. Trypanosomes were never seen in the blood.

FIG. 3.—STEER, *Yolo*, at Kasongo. Note emaciation. The type of horns and tendency to hump indicate a Lake Kivu origin.

Experimental Inoculations at Kasongo

Most of the animals inoculated at Kasongo were so frequently re-inoculated that it has seemed best to treat the majority of them under a separate heading.

* The dogs used in all these experiments were native ones bought at Kasongo.

Rat (EXPERIMENT 132), July 6, 1904. Inoculated with buffalo blood (*Bos nanus*); never infected. (Exp. 221) April 3, 1905. Inoculated with 5 c.cm. blood from *Yolo* showing four trypanosomes to cover. Died August 20, 1905 (no autopsy). Never infected.

Rat (EXPERIMENT 133), July 6, 1904. Inoculated with buffalo blood; never infected. November 8, 1904, re-inoculated (8 c.cm.) with buffalo blood. (Exp. 222), April 3, 1905, re-inoculated with 5 c.cm. blood from *Yolo* showing four trypanosomes to cover. September 8, cataract in one eye, blood in anterior chamber of the other. December 8, TRYPANOSOMES FIRST SEEN IN BLOOD. December 15, died, blood swarming with trypanosomes. Glands and spleen enlarged, organs otherwise healthy.

Rat (EXPERIMENT 134), July 6, 1904. Inoculated with buffalo blood; never infected. (Exp. 177) January 11, 1905, re-inoculated with 12 c.cm. from *Moiuma* showing one trypanosome to a cover; never infected. (Exp. 223) April 3, 1905, re-inoculated with 5 c.cm. blood from *Yolo* showing four trypanosomes to a cover; accidentally killed November 4, 1905. No trypanosomes nor signs of trypanosomiasis seen in it or in a rat sub-inoculated from it.

Rat (EXPERIMENT 135), July 6, 1904. Inoculated with buffalo blood; never infected. (Exp. 224) April 3, 1905, re-inoculated with 5 c.cm. blood from *Yolo* showing four trypanosomes to cover; never infected. Died of skin disease, October 13, 1905.

Rat (EXPERIMENT 139), July 27, 1904. Inoculated with 8 c.cm. blood from antelope; never infected. (Exp. 169) December 27, 1904, re-inoculated with 7.5 c.cm. of mixed blood and citrate solution from *Moiuma* showing four trypanosomes to cover; never infected. March 9, 1905, re-inoculated with 5 c.cm. of blood from *Keowkosiko*. March 21, 1905, re-inoculated with 5 c.cm. of blood from *Zilani*. April 14, died from mechanical effects of inoculation with large amount of blood; no autopsy; never infected.

Rat (EXPERIMENT 140), July 17, 1904. Inoculated with 8 c.cm. of blood from antelope; never infected. (Exp. 168) Dec. 27, 1904, re-inoculated with 7.5 c.cm. of blood and citrate solution from *Moiuma* showing four trypanosomes to a cover; never infected. March 9, 1905, re-inoculated with 5 c.cm. blood from *Keowkosiko*. March 21, 1905, re-inoculated with 5 c.cm. blood from *Zilani*. April 3, 1905, re-inoculated with 5 c.cm. blood from *Yolo*. April 13, 1905, re-inoculated with 5 c.cm. blood from *Yolo*. Never infected* up to September 19, 1905, when it escaped.

Rat (EXPERIMENT 170), December 27, 1904. Inoculated with 2.5 c.cm. blood showing four trypanosomes to cover from *Moiuma*; FIVE TRYPANOSOMES TO COVER WERE SEEN IN ITS BLOOD next day and not again. March 9, 1905, re-inoculated with 4.25 c.cm. blood from *Keowkosiko*. March 21, 1905, re-inoculated with 5 c.cm. blood from *Zilani*. April 13, 1905, re-inoculated with 33 c.cm. blood from *Yolo*. THREE TRYPANOSOMES TO A FIELD were seen in its blood on April 21, and not again. Died February 5, 1906; no trypanosomes seen at autopsy; all organs normal save spleen which was slightly enlarged and fibrous.

Puppy (EXPERIMENT 219), April 3, 1905. Inoculated with 10 c.cm. of blood from *Yolo*. April 5, 1905, re-inoculated with 10 c.cm. of blood from *Zilani*. April 13, 1905, re-inoculated with 125 c.cm. of blood from *Yolo*. Under observation until stolen at Boma. Trypanosomes never seen.

Monkey (*Cercopithecus schmidtii*) (EXPERIMENT 220), very young. April 3, 1905, inoculated with 7.5 c.cm. blood from *Yolo*. April 5, 1905, re-inoculated with 5 c.cm. blood from *Zilani*. April 13, 1905, re-inoculated with 12.5 c.cm. blood from *Yolo*. Died of sunstroke May 10, 1905; parasites never seen. No trypanosomes or signs of trypanosomiasis at autopsy.

* See charts for number of parasites present in blood inoculated.

Through the kindness of Commandant Verdick the four infected cattle which remained when we left Kasongo were kept apart from the herd at Kasongo. After our departure the animals were left quiet, and there was a consequent amelioration in their condition. While we were there they were driven twice daily from their kraal to our laboratory and back—a distance of about one and a quarter miles. The fatigue of these journeys and the time lost through them from grazing had certainly an adverse influence. *Moiuma* and *Keorwosiko* both calved. All the animals were in excellent condition in September, 1905. They were then sent to Lokandu, where there is a great deal of cattle trypanosomiasis and where *Glossina palpalis* is far from rare, in order to ascertain whether they would resist exposure to re-infection. (It must be remembered that the pasturage at Lokandu is not nearly so good as at Kasongo). The steer, three cows and two calves reached Lokandu on November, 23rd, 1905, in excellent condition. A calf died in December after twenty days of manifest diarrhoea. One of the adults died after a "slow wasting" and great weakness early in 1906. In August, 1906, two of the four remaining animals were very thin and seemed ill; the remaining two are still under observation. The Chef de Secteur at Lokandu, in conveying this information, reports that the "health of the herd at Lokandu is excellent."

The cattle at Kasongo graze on a wide plain intersected by several streams which have occasional clumps of bushes along their banks. *Glossina palpalis* are very, very rarely found about the grazing ground, and large game practically never comes near it.

TSHOFA, May 15th, 1905. There was formerly a herd here of some fifty cattle, which was intended to be used for supplying bullocks for work on the waggon road between Tshofa and Pania Mutombo. As the animals were not doing well, all, save fourteen which were obviously ill, were sent to Lubefu. Of that fourteen only eight remain; two were killed by a leopard, four died of a chronic disease characterised by general loss of condition and constant diarrhoea, with straining and small watery stools; there were no oedemas nor lack of appetite. Between June, 1901, and May, 1904, about thirteen animals were said to have died here of this disease. Almost all the calves born or brought here have died of it, and the

only animal present which was born here is affected by it (trypanosomes seen).

The majority of the cattle brought to Tshofa came from Lusambo. Cattle have been sent from the Tshofa herd in 1902 to Kisenga and in 1904 to the Tanganyika, Moero and Lubile districts. Three out of five animals whose gland juice and blood were examined had trypanosomiasis.

There was good pasture in open country at Tshofa, but *Glossina palpalis* and large game were very plentiful.

CABINDA, June 3rd, 1905. Before the advent of Europeans, some of the important chiefs in this neighbourhood had small herds of ten to twenty cattle. Cattle did not do well; many died of diarrhoea, and there were no large herds. At present a few head are kept here for vaccine making. They come from Portuguese West Africa by way of Angola and from as far South as Dilolo. We are told that the Dilolo natives buy cattle from the Zambesi valley. The blood and gland juice of six animals were examined once; trypanosomes were not seen.

LUSAMBO, June 21st, 1905. Nearly all the Lusambo cattle come by way of Malange and Luluabourg from Portuguese West Africa; formerly herds of a hundred head were brought in by this route to be exchanged for slaves. It is said that the animals were used for food and were not kept for breeding. The records of the Lusambo cattle are very badly kept,* but deaths from disease seem to have been rare among them. Six of the thinnest animals were chosen and their blood and gland juice were examined once. Trypanosomes were seen in one of them. About six cattle were sent from this herd to Kutu on Lake Leopoldville II in 1902-1903; all died within a short time. It is said that the cause of death was trypanosomiasis.

* This fault was a very usual one. The system of brands used for marking the cattle was also inadequate. It was consequently often impossible to identify an animal or to learn its past history. As a result it was often impossible at a station to estimate the incidence of disease in the past or to determine the origin of infected animals. It is evident that much valuable information would be obtained through the institution of careful systems of recording and identifying cattle.

III. OBSERVATIONS ON TRYPANOSOMES IN OTHER DOMESTIC ANIMALS

Horses, Mules and Donkeys: Comparatively few of these animals have been brought into the part of the Congo Free State visited by us. Some were seen in apparently good condition at the following places: various localities in the Lower Congo, Leopoldville, Eala (three horses and a foal from Dakar present for fifteen months, not worked), Coquilhatville (donkeys present four to five years), Bamamia, four donkeys (one present for eight years), constantly worked. Nouvelle Anvers, a few horses here were in good condition when we saw them in 1904 and were still well in June, 1905. Umangi (three horses, a mare from Teneriffe present for five years), Lisengi (two horses present for six years). At Nyangwe there is a small drove of donkeys. None of the above animals were examined. At Kasongo no trypanosomes were seen in two mules and a donkey; these three animals had journeyed considerably in the Eastern part of the Congo Free State.

In July, 1904, Commandant Sillye bought two stallions near Dakar in Senegal. They were then in excellent condition, and were six and twelve years old. He brought them to the Congo and took them on a hard journey from Kasongo almost to Lake Tanganyika; from this journey they returned unloaded to Kasongo, where we saw them on January 14, 1905, after they had had a fortnight's rest. Both animals were thin, but this was thought to be due to fatigue and bad pasturage. There was (Fig. 4), as in the Gambian horses (6), slight abdominal fulness without definite oedema. Both had rough coats from lack of grooming and were infected with ticks, fleas, chiggers, trombidium larvae and numerous bots. In addition both showed the weals of many recent fly-bites. If the animals were left to themselves they dropped their heads and certainly seemed to lack vigour.

The temperature of both was about 101°F . and their glands were slightly enlarged. The only sign of oedema ever noticed in either horse was a swelling of the scrotum in one in October, 1904. The conjunctivae were pale and watery in both. Trypanosomes were present in good numbers in the blood of both horses. The animals were relieved of the bots, chiggers, ticks and trombidia (lotion of bichloride of mercury) and were given arsenic in the form of Fowler's solution. At the end of January they reached Romee, where they were turned to pasture and the arsenic was discontinued. For two months both put on flesh. Then the older one became rapidly thinner and very weak; the appetite remained good. It died April 17, 1905, after a very profuse perspiration (6). On September 14, 1905, the remaining horse, though comparatively thin, seemed in fair health and fed well. The scrotum was often swollen.

Inoculations.—Rat (Exp. 180). Inoculated January 14, 1905, intraperitoneally with a mixture of blood, from the older of the two stallions, and citrate solution, showing 15 living trypanosomes to a cover. Parasites appeared in its blood next day and were never absent until it was accidentally killed on March 21.

Autopsy.—Spleen much enlarged ($6.25 \times 1.5 \times .75$ cm.), soft, friable; glands all slightly enlarged.

Rat (Exp. 181). Inoculated as in Exp. 180. Parasites appeared January 31; constantly present till it died of the disease September 24, 1905.

Guinea-pig (Exp. 179). Inoculated as in 180; not infected. March 10, re-inoculated with 1.5 c.cm. blood from Exp. 180 showing 30 trypanosomes to field; infected in five days. Parasites constantly present till death from sunstroke, June 18, 1905.

Autopsy (immediately after death).—Dependent part of abdominal wall firm, water-logged; vulva oedematous; spleen soft (5×2.5 cm.); glands not enlarged. Animal well nourished.

Guinea-pig (Exp. 178). Inoculated as in Exp. 180; not infected. Re-inoculated as in Exp. 179. Trypanosomes in blood in six days, and constantly present until death from the disease on September 17, 1905.

FIG. 4. STALLION infected at Kasongo. Note slight fulness of abdomen.

A donkey about seven years old, also belonging to Commandant Sillye, was examined on January 14th, 1905. This animal probably came originally from Uganda. Since 1902 it had been constantly worked and had just returned from the same journey as the horses. It was very fat and apparently in the very best of health. A few small "tadpole-like" trypanosomes were seen in its blood. Although hard

worked it remained in apparently robust health until the end of June, 1905, when it was accidentally killed.

Goats seem to thrive almost everywhere in the Congo.

Sheep are present in few places, but they usually do well.

None of the score of goats and sheep examined by us were infected with trypanosomes. Broden reports trypanosomiasis in sheep at Leopoldville.³

IV. TRYPANOSOMES IN BIG GAME

MSWATA.

Antelope (adult *Tragelaphus scriptus*), very scanty stumpy trypanosomes in blood; retro-peritoneal glands deeply haemorrhagic, otherwise apparently healthy.

Rat (Exp. 130), June 26, 1904. Inoculated with 3.5 c.cm. blood. Trypanosomes seen in its blood only on July 5. Died (cause, exposure ?) July 24; no trypanosomes or signs of trypanosomiasis at autopsy.

TSHUMBIRI.

Buffalo (*Bos nanus*, two adults). Both fat, and save for a caseous retro-peritoneal gland in one, apparently healthy. No trypanosomes found in blood.

Four rats (Exps. 132, 133, 134, 135) (see Inoculations at Kasongo, page 243) were inoculated with from 5 to 4 c.cm. of blood; none of them became infected.

COQUILHATVILLE.

Antelope (young *Cephalophus dorsalis* ?), no trypanosomes in blood.

Inoculated two rats (Exp. 139, 140) (see Inoculations at Kasongo); never became infected.

STANLEYVILLE.

Antelope (adult *Cephalophus dorsalis* ?). Gland juice and blood examined; no trypanosomes seen. Prescapular gland, enlarged ?, 4 by 3 by 2 cm., cortical congestion of it and retro-peritoneal glands.

LOKANDU.

Two antelopes (*Cephalophus dorsalis* ?) gland juice and blood examined; no trypanosomes seen. The blood and gland juice of an adult buffalo were examined and with its blood a rat (Exp. 133) was re-inoculated; trypanosomes were not found.

KASONGO.

Three antelopes (adult males, *Tragelaphus scriptus*).

1. Shot four hours previously, no trypanosomes in gland juice or blood. Prescapular gland 6 by 3 cm., iliac glands haemorrhagic.

2. Shot three hours previously. *Trypanosoma theileri* in blood. Inoculated rabbit and two guinea-pigs with blood; none became infected with any trypanosome.

3. Shot three hours previously; no trypanosomes in gland juice, many in blood. Abdominal glands much congested and enlarged.

Inoculated from Antelope No. 3.—Guinea-pig (Exp. 188). Inoculated January 28, 1905, with 1.5 c.cm. of blood showing three trypanosomes to field; not infected. April 19, re-inoculated with 2 c.cm. mixed citrate solution and blood from Exp. 189 showing one trypanosome to field; June 19 infected; trypanosomes were constantly present until animal's death from pneumonia on August 30, 1905. Spleen $3 \times 1.5 \times .75$ cm. normal; glands congested, not much enlarged.

Guinea-pig (Exp. 189). Inoculated with 2.5 c.cm. of blood as in Exp. 188; infected February 6, parasites constantly present in large numbers until death from pneumonia, August 30, 1905. Spleen large ($6 \times 3 \times 1.5$ cm.), soft, friable, congested; glands enlarged and congested. No trypanosomes were seen in blood just before death or in organ juices; present in gland juice.

Rat (Exp. 190). Inoculated with 2.5 c.cm. blood as in Exp. 188; not infected. April 19, re-inoculated with 2.5 c.cm. mixture as in Exp. 188; April 25, trypanosomes present, but were not again seen. Animal escaped June 19, 1905.

Rat (Exp. 191). Inoculated and re-inoculated (April 19) as in Exp. 190; infected May 1. Parasites constantly present until it died of pneumonia September 19, 1905.

Young guinea-pig (Exp. 230). Inoculated April 19, 1905, with 2 c.cm. blood from Exp. 189; infected May 6. Many parasites constantly present until death from the disease, July 6, 1905.

On the journey from Kasongo to Lusambo the blood of the following animals was examined by cover-slip preparations: four *Tragelaphus scriptus*, one *Canis anthus*, six *Hippotragus equinus*, one *Bos nanus* (ten antelopes, a jackal and a buffalo). Trypanosomes were seen in none of them.

V. MORPHOLOGY OF THE TRYPANOSOMES

(a) *Trypanosomes of cattle*

The trypanosomes seen in stained preparations of blood from the cattle, horses, antelopes and their sub-inoculations, are so nearly identical that one description will suffice. Slight variations and peculiarities will be mentioned separately.

Three types of trypanosomes were found corresponding closely to the description of *Trypanosoma dimorphon* as given by Dutton and

Todd.⁶ The first of these is a very short form resembling the "tadpole" form. It measures between 8 and 14μ in length (most commonly 11 to $12\cdot5$) by from $0\cdot9$ to $3\cdot4\mu$ in breadth (average $1\cdot5$). In this type the trypanosome is widest slightly posterior to the nucleus, and then gradually tapers towards the anterior end. The posterior extremity presents all gradations in shape from acute to rounded; most commonly, however, it is rounded. The anterior extremity is effiliated. The blepharoplast is small, round or oval, and is situated close to the posterior end and at one edge of the trypanosome. In most of the parasites the undulating membrane could not be seen; in those in which it was visible, it was extremely narrow. The thickened edge of the undulating membrane is poorly marked and in all cases ends abruptly with the anterior end of the trypanosome. A free flagellum is absent. The nucleus lies in the middle third, and as a rule occupies the whole width of the body. It is oval, and either stains quite homogeneously or is composed of a varying number of darkly-staining chromatin granules (5 to 17) arranged in no definite manner. These granules were not joined by connecting threads as far as could be made out. In only a very few cases could a structure suggesting a karyosome be seen. The cytoplasm stains a light blue and appears to be quite homogeneous. It was usually devoid of granules, but in some cases contained them.

The second type is allied to the "stumpy" form.⁶ It measures from 15 to 20μ in length (average 16μ) and from $1\cdot5$ to $2\cdot5\mu$ in breadth (average 2μ). It also lacks a free flagellum or, at most, has an exceedingly short one. In other respects it does not differ materially from the description given above.

The third type resembles the "long" form.⁶ It measures from 20 to 30μ in length (average 23 to 27μ) by from $1\cdot2$ to 2μ in breadth (average $1\cdot5$ to $1\cdot7\mu$). The nucleus is rather elongated in the direction of the long axis of the body and as a rule stains quite intensely and homogeneously. This form has a fairly long free flagellum which measures from $2\cdot5$ to $6\cdot5\mu$ in length. The posterior extremity is rather acute and the blepharoplast is situated farther away from it than in the other two types. In other respects it is comparable to the two other varieties.

EALA.

The trypanosomes observed, with one exception, are of the "long" type, with a well-defined free flagellum. The exception measured 14μ in length by 9μ in breadth, and conforms in all respects to the "tadpole" type. In these parasites the blepharoplast was of comparatively large size. Parasites of the "long" type in the process of longitudinal division were seen in preparations of the peritoneal fluid. In fresh preparations this trypanosome moved so rapidly that it was extremely difficult to keep it in the field of the microscope. By its rapid movement this parasite recalls the description of *Trypanosoma vivax* by Ziemann.²⁰ We are, however, satisfied that it is the "long" form of *Trypanosoma dimorphon*.

NOUVELLE ANVERS.

The parasites conform to the description of the "tadpole" variety. One trypanosome of the "stumpy" variety, measuring 19.2 by 1.9μ , was also found. In the one sub-inoculation the trypanosomes did not show any changes.

ROMEE.

The parasites are of the extremely short "tadpole" variety. In the direct sub-inoculations the parasite preserved the same characteristics with considerable constancy. In two cases (Exps. 148 and 151), in addition to the very short forms, trypanosomes corresponding to the "stumpy" forms made their appearance. The same holds good with regard to the second passage. This fact is of some importance. Dividing forms of the usual longitudinal type were observed in all the sub-inoculations.

LOKANDU.

Trypanosomes of the first two types (the "tadpole" and "stumpy" forms) were found in these cattle. The short "tadpole" forms were very much more common than the "stumpy" type.

SENDWE.

The parasites agree in all respects with the "tadpole" type. The examination was rather restricted, however, as the parasites were very scanty and only a few preparations were available.

KASONGO.

In the cow, *Moiuma* (No. 33), the trypanosomes are of the third, the "long," type, and possess a well-marked flagellum. In many of

these parasites a large vacuole was seen immediately in front of the blepharoplast. In this parasite the blepharoplast was comparatively large, and recalls the trypanosome seen at Eala.

In the other cattle, *Zilani* (No. 8), *Yolo* (No. 9), and *Keowkosiko* (No. 60), the trypanosomes are of the "tadpole" variety. In *Yolo*, however, one parasite was seen of the "long" type with free flagellum and comparatively large blepharoplast. The further history in sub-inoculations of the trypanosome derived from *Yolo* is of great importance in its bearing on the identity of these cattle trypanosomes. In the rat (Exp. 222), inoculated from *Yolo*, all three types were found. Of these the "stumpy" type, measuring from 15 to 18 μ in length, was most abundant. In the subsequent passage this differentiation became more pronounced. The very short forms, measuring up to 14 μ in length disappeared, but the other two types persisted. The number of "long" forms increased with the progress of the disease, as was noted by Dutton and Todd in the case of *Trypanosoma dimorphon* (⁶, page 37).

The remaining two types can still easily be distinguished in experimental animals. The "long" form is more plentiful, is slender, and has a rather acute posterior extremity. The flagellum is fairly long and is actively motile, whipping from side to side with great vigour. The movements of the whole trypanosome are active and progressive. The trypanosomes of the "stumpy" type are rather broad and have a blunt posterior extremity. They move slowly, twisting round on themselves, then straightening out again, and so on. As a rule they maintain the one position and do not move from place to place. The undulating membrane moves sluggishly, and there appears to be no, or, at most, a very short, free flagellum. The body of the trypanosome is itself contractile. When buried between corpuscles the movements of both forms become appreciably slower.

(b) *Trypanosomes of the Kasongo stallions*

In the younger horse the parasites were identical with the "tadpole" forms as observed in the cattle. Unfortunately, no sub-inoculations were made from this animal.

In the second horse, "Toul," the trypanosomes were of the second ("stumpy") and third ("long") types as seen in the cattle. The "long"

forms with free flagellum were in the majority. In both types the cytoplasm often contained small reddish granules, which were most frequently observed in the posterior half of the body. In some thirty sub-inoculations with this strain the trypanosomes of both types have been constantly present. At the inception of the disease the "stumpy" forms are much more abundant, but as the affection proceeds the "long" type assumes the preponderance. *In the monkey sub-inoculated a few of the "tadpole" forms were observed.*

In fresh preparations the two types can be very easily distinguished. The long, slender form has a long flagellum and moves very rapidly, lashing in and out among the corpuscles. It progresses for a short distance, then stops, and in a few moments moves on again. It often moves fairly rapidly across the whole field. Occasionally it adheres to a corpuscle, and after twisting and lashing about for a short time breaks free and moves off. While the parasite progresses with the flagellar end in front as a general rule, it occasionally moves backwards for a short distance. The second form is broader and shorter than the first, and is much more sluggish in its movements. These consist chiefly of doubling and twisting of the trypanosome on itself. It does not progress far, but remains pretty constantly in the one spot. The undulating membrane and flagellum are very poorly developed in this variety. In contradistinction to Dutton and Todd,⁶ dividing forms, of the usual longitudinal type, were seen in this "stumpy" type.

(c) *Antelope trypanosomes*

In the antelope (*Tragelaphus scriptus*) killed at Mswata trypanosomes corresponding to the "tadpole" type were seen, but were very scanty. In the one sub-inoculation the parasites retained this type. Dividing forms of the usual longitudinal type were observed.

In the antelope at Kasongo the trypanosomes were of the second ("stumpy") and third ("long") varieties as found in the cattle. In the sub-inoculated animals these two types persisted; the stumpy forms being in the majority in the preparations examined. It was impossible to study this parasite fully, since the animal in which it was brought to England was accidentally killed and the strain was lost.

VI. ANIMAL REACTIONS OF THE TRYPANOSOMES

(a) *Trypanosomes of cattle*

The slight infectivity for laboratory animals of the trypanosomes in the majority of the cattle found infected is very striking. It is only at Romee that experimental inoculations were at all successful. No morphological variation in the parasites was noted to accompany this difference in virulence. All the parasites seen agree with the types already described. The results of inoculation of various laboratory animals with the trypanosome obtained from *Yolo*, Steer 9 at Kasongo through rat (Exp. 133) are briefly given.

MONKEYS (2).

Two monkeys, a *Macacus rhesus* and a *Cercopithecus* sp ? were inoculated intraperitoneally with small quantities of infected blood (0.5 and 2 c.cm. respectively). Trypanosomes were never seen in the *Macacus*, although it was carefully examined every day. It died 72 days after inoculation, from general tuberculosis. Parasites were found in the *Cercopithecus* on the second day after, but were only present in the peripheral circulation for two days; they then disappeared and were never seen up to the time of the monkey's death, some six weeks after inoculation. The monkey had a rise in temperature to 104° F. while trypanosomes were present in the blood, but afterwards did not have a recurrence of the fever. A rat was sub-inoculated from this monkey on the day of its death with 11 c.cm. of almost pure blood, but has not become infected up to the present, 80 days after inoculation.

RABBITS (3).

The incubation period varies considerably, from four to sixty-nine days, the usual time being about three weeks. The disease tends to be very chronic in these animals, as is strikingly exemplified by the following experiment:—

A rabbit was inoculated subcutaneously on May 3, 1906, with 4 c.cm. of infected blood and became infected 25 days later. The trypanosomes were present in scanty numbers for a week and then disappeared from the peripheral blood. Since June 4, 1906, they have never been seen, although the rabbit has been under continuous observation. On July 31, two rats were sub-inoculated from the rabbit, and both became infected after an incubation period of between two and three weeks. On November 12, 1906, another rat was sub-inoculated from the rabbit and became infected two weeks later. Finally another rat was sub-inoculated on January 30, 1907, and became infected after a prolonged incubation period of 47 days. It will thus be seen that the blood is still infective after the lapse of eleven months. It is said that unfavourable conditions, as lack of food, render animals particularly susceptible to trypanosomiasis and may cause a declaration of latent infection. In order to test this hypothesis this rabbit was placed on a very restricted diet from December 1, 1906, to the middle of February of this year. During this time it decreased in weight from 2,790 grm. to 2,075 grm. Trypanosomes were never seen in the blood, however, and as stated above a rat sub-inoculated at the end of January became infected only after a prolonged incubation. The temperature remained normal throughout.

Rabbits do not show any symptoms, but remain quite healthy and well-nourished. The trypanosomes are never very plentiful, and usually show periodicity. Two rabbits which died had extensive coccidiosis, and their death in less than four months after inoculation was probably due to this secondary infection.

Post-mortem.—The spleen is slightly enlarged and rather congested. The lymphatic glands are usually quite pale, firm, and only very slightly enlarged.

GUINEA-PIGS (3).

The incubation period is prolonged and the disease is also of long duration—up to 139 days. The animals remain quite healthy and the temperature does not rise during the disease. The trypanosomes are rather scanty at first, but before death occurs they increase in number and may finally be fairly plentiful. At the autopsy of those dead of the disease the spleen is found to be enlarged and rather soft. The lymphatic glands are increased in size to a slight extent and are quite pale in colour.

RATS (14).

Rats are rather susceptible to the disease. The incubation period is short, from five to fourteen days. It is interesting to note that in the rat sub-inoculated directly from the steer (*Yolo* No. 9) trypanosomes were not seen until the lapse of 249 days. When once established, the disease runs a chronic course as a rule, lasting for from 40 to 254 days. The usual length is about 80 days. The parasites are scanty, but usually increase in numbers before the animal's death. Periodicity is marked; the parasites may be absent from the blood for two or three weeks. The mode of inoculation has no influence on the incubation period. Large doses may cause the parasites to appear a little sooner than they otherwise would, but rats inoculated with such doses do not die any more quickly than those inoculated with small doses of infected blood. The quick passage of the trypanosome through a succession of rats (six) did not increase the virulence in any way.

Post-mortem.—The spleen is enlarged, congested and rather firm. The lymphatic glands are slightly larger than normal, and are quite pale and firm. The other organs show no changes.

MICE (2).

As in rats, the incubation period is short, about four days, and the disease is chronic. One mouse is alive 219 days after inoculation and still infected. The trypanosomes are always scanty, and may be absent from the peripheral blood stream for many days—78 on one occasion. The post-mortem changes are similar to those found in rats.

It will thus be evident that most of the common laboratory animals are susceptible to the infection. Mice and rats are most easily infected, guinea-pigs least. The disease is chronic and lasts for a comparatively long time. It produces few or no symptoms and the trypanosomes are usually present in but small numbers. The strain is not very virulent, and resembles in this the strain derived from the horse.

(b) *Horse trypanosomes*

The animal reactions of the strain derived from the second horse, *Toul*, are epitomised briefly below.

MONKEYS (2).

Two monkeys were inoculated, a baboon (*Papio anubis*) and a *Macacus rhesus*. The baboon, inoculated intraperitoneally with 5 c.cm. of blood showing one trypanosome in from one to five fields, never became infected. The *Macacus*, inoculated subcutaneously with 2 c.cm. of citrated infected blood, became infected after an incubation period of six days. At the same time the temperature rose to 105.4°. Unfortunately the further temperature chart is not of much value, as the monkey developed tuberculosis. The trypanosomes showed periodicity in their appearance and disappearance in a marked degree. The parasites were scanty at first, but became more numerous in the course of a couple of days and were afterwards present in fair numbers. The monkey died 107 days after inoculation, and at the autopsy the spleen and liver were found to be filled with tubercles. On the other hand, the lungs appeared quite normal. The lymphatic glands were not enlarged.

DOGS.

One puppy was inoculated subcutaneously with 1 c.cm. of citrated blood from a rat, and twelve days later trypanosomes were found in the peripheral circulation. The parasites have been periodic in their appearance and have never been present in large numbers. At the time of the first appearance of the parasites there was a slight rise in the dog's temperature, but since that there have been no further increases corresponding to the appearance of trypanosomes in the peripheral circulation. The dog is quite healthy and presents no symptoms whatever. It is still living, 76 days after inoculation.

RABBITS (5).

Five rabbits have been inoculated with varying doses of infected blood. The incubation period varies from eleven to twenty-nine days; most usually it is about two weeks. The trypanosomes are periodic in their presence in the peripheral blood and are usually rather scanty just before an increase in numbers. One rabbit only, showed in a marked degree the symptoms usually found in trypanosomiasis—emaciation, loss of hair with following ulceration of the skin, oedema of the external genitals and the base of the ears, increased secretion from the nostrils, conjunctivitis, haemorrhages into the anterior chambers of the eyes, panophthalmitis and blindness. The animal also became very anaemic and there was a diminution in both the number of red cells and the percentage of haemoglobin. All the others showed no symptoms. The disease is very chronic in rabbits, and lasted 173 and 178 days in the two which died from the disease. Two other rabbits died early in the disease from intercurrent affections. The fifth rabbit is still alive, 76 days after inoculation. There was no marked rise of temperature when the rabbits first became infected.

At the post-mortems of the animals dying of the disease enlargement of the spleen and lymphatic glands was the most noticeable feature. The lymphatics were pale in colour and were rather firm in consistence. The spleen was congested and rather soft.

GUINEA-PIGS (10).

Guinea-pigs appear to be most resistant. The incubation period varied between seven and fifty-two days, six weeks being the average time. The disease, when once established, is of long duration; death ensued in from 46 to 352 days, about 90 days being the average. Two are still alive, 76 days after inoculation. Trypanosomes are still present in both. In a few of the guinea-pigs the parasites were continuously present from the date of their first appearance in the peripheral circulation until the animal's death. They fluctuated in numbers, however. In the majority periodicity was noticeable. Occasionally parasites were absent from the peripheral blood for long periods, e.g. 34 and 67 days.

No symptoms of any sort are noticeable in guinea-pigs. The virulence of the strain was not increased by successive passages through three guinea-pigs; the incubation period and the duration of the disease were not affected. The temperature chart does not reveal any rise during the course of the affection. The trypanosomes are usually rather scanty, but before the death of the animal they may increase in numbers until they are fairly plentiful.

At the autopsy a more or less marked enlargement of the spleen was seen. The organ was congested and rather soft. The lymphatic glands, as a rule, were unchanged, though in a few instances they were slightly enlarged and in one case haemorrhagic. The other organs appeared normal.

RATS (10).

Rats are rather susceptible to the disease. The incubation period varies between one and forty-one days; as a general rule it is about four to six days. The duration of the disease varied from nine to 253 days, usually about 70. In the acute cases the parasites are present continuously until death, and are usually fairly numerous. In the chronic cases periodicity is observed and the trypanosomes, when present in the peripheral circulation, are usually in small numbers. Increase in the virulence of the strain was not obtained by passage through a succession of four rats. Sub-inoculations made from other experimental animals became infected in approximately the same time.

Post-mortem.—The spleen is enlarged and is congested and soft in consistence. Haemorrhagic infarcts were seen in one case. The lymphatic glands may or may not be enlarged. The enlargement is usually slight when it is present. The glands are pale and rather firm. The other organs normal. In one case subpleural petechiae were observed.

MICE (2).

As in rats, the incubation period is short, in our experiments about two days. The disease is chronic and lasts for months—as long as five. When first present the trypanosomes are very scanty. They disappear in a few days and may not be seen again in the peripheral blood for weeks. In one case they were absent for fourteen. They reappear before death and increase in number until the animal succumbs.

Post-mortem.—The spleen is very much enlarged, congested, dark purple in colour, and rather soft in consistence. The lymphatic glands are not enlarged. The other organs appear normal.

In general, the trypanosome is not very virulent. The incubation period is prolonged and, while the disease has *always* terminated fatally, death only ensues after the lapse of a comparatively long interval. The low degree of virulence is also manifested by the lack of symptoms and the absence of heightened temperature in the experimental animals. Efforts to increase the virulence by successive passages through any one species of animal (four passages) or through an alternation of animals, e.g., guinea-pigs, and rats (three of each) were without result. The parasites are scanty, as a rule, and in the more chronic cases exhibit periodicity in a very marked degree.

In the following sections the cattle trypanosomes in the Congo Free State are treated as a whole.

VII. DIAGNOSIS

An absolute diagnosis, of course, depends upon the demonstration of the parasite. The charts of the Kasongo cattle show that every means may frequently fail to show the parasites in infected animals. Of all the methods gland puncture was the most successful. In thirty consecutive examinations, at which parasites were detected either in the gland juice or in the blood, gland puncture was successful twenty-nine times, the examination of cover-slip preparations of blood thirteen times; on one occasion trypanosomes were present in the blood and were not seen in the gland juice. The same precautions must be taken in puncturing the glands of cattle as in those of men.⁵ The records of the animal inoculations (particularly at Kasongo, page 243) show that the animals we employed frequently remained uninfected after the inoculation of large quantities of blood containing living parasites. As a diagnostic test the sub-inoculation of laboratory animals was therefore often less sensitive than the examination of cover-slip preparations of blood.

If we except the cattle at Romee (seven laboratory animals, all infected), the bovine trypanosomes (i.e., first passages) were remarkable for their slight virulence in direct inoculation. Of twelve rats, four guinea pigs, two rabbits, two monkeys and four dogs inoculated at various stations, only one rat ever became infected. It is noteworthy that at present sub-inoculations into ordinary laboratory animals of the strain derived from this rat are always successful. The virulence of this trypanosome in direct inoculations therefore seems to have increased for the animals employed. The original strains of trypanosomes obtained from the antelope and from Commandant Sillye's stallion at Kasongo were much more virulent in the first passages.

No idea was formed of the absolute efficiency of gland palpation as a diagnostic test. In the animals found to be infected the superficial lymphatic glands were usually considerably enlarged; some of them, not advanced cases, however, had no evident glandular enlargement. Many of the animals examined once, and not found to be infected, had glands as large as, or larger than, those seen in the infected animals (this was especially so at Kasongo).

In the Gambia⁶ it was noted that a heightened temperature furnished a valuable indication of possible trypanosome infection in horses. Charts I, II, III, IV and V fully confirm this observation; but a high temperature observed once in an animal just thrown after a struggle in the sun has but little value. In such circumstances temperatures of from 101.5°F. to 103°F., or more, were noted in

animals carefully examined for parasites without result and believed to be healthy.

The enormous difficulty of demonstrating the presence of parasites in animals known to be infected is well illustrated by the observations at Kasongo. The importance of a well-kept temperature chart is shown by *Liboko* (Chart IV), whose temperature was constantly elevated, although parasites were seen but once.

Animals suspected of trypanosomiasis for any reason should be isolated; their temperature should be regularly and quietly taken; their gland juice and blood should be frequently examined, and laboratory animals should be sub-inoculated from them with doses of 10 c.cm. of blood. An examination of this type extending over some months is necessary before an animal can even tentatively be said to be uninfected.

VIII. SYMPTOMATOLOGY

The symptoms are given in the order of their importance. Fever is practically always present. Listlessness, with progressive weakness, emaciation and anaemia are usually present. A tendency to diarrhoea, with small frequent watery stools, and enlargement of superficial lymphatic glands* are frequently striking features. Oedemas and running from the eyes and nose were seen in only one or two instances. Haemorrhages, eye lesions, staring of the coat and loss of hair were not observed. The appetite remains good to the end. In the autopsies done the enlargement of the lymphatic glands was by far the most striking feature; the glands were either pale and very watery (particularly superficial glands) or congested and haemorrhagic (particularly abdominal or mediastinal glands). Oedemas were very rare, exudates were scanty, the spleen was not enlarged. We saw no petechial haemorrhages of serous membranes. On the whole, these findings are identical with those of Broden.³

IX. COURSE OF THE DISEASE

The disease is sometimes exceedingly chronic, and the infected animal may live for many months. (See Exps. 143, 146, 133, pages 238, 239, 244, and below).

If marked wasting continues death usually follows in both cattle and horses within a few weeks or three or four months. Occasionally an animal at this stage if well cared for will recover flesh, and the

* We are unable to say exactly how long after infection enlarged glands become apparent. We are inclined to think that it may be a comparatively late manifestation.

infection resumes the latent form. As is evident from the observations in many places, domestic animals may live an apparently normal life in districts where trypanosomiasis is rife; some infected animals may live for years in apparent health in such districts (see below).

The following observations are interesting in this connection. The history of Horse VI suggests that animals naturally infected with *Trypanosoma dimorphon* may sometimes recover, but are not immune to re-infection.

A stallion, Horse VI (Ref. 6, page 30), found naturally infected in the Gambia was brought to England. During two and a half years there were occasional rises in temperature, trypanosomes were occasionally seen, and its blood was infective to rats and mice (7). The temperature then became more regular, its blood was no longer infective, and parasites could not be found. In October, 1905, the superficial lymphatic glands were just palpable and too small to be punctured. During the winter of 1905, the animal became thin, &c., but trypanosomes were not seen. During the whole of 1906 the animal was healthy, its temperature was normal, and trypanosomes were absent from its blood. The glands remained too small to be punctured. From time to time inoculations were made into susceptible animals as follows:—

July 23, 1906. A white rat, inoculated subcutaneously with 7 c.cm. blood. As it had not become infected it was re-inoculated on August 14 with 18 c.cm. almost pure blood. It died on the 5th of September without having become infected. Cause of death was pneumonia.

October 23, 1906. A guinea-pig received 17 c.cm. of blood subcutaneously and died February 2, 1907. Trypanosomes were never seen, and at the autopsy all the organs appeared quite normal. On the same day a rat was inoculated with 10 c.cm. of blood. It died on November 5, 1906, from pneumonia; never infected.

January 15, 1907. A guinea-pig was inoculated subcutaneously with 20 c.cm. almost pure blood, and two rats with 20 and 15 c.cm. respectively. They have been carefully followed to date but have never become infected.

From all these points we believe this pony had recovered from a natural infection by *T. dimorphon*.

On the 21st of January, 1907, the pony was inoculated intraperitoneally with 5 c.cm. of infected citrated blood from a mouse infected with *T. dimorphon*. This was followed between the 6th and 9th of February by a rise in the animal's temperature, highest 102.5°, and again after a few days intermission to 103.2° on the 16th. With these exceptions the temperature has been since about 100°.

On February 16, two rats were sub-inoculated from the pony with 17 c.cm. of blood each. One of these became infected on the 6th of March and died six days later with numerous trypanosomes. The second rat became infected on the 15th of March and died on the 28th, also heavily infected. In both the spleen was very much enlarged. The trypanosomes were of the usual *dimorphon* type ("stumpy" and "long" forms).

In addition to the rise in temperature the pony lost its appetite and appeared sick. It lost weight for several weeks, but is now recovering. The blood was carefully examined every day but without result; trypanosomes have never been seen. The glands were palpated from time to time, but have shown no enlargement.

The following experiments indicate once more that animals inoculated in the laboratory with *Trypanosoma gambiense* may recover from the consequent infection. The connection between these and the preceding observations is evident. Their bearing on the question whether human trypanosomiasis is invariably fatal is most important.

I. A brown stallion was inoculated in the Senegambia (6) from a case of human trypanosomiasis. For the earlier history consult Memoir XVI (7) of this School. In October, 1905, the animal appeared to be quite healthy; no enlargement of the glands was present, and no trypanosomes could be found in the blood. Its temperature was always normal. Sub-inoculations from it were made as follows:

November 12, 1906. A guinea-pig was inoculated subcutaneously with 17 c.cm. of almost pure blood. It was accidentally killed on the 31st of December. Trypanosomes were never seen. On the same date a rat was sub-inoculated with 10 c.cm. Trypanosomes were never seen at any time. The rat died on February 4, 1907, from acute enteritis.

January 16, 1907. A guinea-pig and two rats were inoculated with 20, 17 and 20 c.cm. of pure blood respectively. The guinea-pig and the first rat are still alive and have never become infected. The second rat died on the 11th of February from an extensive skin disease.

This series of experiments pointed to the fact that the pony had entirely recovered from the infection by *Trypanosoma gambiense*. On January 21st it was re-inoculated subcutaneously with 7 c.cm. of citrated, infected blood, showing one trypanosome to one to five fields, from a guinea-pig infected with *Trypanosoma gambiense*. This, however, had no effect. The temperature has been taken twice daily for the past year; there has been no rise, even after the inoculation. The animal remained in good health; retained its appetite and did not lose weight. The pony was most carefully examined day by day, but trypanosomes were never seen.

On March 15 two rats were sub-inoculated, receiving 30 and 25 c.cm. respectively of almost pure blood. Up to date they have not become infected. On March 20 the pony was again inoculated intraperitoneally with 25 c.cm. of infected *gambiense* blood showing numerous trypanosomes. For a few days afterwards there was slight auto-agglutination of the cells, but trypanosomes have never been seen. As in the first instance, no rise of temperature or other morbid symptoms have been noticed. The experiments are still in progress.

II. A donkey was inoculated in 1904 (7). Since the fall of 1905, the animal has been in perfect health. No enlargement of the glands, or trypanosomes, have ever been noticed. On January 16, 1907, a guinea-pig (20 c.cm. pure blood) and a rat (20 c.cm.) were sub-inoculated, but up to date have not become infected. On January 21 the donkey was inoculated subcutaneously with 7 c.cm. of blood from a guinea-pig infected with *T. gambiense*. No rise in temperature or other symptom followed. For a few days the red cells showed auto-agglutination, but trypanosomes were never seen. On March 15 two rats were sub-inoculated from the donkey with 35 c.cm. of pure blood each. Both are still alive and have not become infected. On March 20 the donkey was re-inoculated intraperitoneally with 25 c.cm. of blood containing *T. gambiense* (one per field), but without result. No symptoms of any sort are apparent. The donkey is still under observation.

III. The cow inoculated by Thomas and Breinl (7) was under observation until June, 1906, when the animal passed out of our hands. It was in good health all the time. No trypanosomes were seen and the glands were not enlarged.

IV. A monkey (*Cercopithecus*) was inoculated May 17, 1904, with blood from a sleeping sickness case. She showed trypanosomes in her blood June 13; they were seen at intervals up to June 13, 1905, and not again. The animal died August 5, 1905, from miliary tuberculosis; no trypanosomes were seen at the autopsy. (This experiment is reported merely for its interest, as showing a chronic infection by *T. gambiense* in a monkey.)

X. CONCLUSIONS DISCUSSED

A. Cattle trypanosomiasis probably exists everywhere in the Congo Free State. Broden³ is also of this opinion. Since large game and *Glossina* are practically omnipresent¹ (perhaps with the exception of high land about Lake Kivu) it seems possible that it should be so; at all events, trypanosomes were found in every herd examined save those at Nyangwe, Cabinda and Lusombo. That the cursory examinations made at these places might easily have failed to detect infected animals is certain (see charts).

B. The causative trypanosome is probably identical with *Trypanosoma dimorphon*. Three ways of identifying trypanosomes are at present recognised; all of them are liable to error. They are (1) The morphology of the parasite in infected animals and in cultures.* Cultures have been made of very few of the African trypanosomes, and were not used in the present instance. (2) Animal reactions. (3) Cross inoculations.

(1) Morphology. It is well known that the form and dimensions of all trypanosomes may vary more or less, but when an unknown trypanosome varies in exactly the same way as does a known trypanosome (compare the Congo parasites we describe and *Trypanosoma dimorphon*) their variations become a strong proof of identity. And this especially in the present case, since no trypanosome of domestic animals shows such wide divergencies in form as does *T. dimorphon*.

All the forms seen may be approximated to the three types of *Trypanosoma dimorphon* as described by Dutton and Todd.⁶ At Eala, where the cow was suffering from an acute exacerbation of the disease, the "long" type were almost entirely seen, but one "tadpole" form was observed. At Romee, where the disease was chronic, only

* Koch's observations on *Trypanosoma brucei* and *T. gambiense* in the alimentary canal of *Glossina* suggest a realization of Schaudinn's proposal that an accurate classification and differentiation of various haematozoa would come with a fuller knowledge of their life cycles in either or both of their hosts. (Koch. Ueber die Unterscheidung der Trypanosomenarten. Sitzungsberichte der Königlich preussischen Akademie der Wissenschaften, XLVI Sitzung vom Nov. 23, 1905.)

the "tadpole" type was found. In the sub-inoculations, however, "stumpy" forms made their appearance. At Lokandu the "tadpole" and "stumpy" forms were seen. At Kasongo "long" forms were seen on one cow, and "tadpole" forms in the others. In one of these a "long" form was also observed. The "stumpy" and "long" types was also seen in the antelope at Kasongo. Dutton and Todd described the "tadpole" as being present at the beginning of the disease, while the other forms of the parasite appeared later.⁶

It seems quite probable that the "tadpole" forms are really often present in chronically infected animals and that they give place to the "stumpy" and "long" forms, as the disease becomes more acute, in either the original host or in sub-inoculated animals. That this is a probable explanation is supported by several observations in the present paper. For example, the history of the parasite as observed in the case of *Yolo* (p. 253), where we have the change from the minute form to the other two types in the sub-inoculations. The similar change seen by Broden³ in the case of his sheep and its sub-inoculation is of interest in this connection. Broden states that in the animals sub-inoculated from the cattle at Yumbi, the trypanosomes preserved the characteristics of those seen in the original animals. This observation seems to conflict with the explanation we have just given. He does not state definitely that forms with a free flagellum were absent, and from the fact that he compares some of his forms with the hyaline ones of Bradford and Plimmer which had a free flagellum, it seems possible that one was also present in some of the trypanosomes he saw. In this connection it is interesting to note that he observed only the "petite" forms in the cattle at Eala, whereas we saw both the "tadpole" and the "long" forms. The occurrence at the same time of trypanosomes of more than one of the types in several of our animals certainly also seems to point to the infection being caused by only one trypanosome rather than by two or more.

(2) Animal Reactions. The virulence of various strains of trypanosomes (in the laboratory) may vary greatly. The effects of a parasite on experimental animals can therefore only be taken as a general indication and cannot be accorded specific value. A parasite can only be said roughly to be highly, fairly, or slightly virulent. With *Trypanosoma dimorphon* the Congo parasites come under the second class.

The variation in virulence observed in the various strains of cattle, horse, and wild game trypanosomes found in the Congo is certainly not sufficient to suggest that more than one species of parasite was present.

(3) Cross Inoculation. This method depends upon the belief that an animal which has acquired immunity* to one trypanosome can only be re-infected by a trypanosome of a different species. We believe that this method is open to many fallacies, especially because of the enormous difficulties of applying it. (*a, b, c*).

(*a*) Experiments and observations of many authors show how extremely difficult it is to be certain that an animal has definitely recovered from a trypanosome infection. Cases of known infection often arise in which every means of demonstrating the parasite may fail.†

(*b*) For the same reasons an animal may become infected without the infection being detected.

(*c*) Our observations on Horse VI show that an animal may be twice infected by the same parasite.

Laveran (17) infected a rat with *T. gambiense* which had recovered a year previously from a previous inoculation. Martin (15) records somewhat similar experiences with a sheep and a goat. He states that "une même trypanosome peut revêtir des virulences variables et une forme atténuée ne vaccine point contre la forme exaltée," basing this on the work of Koch and Martini. This complicates the question of the identity of any one trypanosome, and shows that additional caution must be observed in placing too much reliance on the results of cross inoculations. It is altogether probable that the immunity in trypanosome infections is quite comparable to that seen in other protozoal diseases such as malaria and spirochaete infections, i.e., only a relatively active and not an absolute immunity is obtained.

Although most authors, in describing a newly-discovered trypanosome, have found it difficult to say to what species their parasite belongs, the majority of the trypanosomes, other than *Trypanosoma equiperdum*, reported in domestic animals in Africa, seem to be of the type of either *T. brucei* or *T. evansi*. For example,²⁰ Baleri as described by Cazalbou, Jinja cattle disease found by the members of the Sleeping Sickness Commission in Uganda, Kidei as described by Sanders, Aino found in Somaliland, El Debab found by Sergeant in camels in Algeria, Mbori affecting animals in French Soudan, Souma described by Cazalbou, and the trypanosome described by Roger and Greffulhe in horses in Algeria.

* In our hands the serum reactions dependent upon such "immunity" have proved unreliable.

† This point cannot be too strongly insisted upon. It must be especially remembered by those engaged in experimental work on the treatment of trypanosomiasis.

The animal trypanosomes we found in the Congo approach *Trypanosoma dimorphon* most nearly in morphology and animal reactions. On these grounds we identify them with that species.*

Broden (3) believes that there are two varieties of trypanosomes, at least, in the Congo. One of these, corresponding to our "tadpole" forms, he calls *T. congolense*, while the other he assimilates with *T. vivax*, described by Ziemann in the Cameroun. At Leopoldville he found a cow with the two varieties of trypanosomes. From the fact that in the sub-inoculations he found only parasites corresponding to his small forms, he concludes that the animal was suffering from a double infection. It is possible that the explanation suggested above may apply in this case. Broden also remarks, in considering the identity of the small form, that Dutton and Todd were unable to discover their trypanosome in Gambian cattle. That their examinations were insufficient has been demonstrated by Captain A. G. Todd, A.V.C. (13), who has since found trypanosomes in these animals.

In the Soudan, Balfour (14) found a trypanosome in cattle which bears considerable resemblance to the "tadpole" type found in the Congo. Five animals—two monkeys, two rabbits and a dog—were sub-inoculated with small quantities of blood, but trypanosomes were never seen in any of them. As the author states, the number of experiments is too small for any dogmatic opinion to be given as to the non-susceptibility of these animals. It should be again noted here that of many animals inoculated from cattle by us only one rat became infected. Balfour's trypanosome was named *T. nanum* by Laveran. Is it not possible that further work on this parasite may show that it is merely the tadpole form of *T. dimorphon*? In addition to cattle, Balfour found mules infected, but in these the trypanosomes were frankly of the *T. dimorphon* type (stumpy and long forms). In these the long slender trypanosomes have a free flagellum.

In French Guinea Martin (15) found that most of the domestic animals suffered from one of two trypanosomiases. Of these, the most frequent was due to *Trypanosoma dimorphon*, and it is interesting to note that in a sheep the trypanosomes had a long free flagellum, thus once again bearing out Dutton and Todd's observations. In sub-inoculations, however, the flagellum was lost as in Dutton and Todd's strain of *T. dimorphon*. Another interesting point is that in cattle Martin noted that occasionally *only one* type of the parasite was present, most often the long form.

Quite recently Laveran (16) has described a trypanosome found in sheep coming from Ségou on the Upper Niger. This trypanosome presents many of the characteristics of *T. dimorphon*, but from the fact that a sheep which had recovered from the disease, and had afterwards resisted a second inoculation of the same strain, became *infective* when inoculated with *Trypanosoma dimorphon*, Laveran concludes that it is a separate species, and accordingly names it *Trypanosoma pecauii*.

Trypanosoma congolense, *Trypanosoma nanum* and *Trypanosoma vivax*, at least, of other African trypanosomes, present marked affinities with *Trypanosoma dimorphon*. If they are identical the distribution of *Trypanosoma dimorphon* is very wide.

* At this juncture it is well to consider the variations in form and virulence described by Koch (20, page 121) to occur in *T. brucei*.

C. The transport of cattle from place to place should be forbidden as far as possible.

Apparently healthy animals may be infected with trypanosomes. It is easy, therefore, to understand the dangers which lie in moving cattle. An infected animal might easily introduce a new, and perhaps, therefore, a more dangerous source of infection into a herd where the disease does not exist or is present only in a modified form.

Or, again, animals may be introduced into an infected, perhaps apparently healthy herd, as at Kasongo, only to die of trypanosomiasis.

For example, Kivu cattle brought to the banks of the Congo; Lower Congo cattle taken up the river to Eala. Broden (3) reports that healthy cattle brought to Galiema from Dolo, about six miles away, became infected with trypanosomes. *Glossina palpalis* and big game occur about both places; the possibilities of infection are equal at both. He suggests that the Dolo cattle, which had no immunity against the Galiema trypanosome, may have been immune to another or perhaps merely a less virulent trypanosome occurring at Dolo. We are in entire agreement with him.

The cattle from Kasongo which we had sent to Lokandu (page 245) were in splendid condition. It seemed probable that they were more or less immune to the Kasongo trypanosome and would live for many months. Out of six animals sent, two were dead and two obviously ill within nine months of their arrival at Lokandu.

If for any reason, e.g., breeding purposes, it is absolutely necessary to move one or two head of cattle, they should be carefully examined for a considerable period (months) before commencing their journey. While travelling every precaution should be taken to preserve them from fly-bites. On arrival at their destination they should be isolated and not drafted into any existing herd until a second examination of some months' duration has been completed.

D. Special care must be taken in the choice and maintenance of posts for cattle-raising in areas where trypanosomiasis is liable to occur.

In the parts of the Congo visited, cattle did best in open plain country, where tsetse flies (*Glossina palpalis*) and big game (antelopes and buffaloes) were rare and pasturage good.

As Bruce first showed, big game are often infected with trypanosomes; their wholesale destruction in the neighbourhood of cattle has therefore been frequently advised. To rid a herd of other sources of infection, the infected animals existing in it must also be destroyed.

Nothing is said here concerning treatment. The results presented in another paper (page 275) are, however, quite promising enough to cause our method of treatment to be given a careful trial in trypanosome affections.

Since the blood of infected animals remains infective for some time after their death, and since some flies (*Stomoxys* and *Glossina*¹) capable of transmitting the disease, will feed on dead animals, great care should be taken to prevent flies from reaching any part of animals slaughtered because of trypanosomiasis.⁸ The *Glossinae* haunt thick bush or grass situated near collections of water; cattle should be kept in clear areas.¹ *Stomoxys* breeds in dung; the kraals should be kept scrupulously clean.

E. Game, as well as native African cattle and other domestic animals, may sometimes acquire a tolerance of certain strains of trypanosomes.

The African big game is usually said to be immune to trypanosomes. Tolerant would perhaps be a better word. A buffalo, zebra and antelopes inoculated with Nagana in Europe have died of the disease.⁹ This "immunity," therefore, does not extend to every member of these species, and must be acquired by individuals. Adult, apparently healthy antelopes (and other wild animals) which are infected with trypanosomes are frequently killed. Because of the percentage* of animals infected and the abundance of biting flies, it is certain that a young antelope is infected with trypanosomes for the first time very soon after it is born, and that it will continue to be frequently re-infected during the whole of its life. The parasites so frequently found in large adult wild animals, therefore, represent either a new, recent re-infection or an original infection of long standing. In either case the animal has grown up normally, in spite of trypanosome infections; *it is tolerant of the parasites*. It seems probable that the course of trypanosomiasis in African domestic animals may some times be of a similar type.

At Kasongo trypanosomes were seen in 5 per cent. of cattle. The percentage actually infected is certainly much larger; yet this herd is increasing. There were no deaths in it from disease during our stay at Kasongo, and the cattle were in splendid condition.

Trypanosomiasis is common and often fatal among Gambian horses (6). But two horses in the Gambia found to be infected with *Trypanosoma dimorphon* in

* Bruce found 22.9 per cent. infected in South Africa. In the Congo two *Tragelaphus scriptus* (eight examined) were the only animals infected among 22 large mammals examined. It must be remembered that all these animals were examined by methods admittedly fallacious. The percentage of wild animals infected must therefore be considered to be much higher.

December, 1902, were still alive, apparently healthy, and were constantly worked in November, 1906.*

The first part of the history of Horse VI is another instance of tolerance of trypanosome infection.

As will be gathered from the notes on the animals present at various posts in the Congo, individual cattle, horses, &c., seem to be resistant, since they live for some years in places where the disease is of a very severe type. Cattle are susceptible to inoculation with *Trypanosoma dimorphon*, yet at many places in the Gambia, at Cape St. Mary for example, large herds of cattle in splendid condition graze over the same ground as the horses. (Captain Todd found trypanosomes in Gambia cattle, and he states that it is a not infrequent cause of death.)

From all these facts it is not unreasonable to suppose that, like the game, domesticated animals may thrive in spite of actual trypanosome infection and exposure to constant re-infection.

It was a "tolerance" of this sort which Schilling had in mind when he spoke of a "symbiosis" of trypanosomes with their mammalian hosts (18). He describes cattle which have apparently recovered from infection with *Trypanosoma brucei*. His later publications (19), we believe, simply confirm his former opinion expressed in (18).

Malaria in African natives forms a striking parallel to this conception. Children suffer severely from the disease.† Those who survive have parasites constantly in their blood until they become adult, and even then they are not infrequently infected, and may have short attacks of fever.

An animal long infected with trypanosomes may have short attacks of fever, with the appearance of numerous parasites in the blood, and afterwards completely recover its former tolerant status (Horse VI). From the fact that adult antelopes are sometimes heavily infected with trypanosomes, it seems likely that there may be recrudescences of the disease in the same way in them. From the conditions obtaining in the Gambia, where "sleeping sickness" has been endemic for many years, it seems probable that man may acquire a similar tolerance of *Trypanosoma gambiense* (1, page 23). Almost nothing is known of the causes which may make the latent form of infection in animal or man virulent, and so produce the death of the individual host or an epidemic of trypanosomiasis in places where it was formerly sporadic (10, page 319), (5, page 27). Such an effect might conceivably be produced by (a) a diminution in the resistance of the host, or by (b) an increase in the virulence of the parasite. (a) Epidemics of sleeping sickness have seemed to follow hard times produced by wars and famines.^{5, 10} In the individual

* One of these animals has been treated at intervals with arsenic in the form of Fowler's solution. In March, 1907, he was still in excellent condition.

† In this connection it is noteworthy that the mortality from trypanosomiasis (?) seems particularly great among calves; see Eala, Nouvelle Anvers, Tshofa, &c.

animal, hard work, lack of food and concomitant disease sometimes seem to lead to a great increase in the number of trypanosomes present and (apparently) in their pathogenic effect.

(b) Laboratory work has also shown that the virulence of trypanosomes propagated by direct inoculation from animal to animal may vary very greatly indeed.

Thomas and Breinl (7, pages 14 and 21) obtained a very virulent strain of *Trypanosoma gambiense*. The animal reactions of the common strain of *Trypanosoma brucei* are no longer the same as those originally described by Bruce (10, page 140). The strain of *Trypanosoma dimorphon* employed by Thomas and Breinl finally became much more virulent for laboratory animals than it was at first.

The strains of trypanosomes obtained from rats in whom *Trypanosoma brucei* had recurred after treatment by atoxyl were repeatedly found to be more virulent than the control strains (page 276).

Whether natural variations in virulence are of the same type as in these laboratory examples is unknown. An observation bearing on this point is that there was no difference between the reactions either at the first or succeeding passages of animals infected with *Trypanosoma gambiense* in the Gambia, where sleeping sickness is sporadic, and those infected at Leopoldville or in Uganda, where that disease is epidemic (11, 12).

XI. CONCLUSIONS

A. Cattle trypanosomiasis is very widely distributed in the Congo Free State.

B. *Trypanosoma dimorphon* is probably the usual infecting parasite.

C. All cattle transport should be interrupted or severely controlled.

D. The posts for cattle raising must be carefully chosen and maintained.

E. Domestic animals probably acquire a relative immunity to some strains of trypanosomes, and may even recover spontaneously (see Section IX).

LITERATURE

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4. Reference No. 3, page 151.
5. DUTTON and TODD. "Gland Palpation in Human Trypanosomiasis," and "Distribution and Spread of Sleeping Sickness in the Congo Free State." *Memoir XVIII*, Liverpool School of Tropical Medicine, 1906.
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8. MUSGRAVE and CLEGG. "Trypanosomes and Trypanosomiasis with special reference to Surra in the Philippine Islands." *Dept. of the Interior, Biological Laboratory*, No. 5, Manila, 1903.
9. PLIMMER and BRADFORD killed a springbok with *Trypanosoma brucei*. KANTHACK, DURHAM and BLANDFORD killed hybrids of zebra with horse and ass by *Trypanosoma brucei*. A bush buck inoculated died seven months later, infected (?)
MARTINI killed a buffalo and a zebra with the Togoland trypanosome (see 10, pages 135, 186).
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20. LÜHE : in Mense, "Handbuch der Tropenkrankheiten," Barth, Leipzig, Vol. III, pages 106 and 125. This article gives an excellent review, with references, of the important facts in our present knowledge of trypanosomes.

CHART I

CHART II

CHART III

CHART IV

[illegible][illegible]

CHART V