Immunity, Susceptibility, and Mortality.

Sir John Kirk said (1), while speaking of the tick-fever on the Zambiese, that after recovery from tick-fever the patient had complete immunity from further attacks. We have been told by natives that a man can only once be made ill by the "*Kimputu*." It seems very probable that those living in infected localities may have relapsing fever while young, and grow up immune to the affection. Several Zanzibar traders have lately told us that the human tick "*Papasi*" (7) of Udjiji and Zanzibar (they assert they are the same as the ticks of this region) are harmless, and that their bite gives no disease. As already noticed, Livingstone, in 1871, did not mention that the ticks—"*Tapasi*"—of the Arab town at Nyangwé produced any disease (3). Nyangwé has at present a particularly bad reputation. The natives living inland who are forced to come to that post always endeavour to avoid sleeping there. A small caravan comes monthly to Nyangwé to bring in produce from villages some two days' walk inland. The porters formerly slept at Nyangwé before returning home. As a result there was always some one sick with "*Kimputu*" in their villages. It is generally accepted that strangers are particularly susceptible, and it seems certain that the majority of cases in this district occur among newcomers. All of our cases, save Nos. 2, 4, 7, had recently been exposed, for, probably, the first time to tick bites.

The mortality from tick-fever does not seem to be very great amongst those who are cared for and not exposed to fatigue and hunger. Under adverse conditions the death rate may be high; for example, of twenty carriers who contracted the disease in one caravan sent from Kasongo to Kabambarré ten died

Incubation Period.

The period intervening between the bite of the tick and the declaration of the disease is, from our experience, about one week. The natives usually put it at five days. Occasionally symptoms are said to follow within a few hours of the bite. In no case have we been able to personally verify the dates of both the bite and the commencement of the fever.

Symptomatology.

In the two European cases slight prodromata, mental heaviness, and lack of acuity were noted. In all the cases the onset of the fever has always been sudden, and in no instance preceded by a distinct rigor. The patient is prostrated, and complains chiefly of severe headache, usually frontal occasionally general. Boneache—in the limbs, and backache are distressing: the patient feels as if well beaten. There is a marked distaste for food. Vomiting generally occurs once or twice, but has never been continued. Slight diarrhoea is fairly constant, constipation may occur. The evening temperature during the attacks frequently reaches 104.5° F.; the highest temperature recorded is 105.3deg. F. There are usually three or four attacks which often end in more or less profuse perspiration. As a rule each attack lasts for three or four days, and the intervening periods vary from five to nineteen days.

The spleen is sometimes, not always, enlarged. Herpes, epistaxis, and hiccough, were complications observed. The most characteristic features of the disease have been the prostration of the patients during the attack of fever, and the quick return to comparative health with the fall of the temperature.

The following case reports, charts, and *post-mortem* finding certainly demonstrate the clinical identity of the tick-fever observed by us with the relapsing fever of the text-books (8, 9).

Reports of Native Cases.

CASE 1.—Female, age 27, seen at Lokandu, October 30, 1904, under observation for two days.

History:— Patient and her husband, a soldier, were on their way from Lake Tanganyika to the Lower Congo. On the night of October 12 she was bitten by ticks on the thigh, neck, and arm. Three ticks were caught in the morning, no obvious marks of the bites were left. The following day Kasongo was reached; here the patient remained for a week. On October 21, the day after leaving Kasongo, she fell sick. The incubation period that is, the interval between the bites of the ticks and the appearance of symptoms, is, therefore, in this case about eight or nine days. On getting up in the morning she complained of terrible headache, accompanied by throbbing of the ears. Her husband says that there was fever but no shivering. The headache, though apparently chiefly frontal, extended around the head to the occiput. There was no accompanying nausea or vomiting.

Present Condition:—Temperature sub-normal; pulse 70; respiration 20. The patient is a fairly developed woman; no wasting. She has a pained expression, and keeps the head fixed. Because of severe headache has a piece of "tie-tie"—native cord—tied tightly around the head across the forehead. It is apparently disagreeable for her to be placed in a bright light. She has lost her appetite, and complains of a bad taste in the mouth. She walks gingerly with the help of a friend; extremities are cold; respirations somewhat laboured. Liver is not enlarged or tender. Spleen is distinctly enlarged, extends 5.5cm. below costal margin, not tender. Tongue is flabby and furred. Patient otherwise normal.

October 31st.—Temperature a.m., 97.8; p.m., 101.2; respiration and pulse as before. Headache is still very severe. A slight fulness around eyes is noticed.

Blood examination:—No malarial parasites or trypanosomes were seen in either fresh or stained preparations. In two stained films taken on October 30th two spirochaetes were seen.

CASE 2.—Female, age 26, seen at Ukungwa, October 31, 1904; under observation for one day.

History:—Patient was bitten a month ago by a tick. A week later high fever with chills commenced. At present has no fever, but is weak, quite thin, and still complains of severe headache and of pain in the eyes. Physical examination revealed nothing abnormal; the spleen was not enlarged. No malarial parasites or trypanosomes were seen in either fresh or stained preparations of blood. In four stained films as many spirochaetes were seen. Many ticks were found in the house—a rest-house for native travellers—in which this patient lived. She was the wife of the caretaker, and was not a native of the district.

CASE 3.—Male, age 20, seen November 6, 1904, at Sendwé; under observation for two days.

History:—Patient, a native of this neighbourhood had been employed as a labourer at Stanleyville. He was on his way home, and while at Ukungwa, where he slept in the house inhabited by Case 2, he was bitten by a tick. Patient says that symptoms

DISEASE.

Spirillar Fever

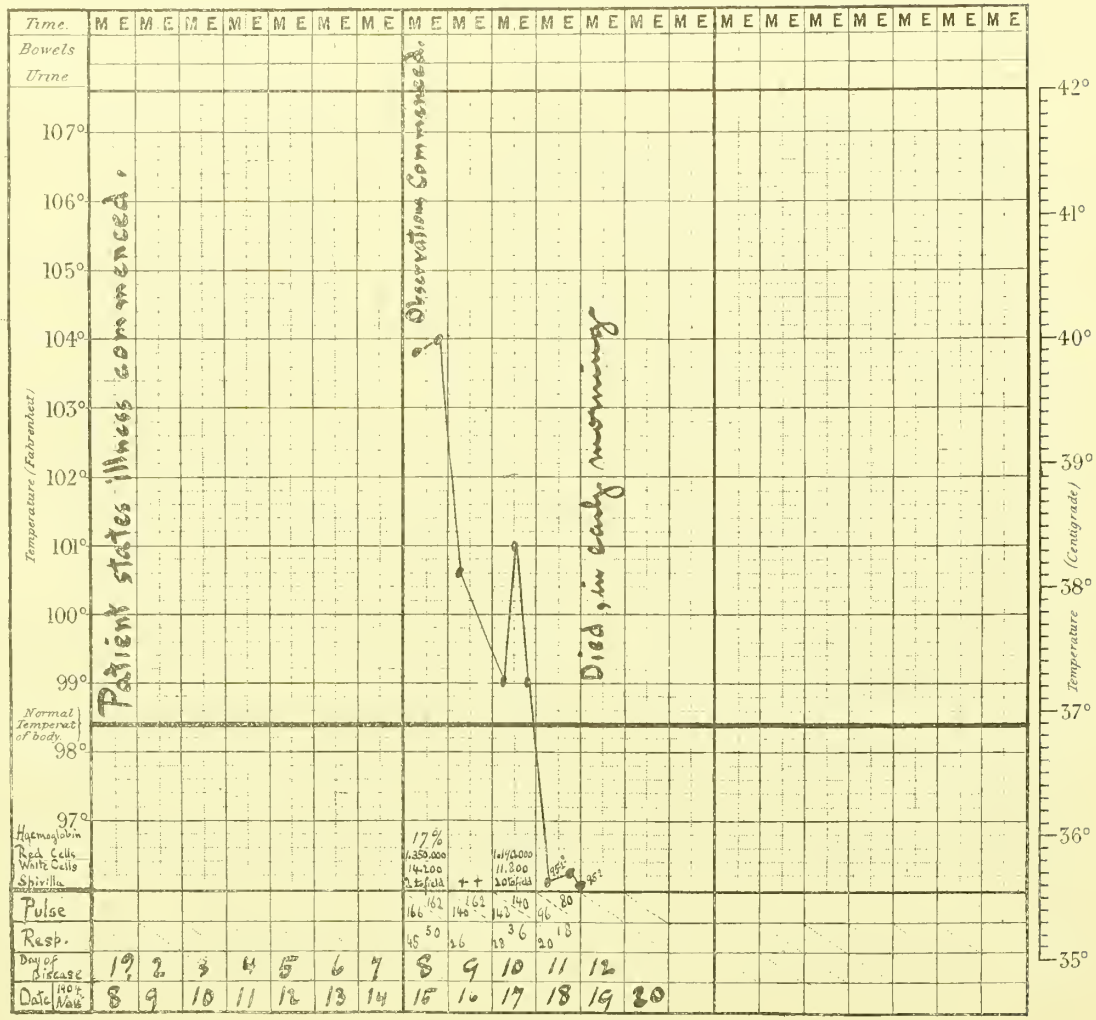
Notes of Case.

Name Case, 4.

Age ♀, 14

: African

Chart I



to Face p 5

commenced on October 15th, four days after the bite. On his arrival at Sendwé, October 24th, where he was employed as a labourer, patient seemed strong and well, and it was not until about a week later (October 31) that he was noticed to be ill. It is very doubtful whether there was any rigor, and the history of fever during the first four or five days of the disease is uncertain. The patient says that his illness commenced with a "bad mouth," and a distaste for food. Pain in the eyes with frontal headache, pain in the nape of the neck and in the loins successively appeared. Patient asserts that these symptoms persisted, though lessening in intensity, up to the present (Nov. 6). There has been no vomiting or diarrhœa—took native enemata. The resident European says that patient is certainly thinner and less robust than on his arrival here.

Present Condition:—Pulse, respiration, and temperature normal. Patient is a thin man, has apparently lost flesh; is obviously weak; has pained expression; eyes watery. Physical examination showed nothing abnormal; spleen not enlarged or tender. The lymphatic glands of the inguinal region were alone enlarged. Blood examination:—Many fresh, centrifuged, and stained preparations of the blood were taken. No malarial parasites, trypanosomata or spirochaetes were seen. A few filaria, sheathed and unsheathed, were present. Fresh and stained specimens of spleen juice showed no parasites. Gland juice was examined with negative result.

The history and record of examination of this patient are typical of six other cases who have been brought to us, some weeks after the commencement of their illness, but while they were still weak.

CASE 4 (*Chart No. 1*).—Female, age 14, seen at Nyangwé, November 15, 1904; under observation for four days preceding death.

History:—Patient was born and has always lived in this neighbourhood. On November 7, at about midnight, she was bitten on the foot by a tick. Before daybreak fever, headache, vomiting, and purging came on. The diarrhoea persisted for four days. The vomiting quickly stopped, and recurred only once on the third day of the disease. Though patient has always eaten well, she does not seem to have relished her food. On the second day of her illness she was brought to Nyangwé. She then had generalised headache and pain in her legs; she was in a fever, trembled continually and felt very weak. In spite of these symptoms she has continued work in the gardens.

Present Condition.—Temperature 103.8, pulse 166, respiration 45. Patient is a well-matured, but slight and thin child; is too weak to walk alone, and prefers to lie, not sit on the floor.

Although patient and her master deny that there has been any abeyance in the symptoms, it seems that she is more ill to-day (November 15) than yesterday. This morning she claims to have got up well and to have gone to work as usual, but as the sun became hot she became "tired."

Physical examination revealed no abnormalities save slight puffiness and yellowishness of face about the eyes, and a greatly enlarged spleen, which reached, patient lying on back, to below the umbilicus. Its superficial markings, in the recumbent position, are indicated in the accompanying photographs (Pl. 3, fig. 1).

Blood examination:—Coverslip preparations showed large numbers of spirilla. No malarial parasites or trypansomata were ever seen in this case. On splenic puncture the fluid aspirated contained spirilla in apparently the same numbers as finger blood.

The patient became steadily weaker, spirochaetes were constantly present in her blood, and she died early in the morning of November 19.

Autopsy:—The examination commenced at 9 a.m., six hours after death. The body was that of a thin, but not emaciated girl. Post mortem rigidity present throughout. Skin fairly clean, no eruption. Oedema of dorsa of both feet and of upper and lower eyelids. Pupils equally and widely dilated; mouth clean; no icterus. The usual incision was made; subcutaneous fat fair in amount; much light-coloured blood escapes from cut vessels—looks like blood-stained water; no oedema present over abdomen.

Abdomen: Contains about 5ccm. slightly blood-stained fluid; omentum retracted.

Thorax: Pericardium and pleura normal; about 50ccm. clear fluid in pericardial sac. Heart, weight 114 grammes, on whole fairly normal; muscle pale, firm, slight fatty change at apex of papillary muscle. The extended valves measure—pulmonary 5cm., tricuspid 9.26cm., mitral 8cm., aortic 4.75cm.

Lungs together weighed 342 grammes, are very pale, otherwise normal.

Liver: Weight 1,132 grammes, measures 23 by 14 by 8cm.; cuts firmly, on section very yellow and shiny; no amyloid reaction. Gall bladder pale, moderately filled with viscid bile.

Spleen: Weight 342 grammes, measures 15 by 8.75 by 5.5cm., cuts firm and hard, not easily friable.

Kidneys: Weight together 114 grammes, right measures 7.8 by 4.6 by 2.5cm., cortex 0.6cm, both are almost bloodless and cut firmly, capsule peels with ease; colour, particularly in pyramids, is dirty, brownish-yellow, suggesting fatty degeneration.

Bladder: Normal, filled with highly coloured urine.

Pancreas normal. Stomach and intestines contained no food, many round worms, and very many anchylostomes.

Lymphatic glands normal. Bone marrow at middle of femur was saffron-coloured and firm.

Films taken at the autopsy showed the continued presence of spirochaetes.

CASE 5.—Female, age 28; under partial observation during course of illness.

History:—The patient, coming from Stanleyville arrived at Nyangwé on November 13. The illness commenced there on November 22 with fever, headache, and pain in the limbs. There was no history of a tick bite. On November 23, fever and pain persist; severe vomiting. November 25, temperature 99.6, feels almost well, complains bitterly of aching thighs and calves. Patient remained well until December 4, when the symptoms recurred and spirilla were found in the blood (first examination). This, the second attack, lasted until December 8. There was then a complete absence of symptoms until December 17, when the third and last attack came on with severe vomiting, boneache, and fever.

CASE 6.—Female, age 18; under partial observation during course of illness.

History:—Patient, coming from Stanleyville, arrived at Nyangwé on November 13. The illness commenced there on November 21 with fever, very severe headache, vomiting (once), diarrhoea, and pain in the back. There is no history of a tick bite. On November 22 and 23 the temperature varied between 104.5 at night and 101 in the morning. On November 24 temperature normal, and patient, save weakness, well. Second attack commenced on November 29, with the same symptoms, evening temperature 104. On the afternoon of November 30 profuse perspiration came on, and the temperature fell to normal. Patient then remained without fever until December 14 and 15, when the usual symptoms returned, evening temperature 103. December 16, temperature returned to normal, and patient remained well.

Rather profuse expistaxis occurred in this case on November 22 and 29. The spleen, slightly enlarged after the first attack, was, after the third, 5cm. below the costal margin. The blood was examined on November 29, and numerous spirochaetes seen.

CASE 7.—Male, age 26; seen January 6, at Kasongo; under observation for five weeks.

History:—Patient has lived in Kasongo for the past two years. He states that about a week or ten days ago he was bitten during the night by two ticks. He caught them, burned them, cut his skin at the site of the bites, and rubbed in the ashes as a preventive against tick fever.*

Two days ago his illness commenced, he complained of feeling cold, having fever, trembling and weakness. He has been unable to take food for two days.

* This is the treatment usually employed by natives of this district for tick bites. Its prophylactic powers are widely believed in. Livingstone mentions (5) an analogous practice.

DISEASE.

Spirillar Fever.

Notes of Case

Name { Case 8

Age ♂ , 19

African

Chart II

to face p. 7

DISEASE.

Spirillar Fever

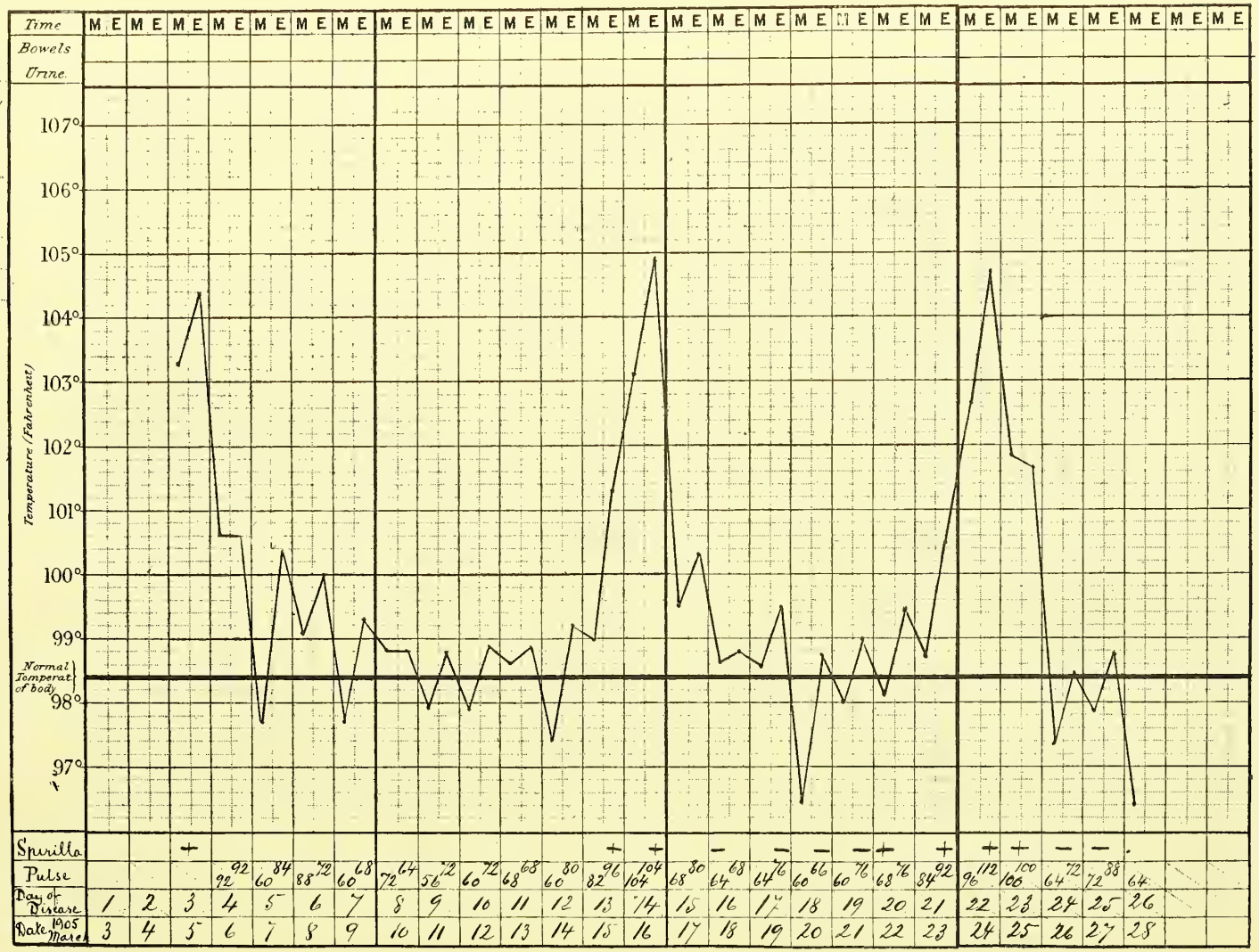
Notes of Case.

Name Case 9

Age 20 ♂ African

Case Book N°

Chart III



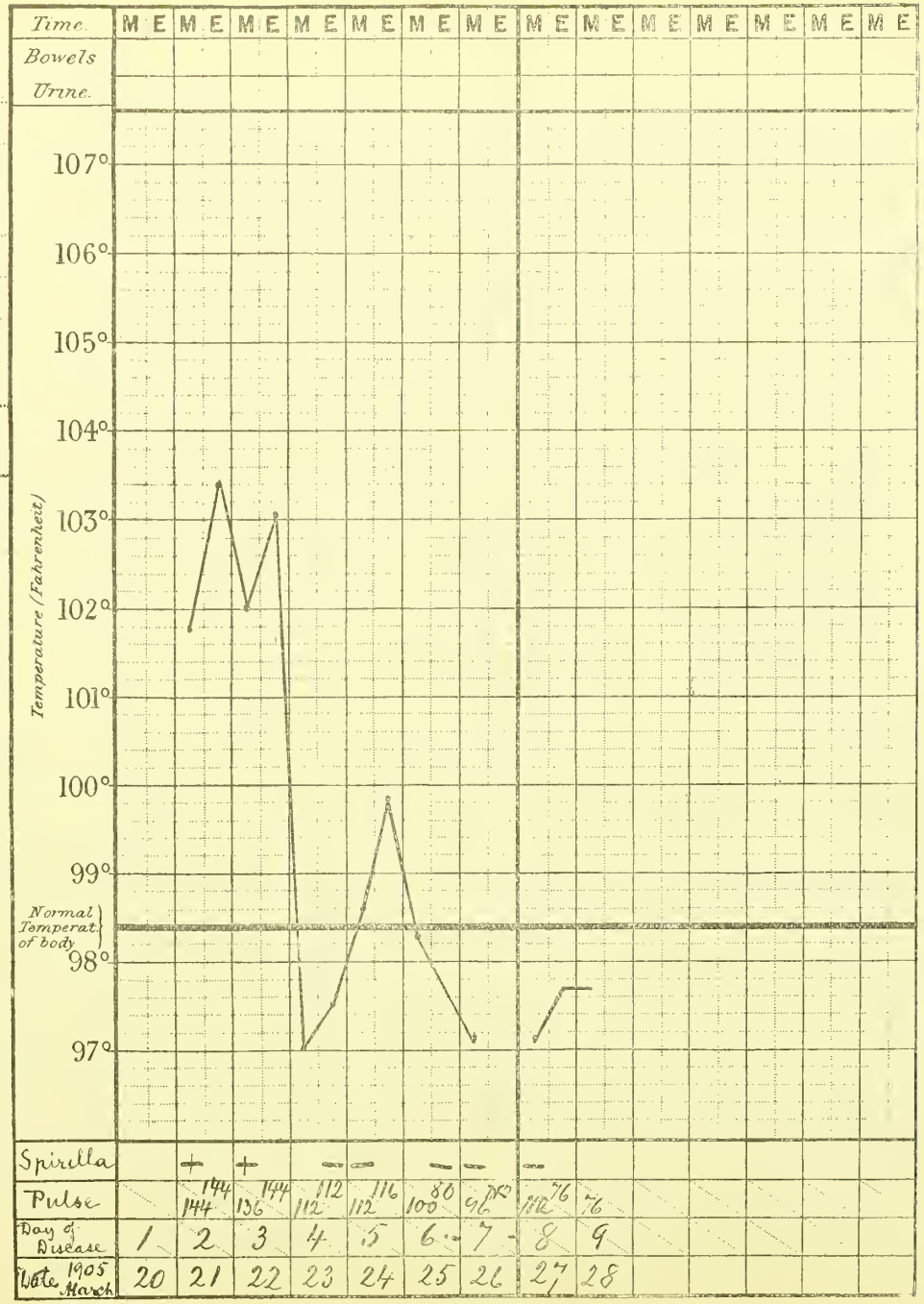
DISEASE.

Spirillar Fever

Notes of Case

Name { Case 10.
5, ♂
African
No

Chart IV



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DISEASE.

Spirillar Fever

Notes of Case.

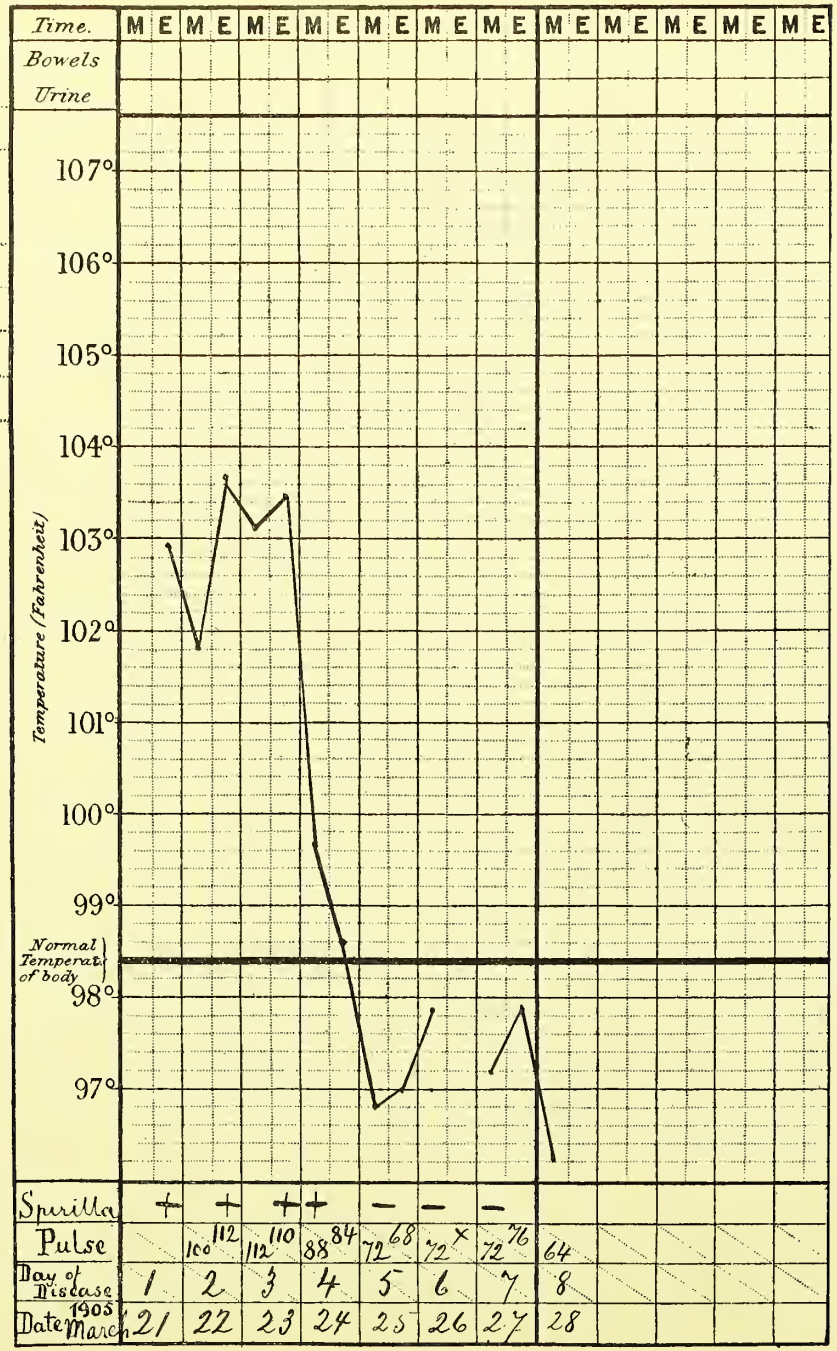
Name { Case 11

Age 28 ♀

African

Mother of case 10.

Chart V



× absent

Physical examination: Temperature 101.4, revealed nothing abnormal, spleen not palpable. Spirochaetes, not numerous, were seen in fresh and stained specimens of the blood by Dr. Heiberg. In spite of repeated examinations, spirilla were never again seen in the blood of this patient, although on January 11 and 13 there was a well-marked rise of temperature (highest 102), and again between January 20 and 31 there was constantly a slight (99 to 100) evening temperature to be recorded.

CASE 8 (*Chart No. 2*).—Male, age 19, first seen March 5, still under observation.

History:—Patient is a soldier, one of a detachment on their way from the Lower Congo to Lake Kivu. He slept on the night between the 23rd and 24th of February at Nyangwé. He fell sick on March 2, at Kasongo, with frontal headache, pain in the back and limbs, anorexia, vomiting, continued constipation, and fever. The liver was normal; the spleen slightly enlarged and tender. The course of the disease was uneventful. The results of blood examinations are entered on the chart.

CASE 9 (*Chart No. 3*).—Male, age 20; first seen March 5, still under observation.

History:—Patient belongs to the same detachment of soldiers as Case 8. The history and symptoms were the same in both, save that the illness commenced in this case on March 3, and there was no vomiting.

The temperature curves of these two cases are remarkably similar.

CASE 10 (*Chart No. 4*).—Female, age 5; first seen on March 21, 1905, still under observation.

The patient is the daughter of a soldier on his way from the north of the Lake Tanganyika to the Lower Congo. She was bitten near Kabambarré on the night between the 13th and 14th of March. The illness commenced on March 20 with headache, pain in all the body, restlessness, anorexia, no vomiting, constipation, and fever. Liver was not enlarged. At the first examination the spleen was found to extend to 8cm. below the costal margin. On March 25 and 26 the pulse was irregular. No malarial parasites have ever been seen in this case.

CASE 11 (*Chart No. 5*).—Female, age 28; first seen on March 21, 1905; still under observation.

Patient is the mother of the preceding case, and was bitten at the same time. Her illness commenced on March 21 with the usual symptoms, the headache being distinctly temporal. There was no vomiting, and the spleen was never enlarged.

CASE 12.—Female, age 27; seen first on March 21; still under observation.

Patient is the wife of a soldier on his way from the Lower Congo to Lake Tanganyika. There is no history of tick bite. Illness commenced March 19 with general malaise, pain in forehead and nape of neck, anorexia — but no vomiting, constipation. Liver normal. Spleen enlarged and tender. Blood was examined on March 21, and spirilla found. The temperature on March 21 was 100.4; it has since been normal, and parasites have not been again seen.

Reports of European Cases.

J. E. D. (*Chart No. 6*). (*Patient's Own Notes.*)

Nov. 25.—This evening felt tired and unable to work as usual; have been partially constipated for past four days.

Nov. 26.—This morning was unable to take breakfast—loathing for food—nevertheless, swallowed a little bread and tea, and started at eight o'clock, after the sun had well risen, on a seven mile walk to Vieux Kasongo. During the first hour felt fairly "fit," and refused to ride on mule. As the sun became warmer, commenced to feel uncomfortable, arms ached so that it was almost impossible to hold sun-umbrella, and reached

White Fathers' Mission at the sixth mile in almost a collapsed state. Was carried in hammock to destination. Blood was examined at 4 p.m., and nothing seen. Six grains of calomel taken, and two small motions obtained. During the night was much distressed by fulness of the abdomen, and vomited four times. A few drops *Tr. Opii.* gave much relief.

Nov. 27.—Felt very slightly better in early morning. Head felt as if "muffled up," and severe throbbing, frontal aching soon developed. Had slight pains in small of back. Fulness and distention of abdomen as distressing as ever. Four cathartic pills taken in the morning had no effect, so calomel grs. 6 was taken, and several small liquid stools were passed during the night. Blood was examined at nine this morning and spirochaetes found.

Nov. 28.—Passed a bad night (7½ grains of antipyrine taken at 1 a.m.), because of severe throbbing headache and distressing fulness of abdomen; vomited twice during the night. Tried to get up in early morning, but soon returned to bed because of fever, weakness, and exhaustion; headache not so bad. Blood examined, spirochaetes present. Antipyrine grs. 10 taken at noon and saline laxative in the afternoon.

Nov. 29.—Was awake, up and down, all night, but not so distressed as during two preceding nights. Started in early morning, carried in hammock, for Kasongo, where arrived at 8 a.m. Throughout this access of fever a constant soapy taste was noted in the saliva.

Nov. 30.—Much better, went for walk; noted bodily weakness.

Dec. 1.—Passed fair night. Woke up after after-dinner nap with distinct oedema around eyes. Herpes has formed on upper lip and just within right nostril; there are two small ulcers on gums.

Dec. 2 to 6.—Save for slight looseness of bowels absolutely well.

Dec. 7.—Slight weariness in arms and legs; on coming in from morning bicycle ride felt shivery.

Dec. 8.—In bed, same symptoms as in previous attack—headache, boneache, lassitude, distaste for food—but no vomiting. Had no great thirst.

Dec. 9.—Same condition, constipated.

Dec. 10.—During early morning temperature fell to 97—a slight perspiration preceding—headache disappeared and appetite returned.

Dec. 11-15.—Fairly well and able to work.

Dec. 16.—Fever recurs in usual manner.

Dec. 17.—Headache bad; 7½ grains of antipyrine at noon. Temperature fell to normal after tepid bath at 10 p.m.

Dec. 18.—Weak, bowels loose, otherwise well.

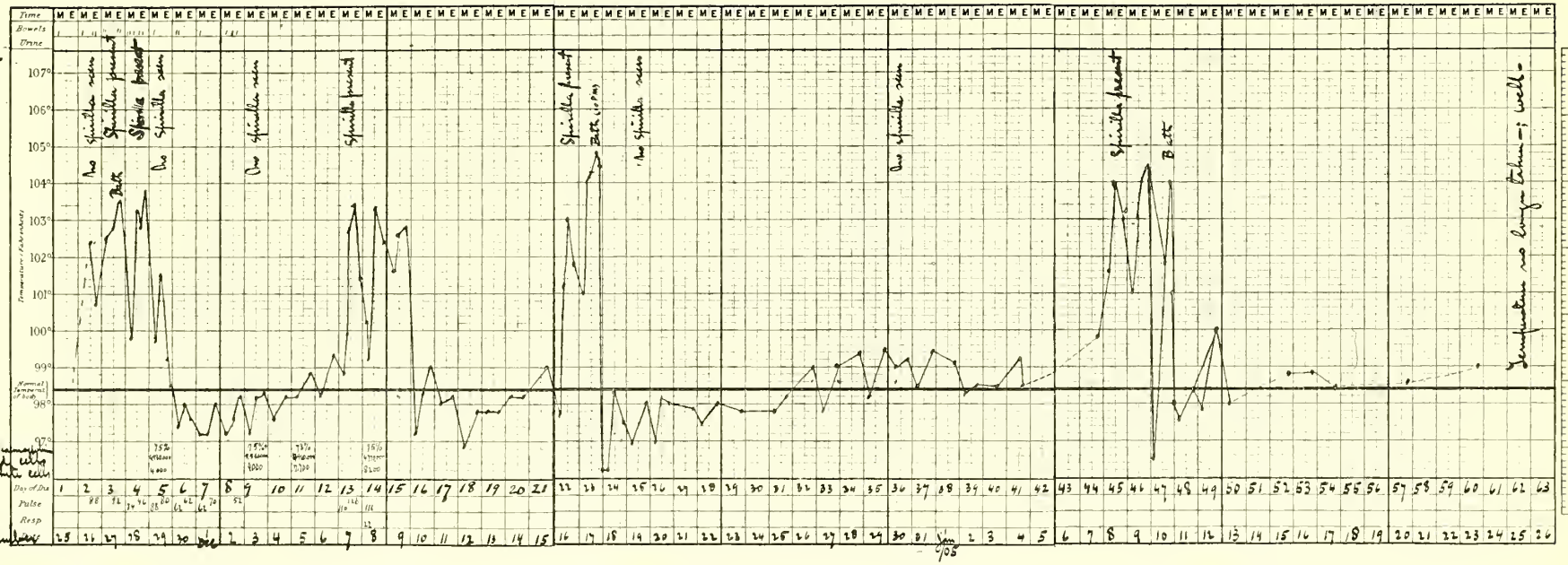
For the following week (Dec. 19-25) felt very well, appetite was good. From Dec. 26 had a constant slight evening temperature, was rather bilious and constipated (calomel grs. 5, Dec. 31), and had a slight localised boneache, especially in the fore-arms.

Jan. 7.—Felt chilly and good for nothing this evening.

Jan. 8, 9, and 10.—Recurrence of fever with same symptoms as before. The temperature suddenly fell on the night of the 9th during a second heavy sweat. There was no further recurrence of fever. After each attack there was slight looseness of bowels and increase in amount and frequency of urine. The slight ulcer in the nostril lasted for some time after the labial herpes had disappeared. The spleen was tender, but was never easily palpable. For a fortnight succeeding the last attack occasional small evening rises of temperature with slight malaise were recorded. The appetite and general sense of well-being quickly improved under arsenic. Good health continued until about February 15.*.

The temperature chart and diary of this case record graphically the classical description of relapsing fever (8, 9). Spirilla were seen in the blood during each access of fever. Malarial parasites were always absent, and the patient has never at any time had malarial fever.

* No spirochaetes were seen during J. L. D.'s fatal illness.



DISEASE.

Spirillar Fever

Notes of Case

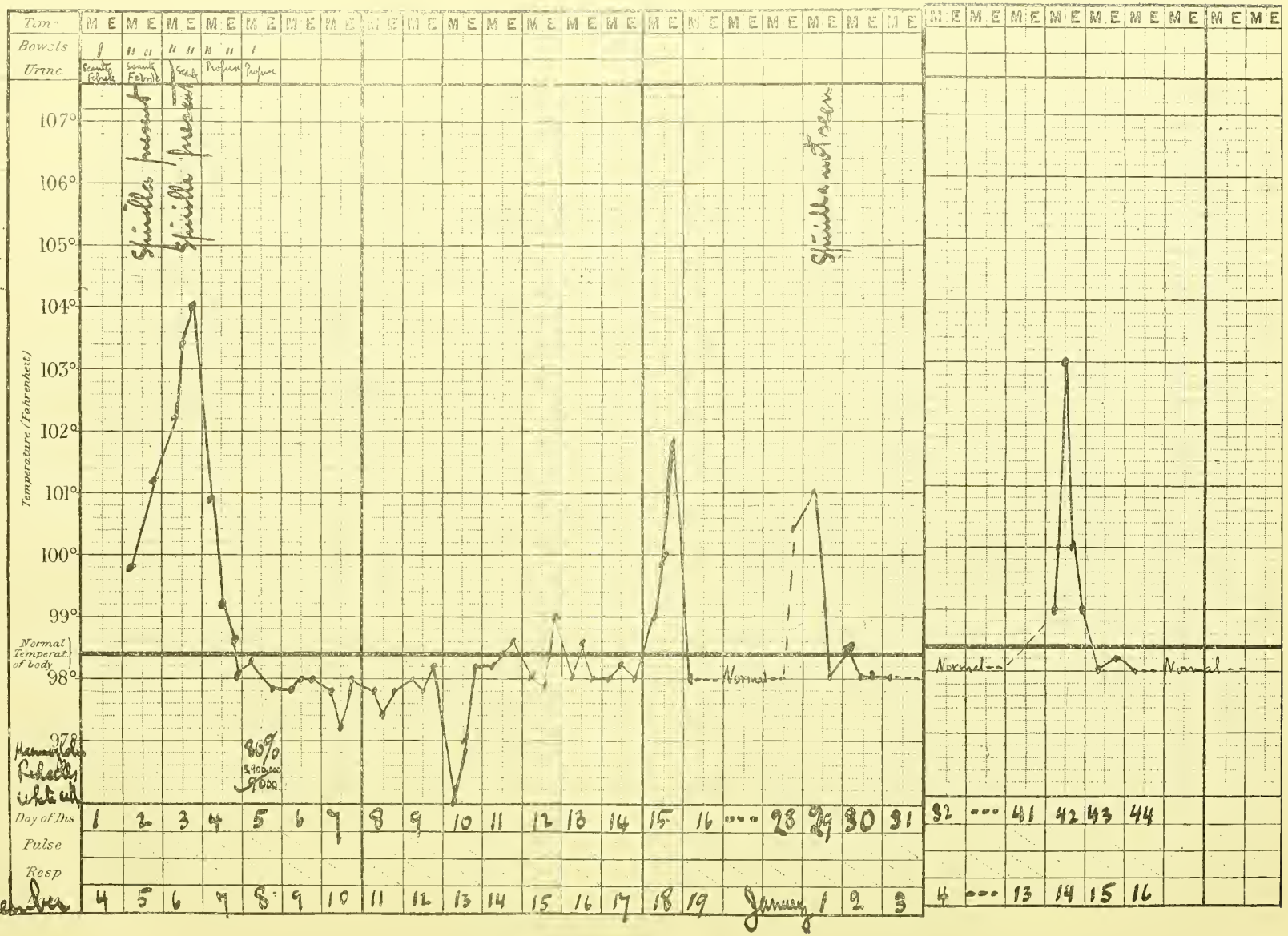
Name J. L. J.

Age 28 ♂

European

Case Book N°

Chart VII



Date of admission

Result

The disease was most probably contracted at the autopsy done on Case 4, at Nyangwé, on November 19; after the autopsy was finished a slight abrasion was noted at the side of one of the finger nails. If such is the case the incubation period was, as usual (8), seven days. Though there is no knowledge of a tick-bite, the possibility of infection by that means cannot be definitely excluded, since on arriving at Kasongo ticks—two—were found in an unopened valise and in a bed-covering in daily use; and this although no ticks were seen in the rooms we had occupied in a few days before at Nyangwé.

The second European case was much the less severe. The symptoms—head and boneache, lassitude, slight nausea and diarrhoea, scanty febrile urine during and increasing micturition after the attack, tenderness over the unenlarged spleen, and fever noted in the first case were all present in the second, but with greatly lessened intensity.

The diary of the case is as follows :—

J. L. T. (*Chart No. 7*). (*Patient's Own Notes.*)

Dec. 3 and 4.—Felt vaguely unwell. Quinine 7½ grains each day.

Dec. 5 and 6.—Quite ill; blood examined, spirochaetes present—no malarial parasites seen.

Dec. 7 to 17.—Felt perfectly well. Quinine grs. 5 taken on Dec. 8 and 9.

Dec. 18.—Only slight malaise; small epistaxis during night. Blood not examined.

Dec. 19 to 31.—Well.

Jan. 1.—Passed a bad night; head and backache annoying. For three or four succeeding days was much troubled with neuralgia (patient not neuralgic). Blood examined, spirochaetes present.

Jan. 5 to 15.—Well.

Jan. 13.—Passed an uneasy night, slight diarrhoea.

Jan. 14.—Usual symptoms; great feeling of weakness.

Jan. 15 to present.—Patient free from symptoms, and entirely well. No malarial parasites were seen during the whole of this illness.

The Disease in Experimental Animals.

As the following abstracts of experiments indicate, the spirochaete does not kill the ordinary laboratory animals. To monkeys alone, the *Cercopitheci*, especially young animals, does it seem uniformly pathogenic. An adult rabbit (Ex. 156) was refractile. A young rabbit (Ex. 154) and a rat (Ex. 162), in whom there were grave accompanying affections, seemed more susceptible. A large guinea pig (Ex. 155) showed spirochaetes in its blood for only two days succeeding the inoculation of a large dose of heavily infected blood. In it, as in three rats (Ex. 163, 166, and 185), from whose blood spirochaetes, once present, finally disappeared, there appears to have been a temporary increase in the number of the parasites, and dividing forms were seen.

RABBITS.

Ex. 154: Rabbit, about one month old, weight 675 grammes.

Nov. 15.—Inoculated with about 5cm. blood from Case 4, showing two spirochaetes to field.

Nov. 16 to 17.—Scanty parasites present in blood. No spirochaetes were then seen until Nov. 24 and 25, when there were about twenty to a field (1-12th oil immersion objective; No. 4, ocular; Zeiss). In spite of daily examination no parasites were again seen. The animal died in convulsions on Jan. 23. The probable immediate cause of death was a very severe skin disease (?).

Preparations of blood and bone-marrow made at autopsy showed no parasites. Organs appeared normal.

Ex. 156: Adult rabbit, weight 2,497 grammes.

Much over 500 ticks, many of them certainly infected, have fed upon this animal. On Dec. 10 it was inoculated with blood containing numerous spirochaetes. Its blood was examined daily up to the end of December, and occasionally since. Parasites have never been seen.

GUINEA PIGS.

Ex. 155: Guinea pig, weight 453 grammes.

Was inoculated on Nov. 15, Nov. 17, Dec. 2, Dec. 10, and Dec. 17 with small quantities of blood containing spirochaetes, taken from patients or experimental animals. Daily examinations were made, but parasites were never seen. On Jan. 23, 4ccm. of blood, showing one spirillum to field (as before 1-12th immersion and No. 4 ocular), taken from an infected monkey, was inoculated. Parasites in very small numbers were seen during the two succeeding days and not again.

RATS.

Ex. 162: Adult rat, weight 266 grammes.

Dec. 5 to 12.—Twelve of the ticks which infected Ex. 157 were repeatedly fed on this animal. Dec. 13.—Spirochaetes seen in blood. Parasites were continually present until Dec. 19, when animal died. Death was undoubtedly largely due to a large, traumatic, subcutaneous abscess.

Ex. 163: Young rat, weight 65 grammes.

Dec. 10.—Inoculated with 3ccm. blood, containing numerous spirochaetes taken from an infected monkey. The blood was examined daily until Dec. 29. Parasites were seen in large numbers only on Dec. 12, 13, 14, 17, and 19 (not examined on Dec. 11).

Ex. 166: Adult rat, weight 168 grammes.

From Dec. 19 to 31, the ticks used in Ex. 162 (see above) fed repeatedly. The rat did not become infected. On Jan. 23 it was therefore inoculated with 3.5ccm. of blood, containing numerous spirilla, taken from an infected monkey. The blood was examined daily until Feb. 1, and since then at intervals of a few days. Very scanty parasites were seen only on Jan. 26, 27, 30, and Feb. 1.

Ex. 185: Rat, young, weight 91 grammes.

Jan. 23.—Inoculated with 2.5ccm. blood, containing many spirochaetes, from an infected monkey. Blood was examined daily until Feb. 1, and at intervals since. Parasites were seen on Jan. 24, 25, and 26.

MONKEYS.

We have been able to infect monkeys, five *Cercopithecus* (?*Schmidti*), one *Cercopithecus campbelli*, and one *Cercopithecus* (Sp. ?), with spirochaetes by the bites of ticks. Each animal was examined with negative result before the commencement of the experiment. Thirty other monkeys of the same species, caught in the same districts, and kept under the same conditions have been used for other experiments. Their blood has been constantly examined, and none have ever been found to be infected with spirochaetes.

Ex. 157: Young Cercopithecus, weight 1,586 grammes. (Chart No. 8.)

Nov. 19, 20, and 21.—Ticks (231 in all), caught in native houses at Nyangwé were allowed to thoroughly feed on this animal. On Nov. 24 spirochaetes were detected in its blood. The parasites later increased greatly in number. There was a high temperature. The monkey became very thin and weak. Anæmia was very pronounced, and death occurred on Dec. 4, after two days of utter prostration, during which the monkey scarcely moved, but remained dozing, crouched on his haunches. The autopsy was done immediately after death. Blood was very pale, and all organs anæmic. Long bone-

DISEASE.

Spirilla

Notes of Case.

Name { Ex. 157

Age

Diet young Monkey

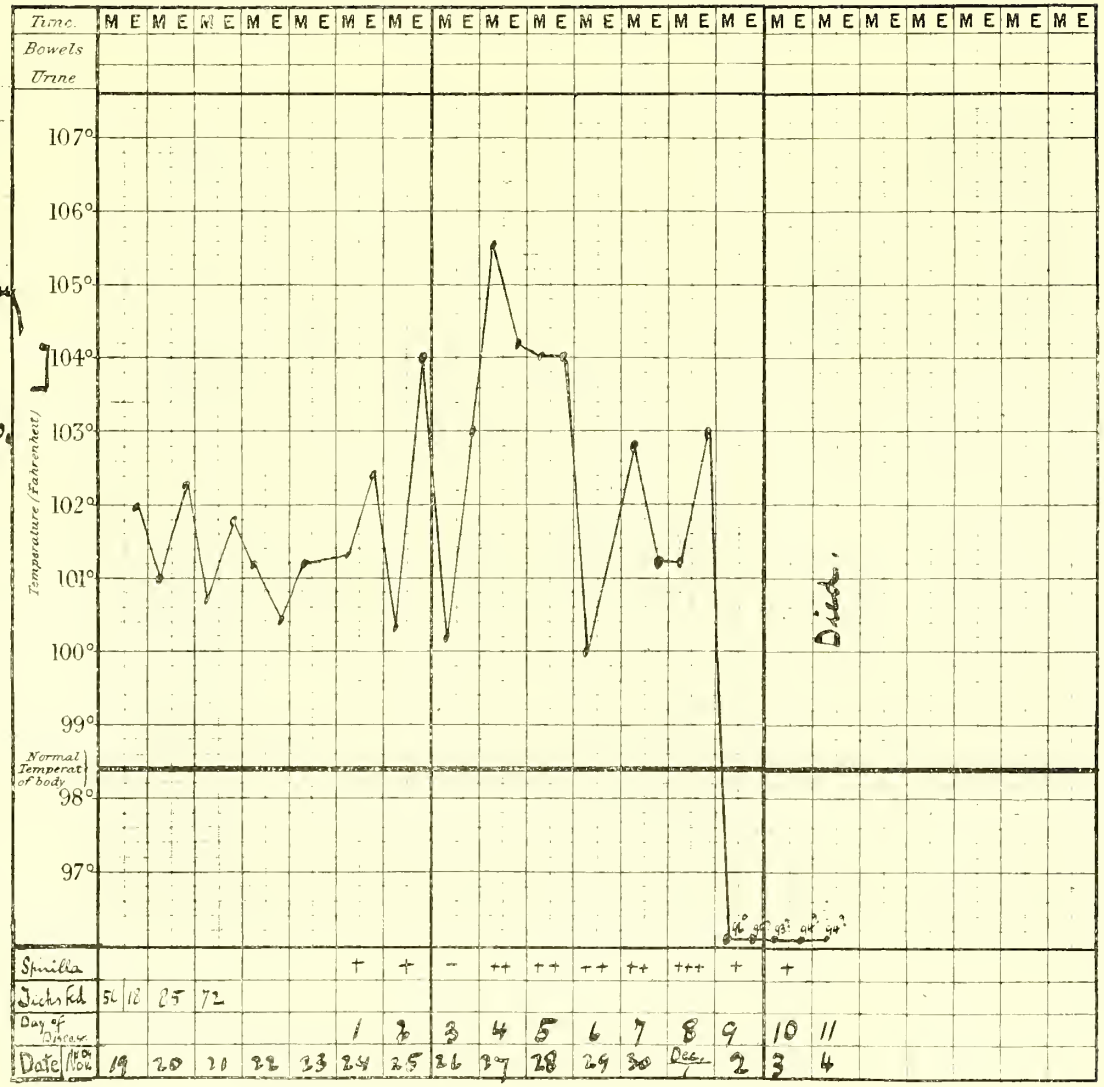
Case Book No

[Cercopithecus

weight 3½ lbs.

No malaise
No lymphangeitis
No chancre

Chart VIII



DISEASE.

Spirillosis

Notes of Case

Name Ep. 192.

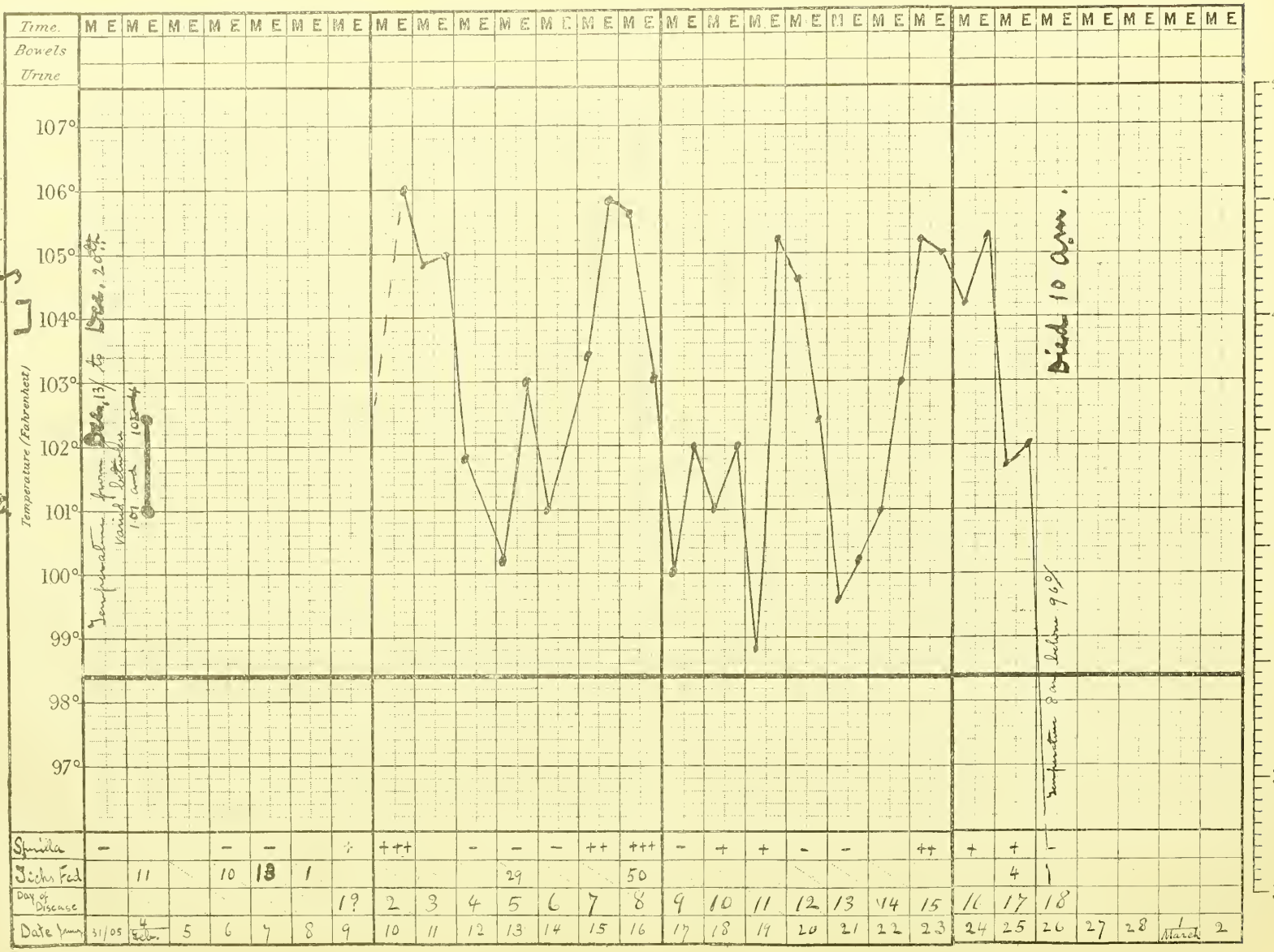
Age Quarry

Diet Cerebrospinal

Case Book N°

Chart IX

No malaria
No trypanosomes
No plasmodia



marrow was diffluent and chocolate coloured. Heart, kidney, and liver seemed cloudy. Spleen, enlarged, measured 7 by 2.8 by 1.7cm.; firm. No malarial parasites, trypanosomata, or filariae were seen in this animal.

Ex. 160: Young Cercopithecus, weight 1,586 grammes.

Ticks caught in native houses at Nyangwé were, on Nov. 24, fed upon a small rabbit (Ex. 154), whose blood contained many spirochaetes. On Nov. 30 twenty-six of these ticks fed upon this monkey. On the morning of Dec. 5 spirochaetes were for the first time seen in its blood. The parasites became more numerous, and were constantly present. On Dec. 10 the temperature was sub-normal, and the animal dying. It was, therefore, killed to obtain blood for inoculating exps. 155, 156, 163. No malarial parasites, trypanosomata, or filariae were ever seen in this monkey.

Ex. 167: Young Cercopithecus, weight 906 grammes.

Dec. 21 and 22.—One hundred and seventeen ticks caught in native houses at Nyangwé before Nov. 23, and not since fed, were allowed to feed upon this monkey. On Dec. 28 spirochaetes were seen in the blood for the first time, and the temperature rose. Parasites were constantly present, at first in large numbers, until Jan. 10. From that date until death on Jan. 19 parasites were absent from the peripheral blood—examined both during the day and at night. During the last few days the animal was extremely weak, hardly able to crawl, and had slight diarrhoea. The autopsy was commenced immediately after death. The animal was very thin, weight 604 grammes, all fat had disappeared. Spleen was slightly enlarged, 3.25 by 1.75cm., dark and firm. All other organs were extremely anæmic. Long bone-marrow dark red. A few spirochaetes were seen in preparations of heart blood, bone-marrow, and spleen juice taken at the autopsy. No malarial parasites, trypanosomata, or filariae were ever seen in this animal.

Ex. 176: Young Cercopithecus, weight 1,020 grammes.

On Jan. 12 and 13 258 ticks, caught at Nyangwé, before Nov. 23, and not since fed, were allowed to feed upon this monkey. On Jan. 16, 76, and on Jan. 19, 240 of the same ticks were re-fed. On Jan. 21 spirochaetes in fair numbers, were seen in the blood for the first time. The animal died on Jan. 23. Death was largely due to rough handling while feeding further batches of ticks. Spleen was slightly enlarged, 4.75 by 3cm., dark and firm. This monkey was infected with malaria, but neither filariae nor trypanosomata were seen in its blood.

Ex. 184: Adult Cercopithecus, weight 2,380 grammes.

On January 23, the ticks which had infected Ex. 160 on Nov. 30, and had since repeatedly fed on uninfected animals, were placed on this monkey; thirteen fed. On Jan. 28, Feb. 1, 2 and 6, they had again opportunities of feeding, the monkey being bitten fifty-nine times. On Feb. 6 another lot of infected ticks were accidentally placed on this animal for a few minutes. Three or four may have punctured the skin, none fed. On Feb. 14 and 18 the monkey was bitten twenty-three times by the first lot of ticks. On Feb. 19 spirochaetes were seen in the blood for the first time, and the temperature rose. Parasites were fairly constantly present in the peripheral blood until March 7. Since then they have been absent, though the temperature remains high. The animal is still under observation.*

Ex. 192 (Chart 9): Young Cercopithecus, weight 1,020 grammes.

It was thought possible that "J. L. T." might have become infected with spirilla through his unprotected hands while doing the autopsy on Case 4. To ascertain whether a susceptible animal would become infected with spirochaetes if parasite-containing blood were placed on its unbroken skin, the hair was carefully clipped from the abdomen of this monkey, a healthy area was chosen, and, after a careful negative examination—with a lens—for cuts and abrasions, a few drops of blood containing many spirochaetes—from Exps. 162 and 163—were placed upon the unbroken skin. The blood was covered with a damp chamber to prevent its drying, and was removed after thirty minutes. This was done on Dec. 13, 15, and 17. The blood was examined daily until Dec. 27. As no parasites were seen, the animal was thought to be uninfected, and it was decided to use it for a second experiment.

* October 23rd, 1905. Temperature constantly elevated (malaria). Blood frequently examined; no spirochaetes seen until May 13th, 1905 (T. 107.2) one to field. None were again seen, though blood was constantly examined, and on August 23rd the animal died in convulsions (no spirochaetes found at autopsy). Cause of death, slight broncho-pneumonia.

It was desired to determine whether young ticks hatched from eggs laid by known infected parents, were capable of infecting a susceptible animal at their first feed.

Young ticks reared in the laboratory were allowed to feed upon this monkey. With the exception of eight young ticks which fed on Feb. 7, all the ticks used were hatched from eggs laid on Jan. 12 by one of the ticks which infected Ex. 157. The accompanying chart indicates the number of ticks fed, the temperature and the results of examination of the peripheral blood for spirochaetes. The animal was found to be infected on Feb. 9, and died, much exhausted, on Feb. 26. No autopsy was done.

If this monkey was infected, as we believe, by the tick bites, it may be assumed that ticks are not merely mechanical transmittors of the spirochaetes, but are alternative hosts in which developmental changes take place.*

Ex. 194: Cercopithecus, weight 2,265 grammes.

It was desired to determine whether young ticks hatched in the laboratory and fed on an animal infected with spirochaetes were capable of transmitting the parasite to a susceptible animal at any succeeding feed, twenty-four hours, at least, intervening between the infecting and transmitting feed. (This experiment was commenced before a successful result had been obtained in Ex. 192.)

Ticks were fed on Feb. 6, 7, 10, 23, March 2, 4, 16, and 19. The monkey was bitten 136 times in all. On March 21 spirochaetes were found for the first time in the blood. The temperature, previously rather irregular, mounted definitely. The animal became much prostrated, and lost weight rapidly. The temperature remained high; spirochaetes were constantly present in enormous numbers, and the animal died on the night of March 27 (weight 1,815 grammes).

We have, therefore, been able to infect, in all, eight animals with spirilla by the bites of ticks—seven monkeys and one rat.

To exclude the remote possibility of the parasite being introduced with dust into the wounds made by the ticks' bites and infection thus produced, on four different occasions 115 small incisions were made in the abdomen of a young Cercopithecus (weight 907 grammes), and earth taken from jars in which much-infected ticks were kept, and from tick-infested houses at Nyangwé was rubbed into the cuts. The animal never became infected.

The incubation period, that is, the interval elapsing between the bites of ticks able to infect at the time of biting† and the appearance of parasites in the peripheral blood, as a rule, is five days.

The Spirochaete.

When the parasites are numerous they can easily be seen in fresh preparations of blood as rapidly-moving spiral threads. When they are scanty perhaps the best method of demonstrating their presence is the searching, with a high power, of thick, dehaemoglobinised blood-films stained by some modification if Romanowsky's method or with a weak solution of carbol-fuchsin. Centrifugalizing the blood is not nearly so good for the demonstration of spirochaetes as for trypanosomes.

The parasites seen in all our cases have the same morphological characteristics. In preparations coloured by modifications of Romanowsky's stain (Leishman's or Stephens and Christopher's) (10) the spirochaetes are seen to stain unevenly, and to vary greatly in length. The results of the measurements of twenty spirochaetes in slides of blood taken from Case 8, for the most part on March 5, are as follows:—Largest 43 μ., smallest 13 μ., average of ten smallest 19 μ., average of ten largest 35 μ., Y-shaped, apparently divisional forms, and groupings of pairs, trios, and tetrads of spirochaete strongly resembling, in their arrangement, the multiplying indifferent

* October 17, 1905. This experiment has since been, twice, successfully repeated.

† Occasionally the bites of ticks, later shown to be infective, have repeatedly failed to infect a susceptible animal.

forms of *Spirochaete Ziemanni*—as figured by Schaudinn—(12)—are frequently seen in films taken from either patients or animals. With the time, instruments, and technique at our disposal, we have, to our regret, been so far unable to observe in animals and ticks developmental processes of this spirochaete similar to those which Schaudinn has demonstrated with *Spirochaete Ziemanni* in the owl and mosquito.

Distribution of the Human Tick in the Congo Free State and some Notes on its Binomics.

Livingstone says: "Before the Arabs came bugs were unknown" . . . one may know where these people have been by the absence or presence of these nasty vermin; the human tick, which infests all Arab and Suaheli houses, is to the Manuema unknown . . ." (2); and again, while at Nyangwé, "My new house is finished—a great comfort, for the other was foul and full of vermin; bugs (Tapasi or ticks) that follow wherever Arabs go made me miserable" (3). Our observations tend to confirm his assertion. Perhaps one of the reasons for which ticks are more often found in Arab than in native houses is that the Arabs make better, drier buildings, and live in permanent villages. Native huts are temporary affairs and a slight cause, one or two cases of sickness, is often enough to make a community leave their homes and build a village elsewhere.

In October 1903, a list of questions was sent for us by the Free State Government to its various districts. Information concerning the human tick was asked for. Since our arrival in the Congo and during our long journey up the river from Léopoldville to Kasongo we have constantly searched for the ticks. From the information thus collected we are enabled to construct the accompanying sketch map which shows the distribution of the human tick in the Congo Free State.

We have indicated every locality from which specimens have been received, or ticks are said, on reliable authority, to exist. Where it has been necessary to indicate places at which ticks are not known to exist squares, not circles, have been used to mark their position.

The main Arab routes into the Free State have been indicated diagrammatically by straight red lines. It must be understood that the Arabs overran the southern part of the Free State before reaching the Upper Congo at Nyangwé. Maniéma then became their stronghold, from which expeditions were sent out. They never penetrated far to the west of the Congo. The Free State prevented them from following the Congo further down than its confluence with the Aruwimi. Their progress to the north was checked, near Avakubi, and to the north-east, near Béni, by powerful native tribes. They were practically confined, in the Free State, to the territory now called the Oriental province.

Ticks seem to have come into the Free State by two routes; from the East Coast, with the Arabs, into the Oriental province, and into the Cataract region, with traders, from the Portuguese territory to the south, where ticks have existed since Livingstone's time, at least.

The rivers are the present highways. Old and present caravan routes used by Europeans, along which ticks are known to occur, are indicated by dotted lines. A glance at the map shows that ticks are found, particularly, along much travelled roads. How easily they may be carried in even a European's luggage is well shown by our experience on leaving Nyangwé, where we were well lodged in well-built houses. Although the ticks are plentiful in many of the Arabised villages along the Congo between Kasongo and Ponthierville, they are quite unknown in the native villages an hour's walk inland. The rest-houses for native travellers are always the most infested. At Kumba, Lokandu, and Ukungwa, the points furthest down the river at which we caught ticks, the rest-houses alone seemed to be infested. At Kumba the native paddlers of the town said they did not recognise, and seemed to have no fear of, the tick. Dr. Christy, in Uganda (11) and the Rev. W. Holman Bentley in the Lower Congo have also found that rest-houses are particularly liable to be infested.

Mr. Bentley believes that human ticks were a chief cause of the great mortality which existed among the Lower Congo porters in the old days when the whole commerce of the Free State was carried over the caravan route between Matadi and Léopoldville.

Names given to the ticks in various localities are as follow:—In the neighbourhood of Léopoldville *Bifundikala*, and, by the Batéké, *Bimpusi*. It exists along the Kwango river, at least between Popokabaka and Francis Joseph Falls, among the Basumbo and Bayaka people. At Popokabaka it is called *Mouyata*. The common name throughout the eastern part of the State is *Kimputu*. Very occasionally an educated man uses the Suaheli word *Papasi*.

In infected houses the ticks are found in the dust and cracks of mud-floors, particularly in dry places near the hearth, in bed-platforms, or immediately inside the door-sill, just where the natives are accustomed to sit down. They may hide themselves in the cracks and crevices of mud or grass walls, and even in the thatched roofs.

When ticks are disturbed they often curl up their legs as if dead. So lifeless do they seem that one might easily be deceived, especially since they sometimes remain motionless for hours.

Ticks can crawl rather quickly. In sand the body of a large one leaves a smooth, central furrow, with the sharp, crab-like tracks of the claws on either side. They seem to be largely nocturnal in their habits, and certainly do not feed quickly enough to get much blood from any but a sleeping person. A big female may remain, firmly fixed, feeding on a monkey for two or three hours before it finally drops off, as large as a cherry, distended and bloated with blood. Others may fall off and attempt to crawl away after half an hour's feeding. In feeding (Pl. 3, fig. 2), the tick first firmly fixes the forelegs, and then, depressing the capitulum, buries its mouth-parts in the host. The bite of even a small tick is painful. In monkeys, immediately after feeding, a small crust of sero-sanguinolent fluid forms at the site of the bite. Surrounding it is a roseola about two millimetres in width. Two hours later the central clot is surrounded by two concentric zones, each two millimetres in width; the first colourless, the second ecchymotic. Six hours later the

clot has become almost black, and is placed at the apex of a slight, colourless weal, bordered by an ecchymotic zone about a millimetre and a half in width.

It has been said that ticks bite most frequently between the toes, in the axilla, etc. Our experience indicates that they bite, indifferently, every part of the body.

Often, while still feeding, the whitish secretion of the Malphigian tubes is passed from the anus. At the same time clear fluid, in fairly large quantities may ooze intermittently from between the bases of the first and second pairs of legs. We have never seen fluid exude from any other situation than this; yet, in spite of careful search—no sections made—we have never been able to find any trace of an opening.

Spirochaetes have never been seen in this fluid.

In coitus the male lays hold of the posterior margin of the female, and, turning on his back, crawls forward, beneath the female, until the genital pores are in opposition. Pairs are often found and remain for hours *in coitu*.

The productivity of the females is certainly increased by large feeding. The number of eggs laid at a time seems to vary greatly. Dissection shows that only a few eggs are mature at one time: ovipositing therefore goes on slowly. On two occasions ticks have been seen to be ovipositing during three days. In each instance only seventy eggs were laid. Our ticks were frequently disturbed, and for this reason, perhaps, the eggs have been usually found in small groups of ten or twenty. Females kept apart for observation have, however, been found to lay from ten to twenty eggs at intervals of from one to two weeks. The largest number of eggs laid at one time was 139. The females have sometimes, but by no means always, died while, or after, ovipositing.

The eggs adhere to one another as they are laid, and look, under a low power, not unlike bunches of glistening, golden-brown grapes. Their covering is soft, smooth, and highly refractile. Their shape is slightly ovoid, the average dimensions being 881.172 by 776.376 μ. The largest egg measures 959.4 by 841.32 μ., and the smallest 767.52 by 664.2 μ. In sandy soil the eggs may be deposited either upon or beneath the surface. The average temperature and the average humidity for the three months during which we have had ticks under observation have been as follows:—

	Temperature		Humidity Percentages of Saturation		
	Maximum	Minimum	6 o'clock	11.45 o'clock	12.45 o'clock
1904 December	29·6° C	19·7° C	94	76·1	76
1905 January...	32·3° C	19·5° C	95	71·5	74
February	29·9° C	20·1° C	94	72·1	77

Under these conditions eggs take but twenty days to hatch; the shortest period noted was eighteen, and the longest twenty-three days. Occasionally, for no apparent reason, a quarter, or even more, of a batch of eggs has failed to hatch.

In about seven days' time the egg becomes more ovoid, and, with a low power (a 3 objective ; No. 2 ocular ; Zeiss, stereoscopic), the hexapod larva can be seen to be forming within the translucent shell (Pl. 1, fig. 2). At about the thirteenth day the egg-shell splits, nearly always posteriorly, in the sagittal plane. It measures at this moment 1.03 by 9mm. A hexapod larva (Pl. 1, fig. 4), which moves its legs but cannot crawl, may now be extracted from the shell. Normally the egg-case and its contents become batter, and the larva's skin wrinkled Pl. 1, fig. 7). Air enters beneath the egg-shell and the larval skin so that the young tick and his coverings form a dull, white disc. If the egg-shell be removed, it can be seen that the tick is about to moult. Its tegument has split anteriorly, sometimes laterally, in the usual line of ecdysis at the junction of the dorsal and ventral surfaces ; and curled up within the hexapod larval skin can be seen the eight-legged nymph. When ecdysis finally takes place, the nymph throws off egg-shell and larval cast together. It usually emerges by getting out one of its hind legs first, and then, often turning around inside its casings, dragging its body out after. The measurements of ten nymphs taken just after leaving the shell were, average 1.02 by 0.87mm., the largest 1.10 by 0.96mm., the smallest 0.98 by 0.8mm.

The newly-hatched nymph (Pl. 1, fig. 8) has no genital pore, and the adult position of the stigmen is indicated by a small white spot and pit. Its capitulum is partially retractile, and is visible from above. Their bodies, under a low power, are translucent. Freshly-hatched nymphs usually do not feed at once. As a rule only three or four days later do they readily suck blood. From observations extending over two months, based on ticks hatched in the laboratory from infected parents, but fed upon uninfected animals, it seems that if food is plentiful a young tick grows rapidly. The intervals between the moults seem to vary very considerably ; but in the two months after it leaves the shell the tick may moult three times and come to measure, roughly, 5 by 2.5mm. If food is lacking, growth is much less rapid.

A full-grown female, filled with eggs and blood, may measure 12 by 10 by 7mm. After the nymphs first moult the stigmen is easily distinguishable, but the genital pore is still absent. The measurement of twenty young ticks at this stage gave, average 1.47 by 1.22mm., largest 1.92 by 1.37mm., the smallest 1.34 by 1.07mm. It is only after the second moult that the sexual pore is seen as a very slight depression in the middle line of the ventral surface on a level with the bases of the first pair of legs. Cleavage of the skin for ecdysis always takes place along the line indicated in the diagram (Pl. 3, fig. 3). The split usually commences anteriorly. The feet and ventral surfaces are first freed, then the dorsum, and the perfect cast is left. Either dorsal or ventral half of the moult may, however, remain attached after the other moiety has been thrown off.

It is impossible to say how long the ticks live, or for how long they remain infective. Ticks caught on October 24, and kept without food, are still alive, and have freely reproduced. Ticks caught before November 23, still alive (March 28, 1905), and have freely reproduced. Ticks caught before November 23, at Nywangé, and kept without food, were able to infect a monkey with spirochaetes $1\frac{3}{4}$ months later.

Ticks are not without natural enemies. Rats eat adults with avidity, and ants carry off young ones and eggs. We have lost ticks in both ways. On one occasion over two hundred young ticks were carried off in a single night by small ants.

We add the following scanty working notes on the anatomy of *Ornithodoros*, and on the presence of spirochaetes in its organs, in the hope that they may be useful to others interested in this subject.

There is a most curious piece of anatomy in the adult tick which, for want of a better name, we have termed the (?) "pulmonary sac." Just above the base of the proboscis is a slit which communicates with a wide membranous tube ending in a paired body, or, rather, a closed sac, whose walls are at first thin, near its attachment to the tube, and distally are thickened and thrown into folds. The accompanying diagram (Pl. 4, fig. 1) illustrates this point.

It is curious that we have never seen these ticks excrete dark-coloured faecal matter. It is always white-coloured secretion of the malpighian tubules which is passed by the anus. This fact may, in some part, be explained by the exceeding fineness of the tube running from the under surface of the "stomach" to the central cul-de-sac of the cloaca. The diagram (Pl. 4, fig. 2) is very schematic, but it will serve to illustrate the course of the alimentary tract.

The position and rough structure of the salivary glands are indicated in a diagram (Pl. 4, fig. 3). The appearance of the salivary duct is very characteristic.

A batch of ticks caught at Nyangwé (November 23rd, 1904) were fed upon one of our infected monkeys. They were kept without further feeding, and one was dissected every day or two. Living spirochaetes were found in their stomachs and malpighian tubules up to five weeks after their feed on a known, infected animal. (It must be remembered that these ticks were naturally-infected adults.) Occasionally very many more spirochaetes were found in the tubules than in the stomach. In some preparations of stomach or malpighian tubules no parasites were at first seen; but if a little human serum, taken from one who had never had tick fever, were added, in from 8 to 24 hours the preparations became fairly crowded with spirochaetes.

As we have noted on page 13, we have so far been unable to follow out in these ticks Schaudinn's masterly observations. We have also been, up to the present, unable to find in the bone-marrow, spleen juice, or blood of monkeys or human beings infected with these spirochaetes forms resembling the large macro- or microgametes, described by Schaudinn in his work.

From the facts here presented we conclude that:—

(1). Tick fever is clinically identical with relapsing fever, and has for pathogenic agent a spirochaete.

(2). The spirochaete is probably *Spirochaete Obermeieri*.

(3). The tick, *Ornithodoros moubata*, can transmit the spirochaete from animal to animal.

(4). The transmission is not merely mechanical, but some developmental process is carried on in the tick.

(5). A considerable degree of immunity or tolerance to the spirochaete can probably be acquired.

March 28th, 1905. We have just seen two other European cases.

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ON THE EXTERNAL ANATOMY OF ORNITHODOROS MOUBATA

ON THE EXTERNAL ANATOMY OF ORNITHODOROS MOUBATA (MURRAY)

BY

ROBERT NEWSTEAD, A.L.S., F.E.S., ETC.

(LECTURER ON ECONOMIC ENTOMOLOGY AND PARASITOLOGY)

(WITH TWO PLATES)

A consignment of the ticks referred to in the previous paper on the Human Tick Fever seen on the Upper Congo was forwarded from the Congo Expedition by Drs. Todd and Dutton. The ticks arrived at their destination on June 8th, after a journey of three months duration. The majority of the animals had died during transit, but seven examples were still living, and with them were found a number of fertile eggs, larvae in various stages of development and several active nymphs. Dr. H. E. Annett kindly handed the whole consignment over to me with the request that the species should be determined, and that if any further details could be added that they should be given in an appendix to the Report of the Congo Expedition. The material to hand afforded ample means for the study of the external anatomy of this species, and as the larva and nymph do not appear to have been described, or the characteristics of the adult female very clearly defined, it seemed desirable that as full an account as possible should be given in order that future investigators may have a more ready means of determining this highly important, but somewhat obscure, member of the Argasidæ.

Ornithodoros Moubata, Murray.

(Plates 1, 2).

Ornithodoros moubata, Murray, Economic Entomology. Aptera p. 182, No. 31, two figures, 1877.

Nec *Ornithodoros savignyi* (Audouin), Neumann, Mem. Soc. Zool. France, IX., p. 26, 1896 (*ubi. synon*).

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Ornithodoros savignyi, var. *cæcus* (1), (Neumann), Lancaster, Journ. of Trop. Medicine, p. 124, 1905.

Adult female: Dorsum dusky-brown, with irregular confluent blotches, rarely lines, of dusky ochreous-yellow; in some examples the blotches were confined to the anterior region, in others they extended almost to the posterior margin; underside usually somewhat paler than the dorsum, abdominal region largely occupied by dull orange-ochreous blotches, which gradually merge into the darker ground colour. Legs and rostrum of a pale,

(1) Calman, who contributes the article, gives the name *caecum*, evidently in error.

translucent, ochreous-white. Sculpture of dorsum fairly constant, but less pronounced in a partly engorged female than in the old and shrivelled examples. Capitulum (Pl. 2, Fig. 3); hypostome not much wider at the base than at the anterior third, margin converging inwards, teeth in three bilateral rows; mandibles (Pl. 2, Fig. 4, 4a), when fully extended, reaching to the second articulation of the palpi, digit with a blunt terminal tooth, exterior apophysis with two widely separated teeth; *interior apophysis bidentate*; palpi tapering towards the extremity second joint much the longest, sides of all the segments highly chitinised. Derm cells (Fig. 5, 5a) large, irregularly ovate, with one or two extremely minute spines at or near the margin, each cell surrounded by a band of dark chitine, the latter character being much more pronounced in the region of the posterior margin. Stigmata (Fig. 6) lunular, peritreme finely pitted and strongly chitinised. Dermal secretion glands (Pl. 2, Fig. 7) irregular in outline and variable in size, the subcutaneous tubes attached to these organs are branched and appear like bundles of muscular fibre; there is a group between the base of the capitulum and coxa 1, another between coxa 1 and 2, and a third between coxa 3 and 4, there is also a long bilateral series commencing immediately posterior to the genital pore. Legs (Pl. 2, Figs. 8, 8a, 8b, 8c) normal. Margin of genital pore deeply crenulated.

Nymph (Pl. 1, Fig. 8): Colour, pale ochreous-brown, legs translucent white with, in certain lights, a faint, pale ochreous tinge. Form broadly ovate. Dorsum thickly studded with minute papillae, increasing in size posteriorly, forming a regular crenulated fringe at the margin. Sculpture of dorsum somewhat resembling that of the adult females. Capitulum (Pl. 2, Fig. 2) partly projecting beyond the margin. Hypostome with two bilateral rows of teeth, basal pair minute, the remaining teeth are large and equal in size; mandibles strong; digit blunt, terminal. Palpi broad, stout, third segment the shortest, apical segment about equal in length to the second, and bears two or three short spines at the tip, all the segments have a broad marginal band of dark chitine. Legs (Pl. 1, Figs. 9, 9a) sparsely spinose, rather long; leg i. (Fig. 9) of seven segments, Haller's organ present; legs ii.-iv. (Fig. 9a) of eight segments, with the femora more dilated outwardly than in leg i. Anal orifice placed a little posterior to the insertion of leg i. Vaginal orifice absent. Spiracles minute, placed opposite insertion of leg iii.

Larva (Pl. 1, Fig. 4) sub-circular; colour dull purplish-brown, varying somewhat in intensity according to the age of the individual; but at or near the period of ecdysis the cuticle becomes more opaque and greyish in tone. At this stage, immediately posterior to the anal orifice, is a comparatively large, subcutaneous arrow-shaped, or Y-shaped, patch of white granular matter, evidently secreted by the nymph, which at this period has reached an advanced stage of maturity. Segmentation of legs not clearly defined after maceration in potash; femoral area of each leg with three pairs of equidistant spines; there are also a few isolated spines on the regions of the other segments; terminal tarsal segment (Fig. 5) of each leg broadly obtuse; claws short, stout, and curved. Haller's organ placed immediately posterior to the terminal tarsal articulation. Capitulum (Pl. 2, Fig. 1) within the anterior margin in the earliest stage, but in more mature larvae it projects slightly beyond; base of rostrum on the dorsal area with two

rather long stout spines; hypostome with two broad bilateral angular teeth, on the anterior third; mandibles extending considerably beyond the apex of the hypostome. Palpi (Pl. 11, Fig. 1) broad and stout, extending beyond the fully-extended mandibles; each of the second and third segments with one minute, and one long stout spine, there are also two or three minute spines at the apex of the terminal segments. Margin of abdominal area finely and regularly crenulated; cephalo-thoracic area also crenulated, but more faintly so and less regular. Dermis (Pl. 1, Fig. 7) with fine wavy lines. Spiracles apparently absent.

Ovum (Pl. 1, Fig. 1): In addition to the "golden brown colour" described by the authors, an irregular faint whitish polygonal reticulation and interrupted radiating streaks showed through the cuticle in the freshly laid examples. For particulars regarding the development of the ova see Report ante p. 15 and also the notes on the habits of the species in this appendix.

When treated in a 10 per cent. solution of boiling potash (KOH) the eggs containing the mature larvae changed to a rather bright red colour, and instead of softening under the treatment became hard and opaque. It was found necessary, therefore, to express the fluids from the body before maceration in the potash; otherwise it was found impossible to examine the structural details.

The adult female of this species may readily be distinguished from *O. savignyi*, not only by the absence of eyes, as has already been pointed out by Pocock (*l.c.*), but also by the presence of the *interior bidentate apophyses* and the apparently narrower base of the hypostome. The authors of the Report of the Congo Expedition (p. 15) have called attention to the singular fact "that a clear fluid, in fairly large quantity, may oose intermittently from between the bases of the first and second pair of legs." They were, however, unable to find "any trace of an opening." I find, on examination, that there are groups of glands in the situations indicated, and also a third group between the base of the capitulum and the first pair of legs, and in addition to these there is a long bilateral series immediately behind the vaginal opening. All the glands have subcutaneous tubes, which later are finely branched and, as already stated in the diagnosis, these organs have much the appearance of bundles of muscular fibres. I find also that a group of similar organs exist in *Ixodes hexagonus*, Leach, but in this species the subcutaneous tubes are comparatively short and unbranched, and they bear a very striking resemblance to the so-called tubular spinnerets found in the Lecanid group of the Coccidae.

It is important to note that the co-types (3) which were kindly identified by Pocock (*l.c.*) as *O. moubata*, are still in the collection of the School of Tropical Medicine. Some specimens of the latter were prepared for microscopical study, and were found on examination to be specifically identical with the specimens recently received from the Congo Expedition. There should be no doubt, therefore, as to the correct identity of the species. I have placed Neumann's var. *cæcus* as a doubtful synonym, as, unfortunately, I have not been able to consult Neumann's original description, but Pocock (*l.c.*) considers it to be the same as Murray's *O. moubata*. On the other hand, Ray Lancaster (*l.c.*) has quite recently (1905) identified some examples

of Ornithodoros from Angola, West Africa, as belonging to Neumann's var. *cœcus*.

Seeing that the specific characters of *O. moubata* are now found to be so markedly distinct from *O. savignyi*, there should be no difficulty in clearing up these somewhat important discrepancies by those who are in possession of the types.

The authors of the Report on the Congo Expedition are to be congratulated on the discovery of the life cycle of *Ornithodorus moubata*, which has not been hitherto observed. In many respects the habits of this species are not unlike those of *Argas persicus*, but so far as I have been able to ascertain the inert character of the larva of *O. moubata* is unique among the Ixodinae, in that it passes the whole of its life within the egg.

Three original drawings illustrative of the development of the larva and nymph accompanied Drs. Dutton and Todds' report, but they were so damaged in transit as to be useless for reproduction.

Experiments with the Ticks Imported from the Congo Expedition.

Experiment 1, June 19.—Thirteen nymphs were placed in a hollow bamboo, which was fastened to the axilla of a young Macaque monkey (*Macacus cynomologus*). The ends of the tube were securely corked, and a large section was cut away, providing the young ticks with ample means of access to the host. As a further means of precaution against admission of light, the tube was covered with a thick cloth. Under these conditions the ticks were allowed to remain on the host for a period of five hours. Result—nil. All the ticks refused to feed.

Experiment 2, June 19.—Five adult female ticks were put into a tube similar to that in which the nymphs were placed, and fastened to an adult Macaque, but as the ticks refused to feed they were subsequently removed and placed together on the monkey in the hollow below the knee of the left leg, and carefully covered with a chamois leather. One of the ticks almost immediately attached itself to the host; this took place at about 1.30 p.m., and the female left the host, fully engorged, at 3 p.m.

Observations on the Engorged Tick and Her Progeny.

The female became very restive after feeding, and made repeated attempts to escape from the bright sunlight. She was put into a Petri dish on a deep layer of dry sand, in which she rapidly buried herself, and was subsequently placed in a dry incubator at an even temperature of 29C. After laying the first batch of eggs, she was removed from the Petri dish and placed in a partly hollowed out banana and enclosed in a cardboard box. The animal immediately left the banana and took up a position in a broad groove, where she was partly concealed, in which position she remained fixed and inert until long after the third batch of eggs were laid. No attention was paid to the banana; indeed, she made a hasty retreat from the fruit and got as far away from it as the limits of her cage would permit. Two additional batches of eggs were laid, both lots being protected for a few days beneath the body of the parent, but both lots finally slipped from beneath her and fell, intact, to the bottom of the box. She defaecated three times during the period of egg laying, the white fluid like faeces, when dry, left a white deposit resembling French chalk in texture. The actual process

of egg laying was not observed. The length of the tick before feeding was 7mm.; after engorgement 11.50mm. The weight before feeding was .0270grms., after engorgement .2602grms., or an increase of about ten times her original weight. This was not a very marked increase, as compared with certain other species of female ticks, which are known to increase to about thirty times their original weight after engorgement. Batches of eggs were laid on the following dates—during the night :—

June 29.—First batch of 17 eggs. These were found in a little cluster at the bottom of the Petri dish.

July 2.—Second batch of 51 eggs laid. These were protected for a few days beneath the body of the parent.

July 10.—Third batch of 26 eggs laid. These were also protected by the parent for a few days.

Development of the First Batch of Eggs.

June 30.—First day—subcutaneous reticulation evident. Poles slightly cloudy.

June 31.—Second to fourth day—no change.

July 3.—Fifth day—subcutaneous reticulation more distinct.

July 5.—Sixth day—form decidedly flattened. Legs and capitulum of larva showing faintly through the cuticle of the egg.

July 6.—Seventh day—Form unchanged. Legs more evident.

July 7.—Eighth day—"Arrow-shaped, patch of secretion" formed *beneath* the cuticle of the larva, near anal orifice.

July 8.—Ninth day—egg shell split. Larva fully formed.

July 14.—Tenth to fifteenth day—cuticle of both egg and larva increasing in opacity, finally forming a dull white disc.

July 15.—Sixteenth day—nymphs hatching. Several examples were seen to escape from the larval exuviæ anteriorly.

Development of the Second Batch of Eggs.

Although these were laid four days later than the first batch, some of the nymphs appeared simultaneously with those of the first batch—i.e., on July 15.

Development of the Third Batch of Eggs.

These were laid twelve days after the first batch, or eight days after the second batch, and the first nymph appeared on July 18, just three days later than the earliest appearance of the nymphs from the first batch.

It should, however, be noted that the nymphs from all three batches were quite erratic in their appearance, as examples from each lot of eggs continued to emerge over a period of twelve days, the last appearing on July 27th.

EXPLANATION OF PLATE I.

Fig. 1.—Egg First day. x circa 40.

Fig. 2.—Egg at about the eighth day, showing the split cuticle, the sub-lying larva, and the "arrow-shaped" sub-cutaneous patch of secretion (ventral). x circa 40.

Fig. 3.—Egg at about the tenth day, with the posterior portion of cuticle broken away (dorsal). x circa 40.

Fig. 3a.— A similar example seen in profile. x circa 40.

Fig. 4.—Larva removed from the egg (ventral). x circa 40.

Fig. 5.—Tarsus of the larva. x 250.

Fig. 6.—Marginal fringe of the larva (a) and nymph (b) at the period of ecdysis. x 250.

Fig. 7.—Dermal markings of the larva. x 250.

Fig. 8.—Nymph (as seen in optical section after maceration in potash). x 25.

Fig. 9.—Leg i of the nymph. x 50.

Fig. 9a.—Leg iv of the nymph. x 50.

Fig. 10.—Posterior margin of nymph, showing character of large derm cells (stained preparation). x 250.

EXPLANATION OF PLATE II.

Fig. 1.—Capitulum of larva. x 250.

Fig. 2.—Capitulum of nymph. x 250.

Fig. 3.—Capitulum of adult female. x 75.

Figs. 4, 4a.—Mandibles of adult female, *ap.* inner bitentate apophyses. x 250.

Fig. 5.—Derm cells of adult female (stained preparation). x 200.

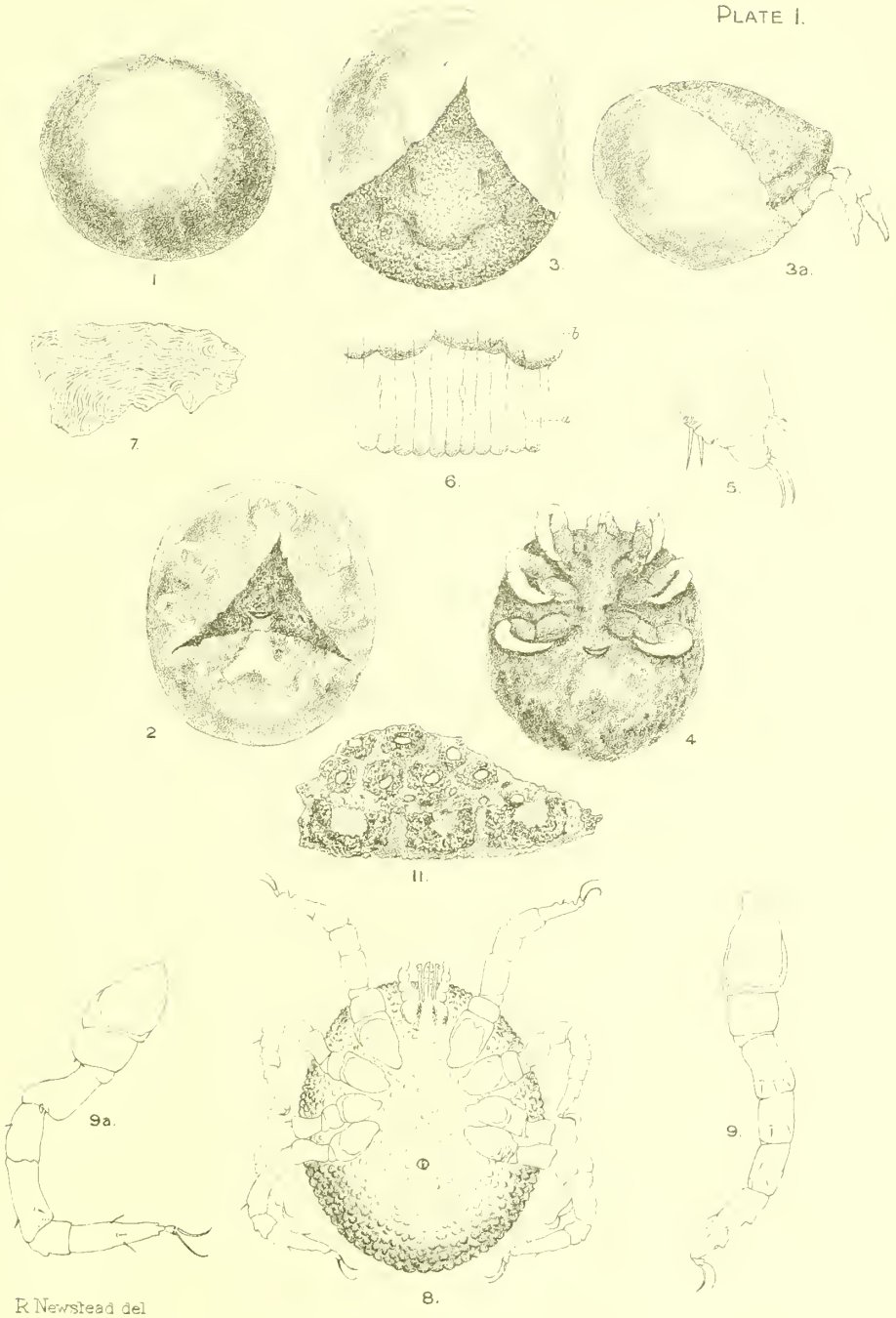
Fig. 5a.—Unstained preparation of same. x 200.

Fig. 6.—Stigmen of adult female, with its finely pitted peritreme. x 200.

Fig. 7.—Secretion glands of adult female. x 250.

Figs. 8, 8a, 8b, and 8c.—Leg i, ii, iii, and iv of adult female respectively. x circa 25.

PLATE I.



ORNITHODOROS MOUBATA.

PLATE II.

ORNITHODOROS MOUBATA.

FIG 2. Ticks feeding on Monkey, Experiment 176

FIG. 1. To show enlarged spleen in Case IV

FIG. 3.
Line of ecdysis in adult tick

PLATE IV

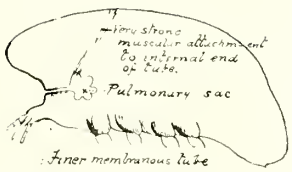


FIG. 1.
Rough diagram showing position of (?) 'Pulmonary sac'

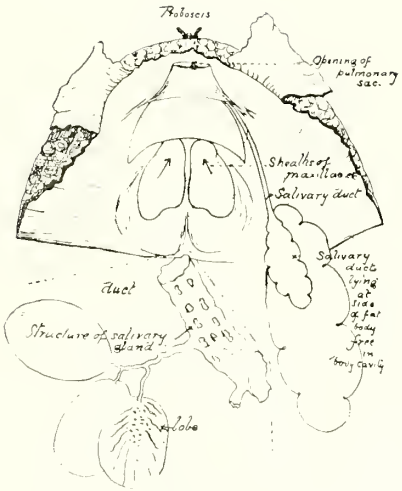


FIG. 3.
Rough diagram showing relative position of salivary glands and (?) 'Pulmonary sac'

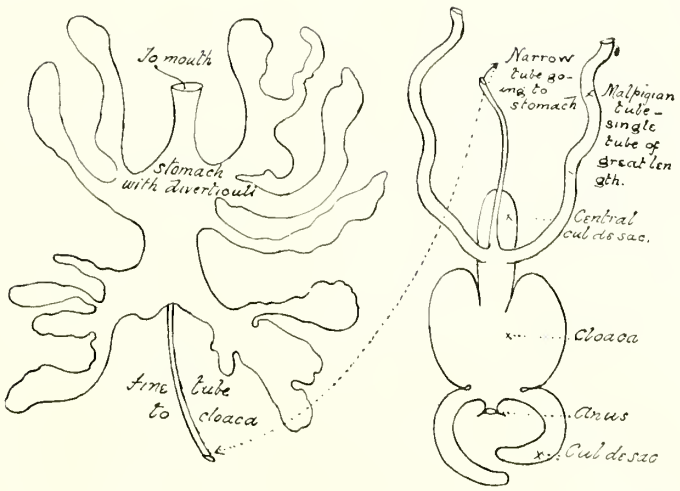
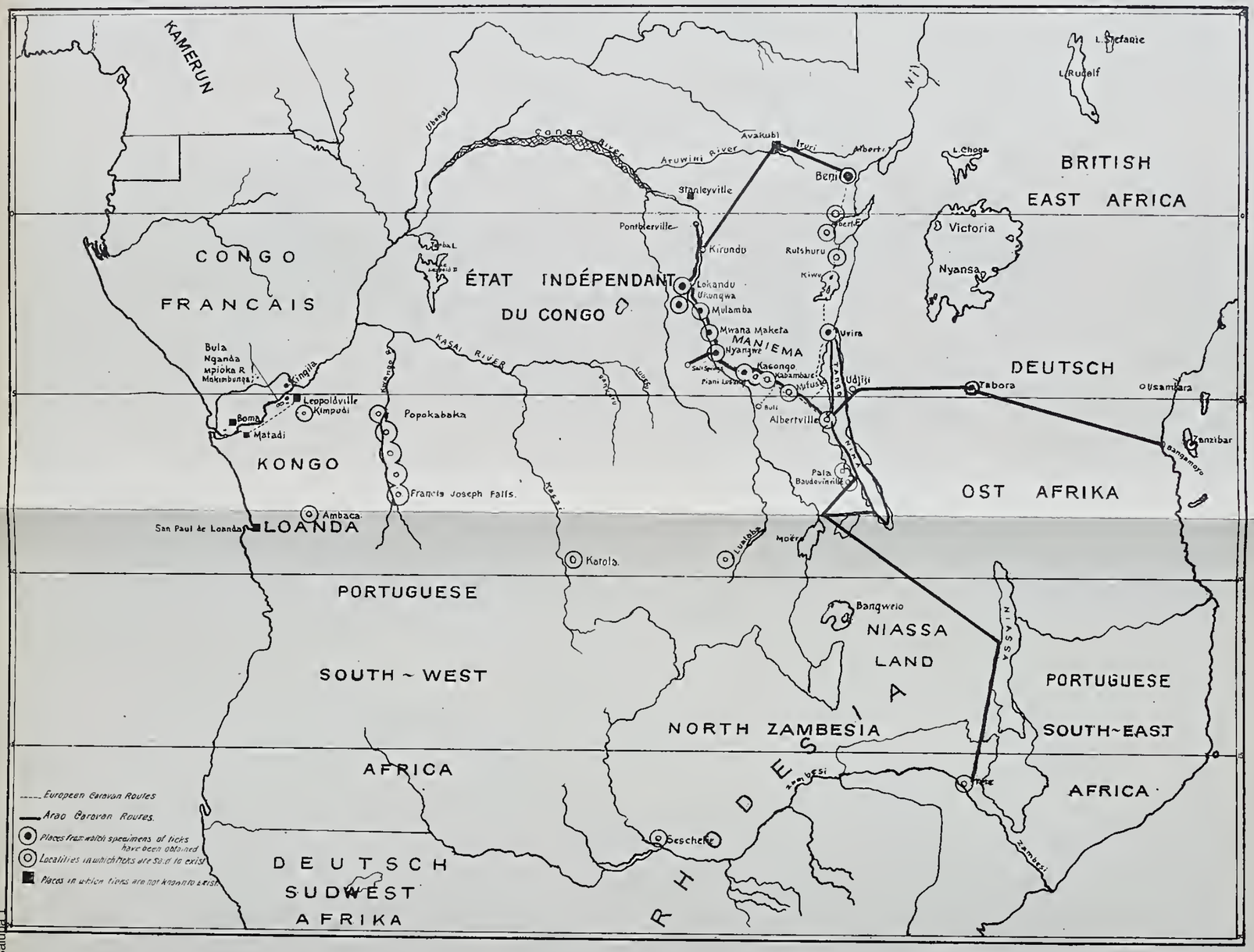


FIG. 2. Diagram of alimentary tract with diverticuli. Tube between stomach and cloaca very much finer than shown in diagram



Baluba 1