

THE ENTOMOLOGICAL ASPECTS OF AN OUTBREAK OF SLEEPING SICKNESS NEAR MWANZA, TANGANYIKA TERRITORY.*

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(Plates XII—XVII.)

CONTENTS.

	PAGE
I. Introduction	317
II. The Country generally	320
III. The Open Country	321
IV. The Acacia Thorn Area	321
V. The People	323
VI. The other Hosts of the Fly	324
VII. The Species of <i>Glossina</i> Present	326
VIII. The Seasonal Distribution and Preferences in Vegetation of the Fly	330
IX. An Apparent Method of Concentration	331
X. The Feeding Habits and Sex Proportions of the Fly	332
XI. Breeding Places of the Fly	333
XII. The Following-distance of Female Flies	334
XIII. Distance of Attack and Protection of Roads	334
XIV. Miscellaneous Notes (Settling Habits, Relation of Game and Cattle, Banishment of Tsetse by Partial Clearing, Test of a Tsetsefuge, Protection against Bites)	336
XV. The Known Infected Area and the Tsetse responsible for the Spread of the Infection	337
XVI. Three Types of Sleeping Sickness Villages	338
XVII. Duration and Course of the Infection	340
XVIII. The Facilities for Direct Transmission	342
XIX. The Relation of the Game to the Outbreak	345
XX. Possibilities of Spread	351
XXI. Immediate Local Measures	353
XXII. A Campaign against the Fly	357
XXIII. General Prophylactic Measures	365
XXIV. Conclusion	368

I.—INTRODUCTION.

Information volunteered by Salim, the native headman of Basheshi, near Maswa, drew attention to the outbreak of sleeping sickness here described late in February 1922.

Dr. G. Maclean, the Medical Officer at Mwanza, at once carried out an energetic investigation. He found by blood examination that the disease (which had at first been regarded by the natives as "safula" or hookworm) was in fact trypanosomiasis. He ascertained roughly the extent of country that had been invaded by it already in the Simiyu-Duma area and, with the Senior Commissioner, at once took steps for the erection of hospitals in fly-free parts of the Sultanates most affected and for the segregation there of the sick.

It was obviously an exceptional opportunity to gain some idea at first hand of the combination of factors necessary to bring about an outbreak of human trypanosomiasis in epidemic form before these should have been masked by remedial measures—particularly so if it should be of Nyasaland type, and in the event, furthermore, of *T. rhodesiense* and *T. brucei* being finally shown to be conspecific.

* This is a revision of a report sent to the Tanganyika Territory Government from Mombasa on 3rd July. The report (in order to be in time to assist decisions as to measures) was written in great haste, under difficulties and without much reference to my notes, while travelling to catch a steamer, and this paper should be regarded as replacing it.

I was especially anxious, with a view to future policy, to gain a first-hand knowledge of the probable relationship of the game to such an outbreak. Therefore, having consulted the Acting Principal Medical Officer, and having ascertained that from his point of view also, and Dr. Maclean's, my visit would be regarded as useful and welcome, I proceeded to Mwanza at the beginning of May, by car and on foot from Tabora to Smith's Sound, and thence by dhow. I found the Senior Commissioner, Mr. A. M. D. Turnbull, already considering the feasibility of wholesale evacuation and other important administrative measures which I shall describe. He accompanied me during the greater part of this investigation, and I was indebted to him everywhere for assistance that was invaluable.

We first sailed up the Speke Gulf with a view to examining the coast and the possibility of a connection, original or still existing, between *G. palpalis* and the outbreak. We then canoed up the lower reaches of the Simiyu River (Pl. xiv, fig. 2), again with the latter object, and, entering the fly-infested woodland two miles from Nyalikungu and (later) crossing the Simiyu, travelled between that river and the Duma to Zagayu. We crossed thence northwards to Luguru, the headquarters of Sultan Mwanilanga of Itilima, and returned to the lake coast through Maswa (the Ntusu capital), Ngasamo and Nasa. At Nasa we separated. This route had covered, very roughly, the piece of country in which cases were known to exist. Halts of from one to five days were made for the purposes of investigation.

Dr. Maclean and Mr. P. E. Tully, the Stock Inspector, joined us at Zagayu, from which centre Mr. Tully had been working a number of my bait-cattle and fly-boys pending our arrival. I am much indebted to him also for the supervision, later, of experimental clearing designed to ascertain the width necessary to render a road safe for traffic, for the marking of flies, and for other help, without which, in the short time at my disposal, I could not have attempted such work.

Finally, leaving Nasa on different dates, Dr. Maclean and I travelled separately to Ikisu—where we met and he took over from me my side of the investigation. Thence he went to Ikoma and the old *palpalis* area of the Mara, and I to Musoma, afterwards proceeding to Kisumu, Entebbe and Nairobi.

There was no lack of assistance. I have already mentioned Mr. Tully. Major L. G. Murray, M.C., commanding the 2nd Battalion, King's African Rifles, in Tabora, offered me the services of Lieut. Moore, V.C., a keen amateur entomologist who was anxious to help, and whose temporary seconding to tsetse work had previously been approved by H.E. the Acting Governor. The Medical Officer and I felt that he would be most usefully employed in combining entomological work with a search for sleeping sickness cases in the direction of the points—such as Seke and Uzinza—the infection of which would be most disastrous, but from which infection had not been reported. The Assistant Political Officers of Musoma and Mwanza (Mr. O. Guise-Williams and Capt. G. H. R. St. J. Owen, and Mr. G. F. Webster) were contributing on safari to the same useful search for cases and for the boundaries of the fly-areas, and were supplied with fly-boys to accompany them and collect. Mr. G. G. Griffiths, passing through the Chinyanga belt, most kindly collected and sent in flies and notes. Fourthly, at the request of the Senior Commissioner, I instructed one of my assistants, Mr. A. Loveridge, an entomologist and an expert and enthusiastic collector of small vertebrates, to proceed to the area at the end of August to undertake the watching of the grass-fires and the breaking up of the traffic in wildebeest tails that I shall describe as occurring about Ikoma and causing much dangerous movement of natives. He was also to assist Dr. Maclean with regard to the further entomological study of the fly, particularly as to its primary centres, and to collect on as large a scale as practicable the smaller vertebrates of the area in order to supply Drs. Duke and Maclean with abundant material for a study of the blood of the smaller potential food-animals of the incriminated tsetse. Dr. Maclean himself I found to be an enthusiastic yet cautious investigator anxious to work on every side of the problem.

All these opportunities for extended entomological investigation were particularly welcome at a time when this fly could still (for a few weeks) be studied in its normal relation to the infected population, and especially useful in the case of a tsetse, which I was convinced was undescribed and of the habits of which—so all-important in relation to control—nothing whatever was known. The assistance was well-timed also in relation to the need for an immediate knowledge of the distribution of the infection.

Native assistance was freely employed on this investigation, as it was felt that much might be at stake and that no time should be lost in ascertaining the distribution of the infection and the present limits of the tsetse. Expeditions composed of fly-boys with bait-cattle, to report eventually to Dr. Maclean and to continue to be employed by him for fly-work for as long as might seem necessary, were sent by me through the infested woodland to the Serengeti Plain, Lake Eyasi, the Tungu River, Ukerewe Island, and elsewhere. Only quite local expeditions had rejoined us before I left. I also, throughout the investigation, kept native shooters employed in obtaining material, particularly rock-rabbits (*Hyrax*) for blood examination by Dr. Maclean and to keep me well in touch with the presence or absence of game.

I am indebted for information bearing on this investigation and other direct assistance to the persons already mentioned, to Capt. B. D. Armstrong and Capt. R. G. H. Wilson, D.S.O., M.C., of the 2nd King's African Rifles; to the Senior Commissioner, Tabora (Mr. H. C. Stiebel); to the Assistant Political Officer, Chinyanga (Mr. G. F. Bell); to the Rev. A. X. Davis; to the Senior Commissioner, Medical Officer and Sanitation Officer, Kisumu (Mr. H. R. Tate and Drs. G. R. H. Chell and F. J. C. Johnstone); and to the Principal Medical Officer, Principal Sanitation Officer and Government Entomologist, Nairobi (Drs. J. L. Gilks and A. R. Paterson and Mr. T. J. Anderson).

It will be seen that the outbreak offers several points of exceptional interest. The fly responsible for it—"sali" of the local natives—is of the *morsitans* group, yet the disease is in epidemic form and six and a half degrees farther north than the most northerly recorded case of *Trypanosoma rhodesiense*.

Whether the parasite actually is *T. rhodesiense* or whether (as a little of the evidence suggested) it might be *T. gambiense*, was being studied by Dr. Maclean and has, since I left, become the subject of a special investigation by Dr. H. L. Duke, who was lent by the Uganda Government for this purpose. It is to be hoped that definite evidence as to the relations of the trypanosomes and as to the actual importance of each of the two modes of transmission may emerge from his results, which must in any event be of the very highest interest.

Further outstanding points were the dense stand of very young woody growth that is threatening to convert the greater part of the belt of wooding into thicket; the effect of population in completely clearing great areas; the evidence therefrom of the number of settlers required to keep down tsetse automatically, and the possibility that local surpluses of men and cattle might by organisation and inducement be diverted to the suppression of tsetse belts; some evidence for the probable effectiveness of merely partial clearing; the peculiarly anthropophagous habits of the fly; the free "following" of female flies across open barriers; the evidence that the fly ranges out to conspicuous trees, etc., in the open; the fact that it differs from *G. morsitans*, its nearest described ally, in certain important details; the position, in the bush villages, as regards the possibility of much direct transmission of the trypanosome; the apparent man-to-man nature of the infection, travelling chiefly, it appeared, outwards from a centre; and, most important of all, the light which the history of the outbreak appears to throw on what would be the effect (1) on the tsetse, (2) on the trypanosomiasis of man, of a destruction of the game. I believe that the much-needed experiment in game-destruction has here, for practical purposes, been carried out, and that we know the result.

The information I have included in the map on the distribution of fly and sleeping sickness in South Kavirondo is taken from maps which were kindly placed at my disposal in Kisumu and Nairobi. The map, and this paper generally, should be regarded as preliminary and provisional only, a basis for correction and addition by the medical, political, and other officers who are continuing to work on the problem.

The specific names of certain of the plants referred to in the paper are provisional also. They will be revised and added to when my plant collection has been worked out. I am much indebted to Dr. A. B. Rendle, F.R.S., Dr. H. Harms, Dr. M. Burret, Mr. E. G. Baker, and particularly Mr. C. Norman, for their kind assistance in connection with the naming.

II.—THE COUNTRY GENERALLY.

As regards vegetation, the country is divisible primarily into (1) perfectly, or nearly perfectly, open country, free from tsetse (Pl. xii, fig. 1); (2) acacia wooding, infested nearly throughout by a new tsetse of the *morsitans* group (Pl. xii, fig. 2); and (3) *Brachystegia* savannah forest, also fly-infested.

The bulk of the open country itself may be described as "suppressed" acacia wooding. The suppressive factors at work are merely temporary, and their removal or weakening even for four or five years would, and does, allow this wooding to grow up. This results in continual modification in the distribution of the two contrasting types. Each of them, however, covers a great area of country, and their present distribution is shown approximately in the accompanying rough map.

No primary forest was seen. Though it occurs, it is said, on Kome Island (where is a forest reserve) and, in its mountain form, on Oldeani and in some places in the volcanic area north of the Kenya border, both general indications and native information as to past alternations of acacia savannah and settlement suggest that it is long since it was exterminated in the bulk of the country I have shown on the map. But an enormous area of "miombo" or *Brachystegia* savannah forest, already described and figured by me under its Shangan name "itondo" (Bull. Ent. Res., xi, p. 320, Pl. xvi) fills the west of Tanganyika Territory and borders the special area I am here dealing with on its west and south. It is infested throughout by *G. morsitans*, and its possible infection constitutes the greatest danger of the present outbreak.

The general geological formation is granite. Granite boulders, and kopjes and hills composed of them and reminiscent of Mashonaland (Pl. xv, fig. 2), are scattered thinly or in groups over both the wooded and the open areas and everywhere crown rising ground. Hilly plateaux, a small one at Kilalo, a greater one in Ushashi and the country to its north, occur in the granite.

Schistose, diorite and diabase hills of more rounded outline occur at Zagayu (Mount Sansui) and at Ngasamo, and (as a view from the last-named hill showed) become very general in the direction of Ikoma. They are associated with a red soil that contrasts with the grey and sandier soil of the granite.

North of Ikoma both the above-mentioned formations are said to give place to ancient shales and quartzites that fail to reach the coast but extend far into Kenya Colony. These are associated on the whole, it would appear, with lighter types of bush. Doubtless not everywhere, for where the Mara crosses the border there is, at the foot of the Isuria Escarpment, an area inhabited by *G. pallidipes*.

On the coast just north of the Kenya border the intervening granite gives place to the volcanic rocks of the Tertiaries and generally loftier country. The change in the form of the hills is very noticeable from the Lake. A similar geological, not physical, change takes place also on the eastern border of the three great bush-covered Sultanates of Ututwa, Kanadi, and Meatu, on reaching the Serengeti Plain. The change in each case appears to coincide with a change in the general vegetation.

The elevation of the country varies from 3,726 feet at the lake level to 4,500 feet and more on some of the more prominent hills and plateaux, and as much as 6,600 feet at points north-west of the Isuria Escarpment.

German charts show the main area with which we are here concerned as possessing a break in the rains, a very strongly-marked dry season and a rainfall of 20–30 inches. Passing south-west and south the dry season remains marked, the break in the rains gets weak and disappears, and the rainfall rises to 30–40 inches; this area appears to coincide approximately with that which is covered with *Brachystegia* wooding. West of the Lake, in the Bukoba area, the dry season is shown as shortened, the break as weakened, and the rainfall at a figure of 60–80 inches.

Ukerewe, the town and Sultanate of Mwanza and the northern portion of Uzinza are shown in a category intermediate between the last two and with a rainfall of 40–60 inches. That is, the dry season is more marked in the main (Usukuma) fly-area investigated than at Mwanza, and the rainfall just half, though the same fly occurs on the Ukerewe mainland, where the rainfall is apparently the same as at Mwanza. The point is of importance in relation to the possibility of effective grass-burning.

The dry season was commencing when I arrived early in May, and the climatic conditions contrasted strongly with those of the same months at Entebbe. This difference is perhaps reflected in the persistence, in spite of probable vicissitudes, of some of the splendid primary forest of the latter region, in the always green grass of Entebbe and the northern islands, and in the contrast of both with the low, dry, savannah woodland and xerophilous shrub formations of Usukuma (Pl. xii, fig. 2).

III.—THE OPEN COUNTRY.

This includes (1) rolling, grassy, undulating country, close-grazed by numerous small herds of cattle and dotted over with millet fields and village-enclosing rings of black-green *Euphorbia*—great areas that are one cleared field and owe their nearly complete freedom from bush to the presence of a long-concentrated human population and the browsing of stock (Pl. xii, fig. 1); the granite kopjes of this open country in a few places carry bush or scrub, but, even then, owing to their isolation, harbour no fly; and (2) great mbugas (Pl. xiii, fig. 1), kept open and, in parts, fly-free by excessive seasonal moisture or by the browsing of game. The outstanding examples are (a) the extensive mbugas of the Rowana and Mbarangeti, that form a broad, relatively clean and useful break across the north of the infected thorn area from the Lake in the direction of Ikoma, and (b) the Serengeti Plain, which bounds this area on the east.

Small vleis or mbugas (seasonally swampy glades) are scattered very freely through the woodland area generally. The nearest short English rendering for a “vlei” (South Africa and Southern Rhodesia), “dambo” (Nyasaland), or “mbuga” (East Africa) would be “seasonal swamp.” On the other hand, “mbuga” includes naturally open land that is not swampy, and all three words, I believe, may include open land that is permanently swampy.

IV.—THE ACACIA THORN AREA.

The general acacia area includes—and encloses—a number of woodland formations:—

(1) *Acacia Savannah Forest*.—There are several actual acacia-dominated formations. Each is dominated by a different species of the genus and is confined to particular conditions, especially as regards drainage. These formations between them cover the uncleared country with savannah wooding and tree savannah and the cleared country with their live roots. The five most important formations are:—

(a) That of the fine tall “mgongwa” acacia on the best-drained deeper soils.

(b) That of the dainty yellow-flowered “sesa” acacia (*A. stenocarpa*, Hochst.).

This dominates on the higher hills, as on Ngasamo and on the Ushashi plateau, and is far more freely intermixed with broad-leaved trees than any of the others. On the Ushashi plateau the broad-leaved trees predominate and, with a *Combretum* (near *tetraphyllum*, Diels) as their commonest element, they include also such trees and shrubs as *Erythrina tomentosa*, R. Br., *Kigelia*, *Anona*, *Cussonia*, *Grewia*, *Rhus glaucescens*, Rich., *Rhoicissus*, *Parinarium*, and two species of *Vitex*. This bush is in places sufficiently close to make one marvel (in spite of the relatively high elevation) at the absence of fly and the presence in it of numerous cattle. It is very distinct from anything else seen on this safari. The granite heads that here and there project are densely thicketed, but old euphorbia hedges indicate that the country was once more densely settled than now.

(c) The formation of the most xerophilous of the acacias—the grey-leaved “mhali” (*Acacia spirocarpa*, Hochst.), often with rock below and therefore somewhat liable to water-logging in the rains and an extreme of dryness in the dry season. This type clothes the ground round and between the granite kopjes and (interspersed somewhat with mgongwa) forms (i) extensive fly-infested forest on poor, sandy, badly-grassed granite soil in Nasa and Msanza Mdogo (Pl. xii, fig. 2), and (ii) similar forest, but without fly, in granite country at the back of Musoma.

(d) The swamp-fringing acacia, the “ilula” (*Acacia drepanolobium*, Harms, and an allied species), a small, straight, often unbranching tree, its twigs studded with large round galls that house ants of the genus *Cremastogaster*, grows somewhat densely, yet without giving much shade, on the margins of the seasonally-wet mbugas. It is sometimes associated with a *Combretum* of the *tetraphyllum* type (as in Pl. xiv, fig. 1) and ventures, in clumps, into parts of the mbuga itself.

(e) The larger, shadier, blacker-foliaged “tulangoi” (*Acacia hebeoladoides usambarensis*, Harms). This may be associated with the ilula, or with the margins of ill-drained spots on the borders of mgu country, or it may itself, more rarely, locally dominate. In the latter event it tends, I think, to be rather specially associated with tsetse.

The acacias (regarded alone—for I have yet to touch on thickets) form open to fairly open wooding, and are high where there has been no recent cultivation, low and scrubby (but growing up) on the sites of abandoned fields. Their most widely distributed associate, rather linking the mhali and the ilula in its tastes but occurring also with the mgongwa, is another of the Mimoseae—the “mpogoro” (*Albizzia hypoleuca*, Oliver); while a small stubby tree, the “tinji” (*Odina* sp. ?), an early leaf-shedder, was abundant on many vle edges, being more daring in the matter of badly drained moisture than the mpogoro or mhali, yet less so than the ilula. It is always gregarious, but it may be found in association with any of these species or bordering a swamp itself. The fly had already left it in June.

(2) *Fringing Forest*.—To be distinguished from the foregoing tolerators of relatively ill-drained ground are the true (albeit secondary) fringing formations of the lake and the rivers, and in particular the rather fine fringing savannah forest that is dominated by the tall and handsome “mgu” (*Acacia campylocantha*, Hochst.) (Pl. xiv, fig. 2). This grows on deeply cracking cotton soil that is liable to be extensively flooded in the heaviest rains, and that even in June, though dry, stood out as a bright green ribbon of tall, coarse grasses; it thus contrasted sharply in the distance with the dry reddish grass of the adjacent mhali formation, and along the lower reaches of the Duma in particular was two miles or more in breadth.

The other fringing formations are (a) the mixture of ambatch, *Grewia*, *Hibiscus*, reeds and papyrus that covers the broad Simiyu delta in Magu Bay and (papyrus chiefly) partly blocks the mouths of the other large rivers; (b) the close fringe or hedge of bushy Vernoniads(?) that, below the upper bank, lines the rivers along sandy reaches, and appears in Plate xv, fig. 1, in its usual position in relation to the heavier wooding; and (c) the combination of fine mgu acacias, large, shady *Ficus* and dense under-shrubs (same Plate and figure) that tends to reproduce the shelter-conditions of primary forest and should, and on some rivers does, harbour *G. brevipalpis*.

(3) "Enclosed" Formations.—These are (a) the broad-leaved, very distinct formation of trees and shrubs (*Grewia*, *Sterculia*, and many others) that closely fills the interstices between the great boulders of the kopjes and (on the island at Musoma and the coast opposite, as well as at points on the Mwanza Gulf and elsewhere where kopjes are half submerged) comes down to the lake and harbours *G. palpalis*. This formation (Pl. xv, fig. 2) takes the guise of little rocky islands and archipelagos, not thorny and devoid of acacia, dotted through the acacia thorn woodland; (b) the thickets, which are, in part, composed of the densely growing seedlings of the savannah trees, and partly, more or less low, dense shrub-thickets (Pl. xiii, fig. 2), in places scattered, in others more massed. Such thickets occur throughout the woodland, and with the aid of the sapling thickets (which they invade) are tending to cover the entire area with the quite intractable type of tsetse-infested bush that occurs, for instance, over great stretches of country between Dar-es-Salaam and Morogoro. They often enclose and are overshadowed by from one to many large or small acacias (as in Pl. xii, fig. 2), doubtless owing to the fact that the grass in the shade of a tree dries later than the grass outside, escapes the weak fires of the early months, and allows shrubs and saplings to obtain a start. They comprise, especially, species of *Grewia* and *Commiphora*, *Acacia vereke*, Guill. & Perr., and in places *Markhamia lanata*, the small-leaved, thorny trailer (*Harrisonia abyssinica*, Oliv.), and (especially in the drier situations and in association with *A. spirocarpa*) *Kalanchoë*, *Aloë*, *Sansevieria*, and much of the fleshy-looking liana (*Strophanthus* sp.) that is shown in Plate xvii, fig. 1, and that sometimes coils all over the thicket floor and shelters both tsetse and their puparia; (c) a kind of thicket that I found containing flies in small numbers near Zagayu and north of Kahama and that occurs here and there throughout the area, and particularly on the margins of certain seasonally damp spots, is composed of large, round brakes of a trailing *Combretum* that gives a little the effect of a much-enlarged blackberry bush, and may or may not occur in connection with the types of thicket I have referred to already.

Reproduction is only too good. An enormous amount of young growth (*Acacia* and *Albizzia* especially) is everywhere springing up more or less densely, and unless this can be kept down by systematic burning, the whole area will become as thicketed and as heavily fly-infested as patches of it now are. I cleared of grass two squares, each of nine square yards. In one I counted 95 young trees, and in the other 77. These squares were not exceptional, but represented the present position over broad patches of country. Some early grass-fires had already taken place at the time of our visit and had killed not a twig of these little trees that an October fire would have burned to the ground. The results of past ineffective fires were seen in places where masses of these small trees were already growing up and forming thickets.

V. THE PEOPLE.

The people generally, for our present purpose, are to be distinguished into (a) cattle-keeping cultivators, who live relatively thickly in the cleared areas, and who, where near enough, visit the woods for wood, bark rope, water, hunting, fishing, young birds and honey, medicines, ancestor worship, and material for the Ifubo or silver-leaf dance; and (b) hunting and fishing cultivators, who, owing to nagana, can keep no cattle, and who live in a more scattered fashion in the woodland area itself. It is a most interesting point that they have been enabled to do this, as they themselves state, by the freedom they have now obtained from the old tribal raids and clan warfare that forced on them the concentration that has usefully cleared so much country; and they have been induced to do so by the loss of their cattle in the epidemics that have accompanied the European régime during the past thirty years. Game skins and fish nets may be found in most huts of this section. The fruits of *Strophanthus eminii*, Asch. & Pax., are used for the manufacture of arrow poison by every native in these parts and are found lying in the villages. Pits, game nets, and heavy rope snares are also employed. Along the whole lower course of the Simiyu

and at the points at which we saw the Simiyu and Duma higher in their courses large stationary fish traps, often in the form of a ditch and protected against crocodiles by palisades, were abundant; fish baskets are in places supported against the current and floods by stone dams across the river; and during our canoe voyage we came on anglers with rods, one at least of whom had been extraordinarily successful. The Wantusu, in particular, whether in the clean areas or in the woodland, are clothed almost entirely in well-brayed skins of game; these also cover their beds. Long necklaces made from discs cut neatly from the shells of ostrich eggs are worn by everyone, and whole ostrich eggs are mounted as charms on the summits of the huts.

- It follows from all this that those people who live in the woodland, and those who live near it and enter it for the same purposes, are nearly as available to the tsetse as food-animals as the game itself; they are also far more available than the game when it is scarce, and must then carry great numbers of tsetses to their villages.

A further division of the people that may be of great importance in relation to the spread of sleeping sickness is tribal. They may be divided into (a) the Bagwe or (Kiswahili) Wasukuma, the real occupiers of the sleeping sickness area; and (b) members or sections of other tribes permanently settled amongst them. More will be said on this point in Section XX.

VI.—THE OTHER HOSTS OF THE FLY.

As regards game animals, the area is divisible into three parts. The first line of demarcation passes a little north of the Duma, through Ngasamo and Nasa, and swings southwards round the cleared area in which are Maswa and Luguru, though giving it a fairly wide berth. North and east of this line game of most kinds, excluding elephant and situtunga, begins to become abundant until, in the Ikoma and Serengeti areas, it is very abundant indeed, particularly wildebeest, zebra, Thomson's and Grant's gazelles and topi, and carnivora are proportionately abundant.

South and west of the line I have described, that is in the woodland areas most closely associated with the outbreak, game animals were exceedingly scarce. They consisted, in order of apparent scarcity during our visit (I prefer to put it in this way, as there was no trace of "abundance"), of situtunga (alleged to be very rare, at spots with papyrus), bushbuck, giraffe, reedbuck, waterbuck, duiker, impala, ostrich (localised), roan antelope and eland (not many of either), topi, hartebeest and zebra. Even in this impression is included to some extent the game that occurs on the border line of abundance, as the ostrich and zebra near Kilalo. The Duma—or rather north of it—is the present southern boundary of the rhinoceros, though a single individual is said to haunt Ndagalo and Igombe. Buffalo were so plentiful here formerly that one person (so an old man told me) killed thirty at one place, but they have never been allowed to recover from the original rinderpest. They are absent from the Simiyu side of the area, and are in numbers "only beyond Kanadi." A few small parties, alleged migrants from the Mbarangeti, occur sometimes on the Duma on the borders of Nasa and Ntusu, or appear for a time near Ngasamo; and wildebeest, formerly abundant right down to the Simiyu, are now scarce, but still arrive in the late dry season in Nasa and Ngasamo. Impala are plentiful at Nasa. Warthogs were present at various points, though nowhere in any numbers; bush-pigs (and this was remarkable) were extremely scarce, except (it was said) in the very limited area of the Nasa hills.

Game was particularly scarce on the Simiyu side of this area, as was indicated by personal observation, by the failure of our shooters, by native statement, and by the very high percentage of female tsetses taken daily and the special avidity of the flies. Practically all game animals shot in this section were obtained in the Mtukuza mbuga, in which such game as was in the surrounding bush areas congregated, and the only giraffe seen by any of us and the only appreciable traces of eland or roan antelope (outside of the mbuga) were in an uninhabited piece of country towards the centre of the area. While this Simiyu game would appear sometimes, perhaps

annually, to be reinforced (and game, though scarce, is probably less scarce than it was at the time when the sleeping sickness began), native statements show that the foregoing is nowadays the normal relative position. The natives admit that they had much reduced the game within this ring of population even before the war; statements show further that, here as everywhere, the relaxation in the enforcement of the game laws that accompanied the war resulted in more intensive hunting, and that this became yet more intensive, especially in the neighbourhood of the greatest population, during a famine that took place in 1917-18. The passage of troops through this very area just before the famine will probably also not have been without some effect. Such further explanation as is needed of the special scarcity of game in this area is supplied by the fact that the great annual game movements in search of water are from the north and east. That from the east is intercepted by the heavily settled strip of Maswa and Luguru, and that from the north is checked by the villages north of the Duma, the area of dense settlement that has grown up about Kilalo in the last twelve or fifteen years, and, until 1917, the mine at Ngasamo. This employed some hundreds of labourers and the shooting carried on there for meat must have constituted it a strong link in the barrier. Even its shutting down, backed as it was by a certain number of villages that remained, does not seem to have led, up to the present, to any great irruption of the game.

It will readily be seen that we have here the position that a great piece of tsetse-infested woodland was surrounded with a barrier and the game within it enormously reduced. Neither the barrier nor the game destruction were by any means absolute, but the contiguous native population of keen hunting tribes was very great, and guns were present in addition to highly effective native weapons and methods. The resources of destruction that were turned on to the game of this hemmed-in area were at least as great as could have been marshalled for any experimental destruction, and the killing was very persistent, so that it is probable that, by the end of the famine, the game had been brought down to the minimum below which, in savannah forest country, it is not humanly possible to bring it, excepting by means of fairly heavy settlement.

It may here be noted that the clear area of Kilalo as shown in the map includes some half-cleared country on its east and a natural mbuga on its west. Such clear ground as there is immediately round the Ngasamo Gold Mine is due partly to clearing for mining purposes, partly to natural mbuga.

The third division of the Usukuma-Musoma area as regards game is that comprised within the closely settled country. This is nearly destitute of game and is avoided by it, though zebra and ostrich come out in places from the bush to the nearest crops, and the narrow cleared littoral of Nasa is traversed by game seeking water on the Lake when other sources fail.

The granite kopjes have a fauna of their own. They are probably unattractive to ordinary game, being for the most part (Pl. xv, fig. 2) densely clothed with rocks and trees, but rock-rabbits (*Hyrax*) of two species are common, and so in places are baboons. The latter appeared to be the only animals that visited some kopjes beside Ngasamo in which my natives found tsetse puparia (mostly empty) under every suitable rock to the number of over 2,300 in a couple of hours, and round the bases of which baboon tracks were everywhere conspicuous—as indeed they were in the bush near Nasa, in the lower rocks of Mount Baridi, and in some other places in which the puparia abounded. Occasional klipspringers, leopards, porcupines and hyaenas frequent the kopjes; two species of lemur were found; and bats were in places hanging in some numbers in rock-clefts that, to judge from finds of puparia, were sometimes utilised also by the tsetses.

Crocodiles are abundant in the rivers and hippopotamuses are present in places, but neither animal appeared to be in appreciable contact with the fly that was associated with the outbreak.

One final point may be referred to. In Musoma (as Capt. Owen informed me), except in one area, game is abundant where tsetse is absent and tsetse abundant where game is scarce. This may represent a temporary phenomenon, as Dr. Duke, who took part in the operations here against Neumann in 1917, speaks (Bull. Ent. Res. x, p. 11) of an abundance of game between Ikoma and the Mara, and Ikoma and Olgoss, both fly areas. However, the influence of game, when really abundant, in keeping down bush that might otherwise harbour tsetse has been referred to and cannot be doubted, while apparent evidence of its avoidance of established tsetse-harboursing bush where an alternative exists close by was seen by ourselves, and either factor might contribute to the phenomenon referred to by Owen.

VII.—THE SPECIES OF *Glossina* PRESENT.

1. *Glossina palpalis*, R.-D.

In the Mwanza Gulf there are stretches of granite-kopje wooding that come to the shore both on the mainland and some islands, and Fiske and Marshall took *G. palpalis* in the latter. From Mwanza to beyond the Rowana River, the Lake and river front that covers the sleeping sickness area, no sign or news of this fly could anywhere be found by us. With the exception of a few very small points, some of which were carefully searched, the coast from Mwanza to Nasa has been completely cleared of woody vegetation by native settlement. The islands generally of the Speke Gulf and the margins of the mainland on its north, as seen from the dhow, also appeared to be clear on the whole, but in Nasa the mhali acacia wooding (Pl. xii, fig. 2) comes to the shore and, as a broken marginal to submarginal strip, stretches to the Rowana and beyond. Here again, as in Magu Bay, I searched carefully by canoe, coasting close and sometimes landing and searching for the fly and its puparia, but without success as regards *G. palpalis*.

The vegetation at Kianzi point and the little Yamagata Islands in Magu Bay closely resembled vegetation in which I had taken *palpalis* elsewhere, but these widely isolated little points of wooding on a clear coast are obviously as insufficient for the requirements of the fly as are the isolated wooded granite kopjes and small *Acacia* woods of Sultan Tshasama's settled country for those of *morsitans*, nor were there, even in the mhali north of Nasa, any patches of "massive" wooding to serve as centres of distribution. Fiske has mentioned this also in a report, I believe unpublished, on the Cruise of S.S. Sir William Mackinnon into Tanganyika Territory in 1920.

Neither, however, could *palpalis* be found in the mgu wooding (Pl. xiv, fig. 2) that borders the lower Simiyu, nor in the far more likely fringing forest of shady *Ficus*, some mgu and thickets of dense green *Grewia fallax*, a *Gardenia* of the *thunbergia* group and the thorny shrub (*Harrisonia abyssinica*) that borders the Mbarangeti and Rowana (cf. Pl. xv, fig. 1), though these rivers are full of hippopotamus and crocodiles and infested by baboons.

On the other hand my natives took *palpalis* and its puparia in numbers on the small Mgasiro Island in Mara Bay near Musoma (where it was known to exist), and Dr. Davey had already found it at Musoma point. More wooding of a more or less dense nature comes to the shore in Mara Bay than in the Speke Gulf, and (as could be seen from the steamer) this condition tends to recur here and there till one turns into the Kavirondo Gulf.

Fiske and Marshall also, in 1920, failed to find *palpalis* in the Speke Gulf from Mwanza right round to Nafuba Island off the Ukerewe mainland. Here it was found both on the island (densely) and the mainland near, the conditions (shelter and lack of cultivation) having become favourable. Extensive uncultivated beaches of the Ukerewe Island shore eastward of Wiru Island were found very densely infested, as were parts of Kome and the islands to its west.

So far as the fly on the rivers is concerned, I am not clear as to the position on the Mara River, which Dr. Maclean was about to revisit, but Dr. Davey had failed to find *palpalis* on the Mori River, where the very extensive clearing carried out by the Germans was still effective; but I was informed in Kenya that on the Gori and Kuja Rivers just north of the Tanganyika Territory border the position as regards infestation remains much as it has always been and as it is shown on the map. The Kuja flows through heavy bush and forest and has been reported by Dr. J. O. Beven to be infested in its whole extent to Ramba, where are grassy uplands. The Gori (Magori) had forested banks as far as he followed it.

2. *Glossina brevipalpis*, Newst.

This fly and its puparia, many of the latter living, were found in numbers in the denser thickets fringing the Rowana (*cf.* Pl. xv, fig. 1), and especially in the deep narrow cuttings made by hippopotamuses through the steep bank. Crocodiles were numerous also. *G. brevipalpis* also occurred on the Mbarangeti and (in smaller numbers) on the small Nyakurunduma stream an hour north of Tshamagasa, and in the mhali acacia wooding with much dense thicket that occurs from Tshamagasa northwards as the marginal to submarginal fringe to the Lake that I have referred to. Between this fringe and the Lake (north of the Mbarangeti) is a very narrow cleared strip in which cattle are kept, it is said safely. Contrast with this a position near Nasa where, with a more adventurous fly (*G. swynnertoni*) at the back of a narrow cleared fringe, cattle cannot be kept.

During the working of the Simiyu area a solitary *G. brevipalpis* was found at the bottom of a cyanide bottle, but no fly-boy claimed it, and it was unsafe to assign to it either date or place. I was surprised at our failure, despite careful search, to find either *brevipalpis* or its puparia in the rather heavy fringing forest on the Simiyu that is shown in fig. 1 of Pl. xv.

On Mgasiro Island, in Mara Bay, we took a considerable number of *brevipalpis* puparia, though we failed to find either the fly or its puparia in the very extensive acacia woodland and granite kopjes, in which cattle run, behind Musoma itself. The search was perhaps insufficiently prolonged to be conclusive. It would be interesting to know whether on Mgasiro this fly fed on crocodiles.

3. *Glossina fusca*, Walk.

As Mr. T. J. Anderson informs me that there is no doubt as to the fact that the large tsetse found hitherto north of the Kenya border is *G. fusca* only, and as there is equally no doubt that the specimens taken by myself and my native collectors as far north as Mara Bay are *brevipalpis*, it would seem that the Kenya-Tanganyika border may at this point constitute approximately the dividing line between these two flies. It may be a matter of the bush conditions associated with the volcanic and the granite formations respectively.

4. *Glossina pallidipes*, Austen.

We took a solitary male *pallidipes* on my bait-cattle beside a small glen lined with a narrow strip of bush with woody, sclerophyllous, ravine-type undergrowth (*cf.* Bull. Ent. Res., xi, p. 319) at 8 a.m. on 16th June. It was taken just after and just above the last two flies of the *G. swynnertoni* belt at the bottom of the hill—the south side of the Mount Baridi (Ushashi) escarpment. Another, showing close approach in its genitalia to *G. longipalpis*, was taken on the 18th by Dr. Maclean at Uhemba village (not Uhemba district) east of Ikisu on the same plateau. It is shown much too far east in the map. Further north, on the Kenya side of the border and also on ours, definite *pallidipes* areas exist, and this is the only fly of the *morsitans* group that is known to occur anywhere in Kenya.

The fly area shown in the map south-east of Shirati is one of *pallidipes*, Dr. J. B. Davey having taken this fly in small numbers in country that was on the whole open and in which numerous cattle were present from Bukina (two hours from Shirati) to Kinesi. Dr. Beven (unpublished report) found it in dry thorn bush (1) with *G. fusca*, along the south bank of the Kuja River, some distance from the water, from near Welbondo to a short way beyond the Gori; (2) in Kasiganga, between Nyangoma and Moita, in numbers that precluded the keeping of cattle; (3) heard of only, probably this species, in the Lambwa valley. I have already referred to the Isuria-Mara belt.

It will be noted that we first met *G. pallidipes* on reaching the border line (a) of a better rainfall area; (b) of a less xerophytic vegetation; and (c), perhaps only indirectly important, of a more mountainous area.

5. *Glossina swynnertoni*, Austen.

The only tsetse that could anywhere be found in the known infected area by a most thorough search, stimulated by means of rewards and carried out by a large number of natives and, in all, 30 bait-cattle, and the only fly that had been taken therein previously to my arrival, was a species of the *morsitans* group.

This tsetse, referred to hereinafter as "the fly," has been named by Mr. Austen after myself as this paper goes to press. I greatly appreciate the linking of my name with a subject in which I am so keenly interested, but I can lay no claim to having first taken the fly. The Germans took it for *G. morsitans*; Mr. Fiske told me that he took numbers, presumably of this fly, at Nasa over two years ago; and the earliest flies now in my possession were captured by Mr. G. G. Griffiths in the Seke-Chinyanga belt early in March of this year. Dr. Maclean, the discoverer of the outbreak, and, helping him, Mr. Tully and (I believe) the Administrative Officers, also took many in that and the following month.

It is nearest to *G. morsitans*, though in certain characters, both in the adult fly and the pupa, it resembles the flies of the *pallidipes* sub-group. It does so also in its preference for breeding in thickets of the type frequented by *pallidipes* (v. p. 333). It resembles *G. morsitans* in its savage attachment to man, in the relative absence of game. I have seen no tsetse that so readily attacks man with cattle present, and no fly the females of which travel so freely and far on man. Both traits were undoubtedly due largely to the fact that in the places in which they were specially prominent man had successfully replaced the game as the fly's chief food-animal. In the order of readiness to attack man the tsetse on which I have done most work may be ranged thus: (1) *G. swynnertoni*; (2) *G. morsitans*; (3) *G. pallidipes*; (4) *G. brevipalpis*; (5) *G. austeni*.

From what I have read of *G. palpalis* rather than from my very few days' work on it (on Lake Tanganyika, in particular), I would bracket it with the first two of these species.

G. swynnertoni inhabits, to the exclusion of *G. morsitans*, a solid tract of country that is cut off from a partly surrounding arc of pure *G. morsitans* by a strip of native cultivation, and it may prove to come into contact with the latter fly east of Chinyanga or on the Nanga. It is remarkably unvarying in appearance and in its genitalia, and *G. morsitans* (as my material shows) varies much even in single localities, an extreme form showing an approach to this fly in colour-pattern, though not in colour. It looks like a case in which a variety has become fixed as a species through long isolation. On the other hand, the occurrence of an unvarying fly possessing characters in common with *pallidipes* on the border that finally, on the north-east, separates the distribution of much-varying *G. morsitans* from the unmixed distribution of relatively unvarying *G. pallidipes*, suggests a greater age for it, and this view is supported further by the consideration that the barrier of native settlement that in one part only slightly, and perhaps not entirely, separates the two flies can hardly be of such age as to have brought about the fixing of a species.

The main area occupied by this fly in East Mwanza would appear to coincide with that of the main acacia woodland area shown in the attached rough map. In the north it occurred in the strips of *mhali-Combretum-Grewia* wooding at the immediate foot of Mount Baridi (Ushashi escarpment) and its pupae under the lower boulders of the mosaic that covers this hillside; and the same fly, taken again in numbers by two of my natives, has been sent to me by Mr. Turnbull from the mainland of Ukerewe since I came to England. Dr. Maclean took it an hour east of Chamliho.

In these circumstances it would seem likely that it is the chief fly that occurs about Ikoma and northwards as far as Bwasi—also that it is the fly that is said to infest the bush in the centre of Ukerewe, though my native collectors failed to find fly there. With reference to the area about Lake Eyasi that is shown green in the map, Mr. E. D. Browne, the Senior Commissioner of the Arusha District, wrote to me in a letter, dated 10th September 1921, "I am well acquainted with the area in different seasons. I believe that only *Glossina morsitans* infests the Yaida Valley and is of course rampant to Eyasi and probably all round this lake, except possibly at the extreme north-east corner, and even there I am doubtful of its absence at all seasons." It becomes doubtful now if the fly referred to and that on the Manyonga River (where "and," in the map, should read "area") is actually *G. morsitans* or if it is *G. swynnertoni*. The latter species, as I have said, is present in the Chinyanga-Seke belt, which is separated from the area known to be infected only by the comparatively narrow populated strip of Nung-hu and by a strip of thin thornland, as to the infestation of which I have at present no information (*v. map*).

Its belts, then, would appear as at least two compact areas of *Acacia*, one large, one small, which have been split off by mbugas and population from the great western fly-belt of *Brachystegia* inhabited by *morsitans*. From the Mbarangeti and Ikoma northwards the larger is broken into blocks by open mbugas, cleared areas of heavy population, and such uninfested wooding as that behind Musoma, the latter being free perhaps through having been surrounded since it was last a cleared area by fly-proof barriers. The smaller belt, at Chinyanga, consists of at least one considerable "island" in the inhabited country between the main belt and the *morsitans* belt.

The fly is completely absent from the continuously cleared areas, though individuals are carried in for some distance, and the villages within half a mile or a mile of the bush would occasionally receive invasions of half a dozen or a dozen at a time travelling on people who have been hunting, fishing or wood-cutting. Cases of nagana occur in herds living beside the bush or habitually driven through a piece of it to water.

6. *Glossina morsitans*, Westw.

No other tsetse than *G. morsitans* has to my knowledge been taken in the strongly infested *Brachystegia* area, the margin of which, very roughly indicated, is shown brown in the map. The genitalia of the flies there taken show sometimes the *morsitans*, sometimes the *submorsitans* characters. The margins and outlying patches of the area do not always contain *Brachystegia*, and nearer Lake Tanganyika this great *Brachystegia* area is divided by the acacia-dominated formation of the northern part of the Rukwa depression. Yet in this also I took nothing (in December 1921) but *G. morsitans*, and this fly inhabits extensive acacia-formations elsewhere in the Territory also, as in the Morogoro District. So that while *morsitans* is, I think, probably *par excellence* on this side of Africa a *Brachystegia* fly, it cannot be merely the domination of *Acacia* which excludes it from the Chinyanga-USUKUMA fly-belt. Similar considerations apply to *G. pallidipes*, which in some belts occurs with *G. morsitans* and in some separately, and it would appear to require merely a little intensive oecological work of a comparative nature to show us the essential requirement of each of the three species.

VIII.—THE SEASONAL DISTRIBUTION AND PREFERENCES IN
VEGETATION OF THE FLY.

When I left the belt in mid-June, the fly was still dispersed through the bush. "Tinji" (*Odina* sp.) was the only tree that had everywhere lost its leaves, and in patches of this I failed to find fly, though searching carefully. This observation and the consideration that the acacias generally are not merely themselves deciduous, but, being for the most part low, must inevitably be defoliated by the fires, suggest that the distribution of the fly in August must be far patchier than it was as we found it.

The choice of a retreat would appear to lie between the granite kopjes, the thickets, and the borders of damp mbugas, streams and water-holes. It may be of interest to state my observations in this connection. The period covered is 10th May to 16th June.

Granite Kopjes (Pl. xv, fig. 2).—It was difficult to find tsetse in the bush of the granite kopjes even when they were abundant in the wooding immediately round, yet puparia, a small proportion of them full, could be found under most rocks, even to the summits of some of the kopjes searched, and natives frequently referred to the fondness of the flies for the rocks, saying: "There are few here, but many at the kopjes yonder."

The natives also stated that the kopjes are less scorched by the grass-fires than the country round them; and it was obvious from the relative lack of grass on most of them, that resulted from the fact that scrub filled the interstices between the rocks, that this must be the case, and probable that (as the natives stated further) the kopjes would tend to retain leaf when their surroundings were already leafless.

Thickets (Pl. xiii, fig. 2).—In general the fly was found in its largest numbers in mgongwa acacias interspersed with considerable but broken thicket undergrowth, and in mhali wooding, chiefly where there were thickets of a type that would have attracted *pallidipes*. The ihusi, mkwata and mhali (the first two unidentified botanically) were stated by the natives not to lose leaf readily, the mgongwa and ilula coming next. The bridge of bush between the Sansui mbuga and the cleared country of Luguru, composed largely of ilula and other Mimoseae with overhead mhali (*A. spirocarpa*), was all very leafless on 1st June with the exception of the ilula, and in the latter, light though it was, occasional tsetses, mostly males, were taken.

Not all thickets or all mhali were equally suitable. To judge both from native accounts and from my own results, the fly was nearly absent from the strip of unusually fine spreading mhali acacias (with and without heavy thickets that sheltered some *brevipalpis*) that follows the lake submarginally between the Mbarangeti and the Rowana, though it occurs in drier, thinner bush on the mbuga side of the strip.

On the other hand, the worst place in Itilima was stated to be near Zagayu on the right of the road to Luguru—a jumble of granite kopjes, small vleis and thickish bush.

The following extract is from my road notes of 22nd May:—

"4 p.m. Entering broad-leaved bush dominated by mgongwa and numerous thickets—*Commiphora*, *Combretum*, *Albizzia*, *Markhamia*, some *Odina*. Numerous tsetses.

"Further, on down slope, drier bush—scrub patches with kinumburi, some ilula, a great tendency to leaflessness, especially in *Commiphora*. No bigger trees or mgongwa. No tsetses.

"Then much *Odina*, practically leafless. Two flies only, taken at thickets in between with dense *Euphorbia*.

"4.30. Narrow green vlei and pool with lilies, surrounded with tall green grass and overhung by dense mwotobarasi bushes. Beyond it simply *Odina* and light ilula. Took great numbers at the pool."

Water-holes and Swamps.—On three occasions in the Simiyu area, working with the cattle, I sustained considerable attacks on arriving at water-holes. Two of these were beside bushy granite kopjes, but themselves in lightly infested bush (in one case mere brakes of a shrubby *Combretum*), and the third has just been described. In general, we seemed able to count on an attack, large or small, on reaching a water-hole (as opposed to a pool in a stream).

The edges of open swamps bordered by numerous ilula acacias, and for the most part now dry, were sometimes points of attack by several flies together, or (if we stood) a succession of them. Such points were regarded as bad by the natives, who said of the seasonal connection between the fly and the ilula (and mkwata), "The fly never leaves them." I failed to find at these places the visible fly-concentrations on grass and paths that I found in the case of typical *morsitans* in similar situations in Portuguese East Africa—though Turnbull one day sustained an extraordinarily heavy attack at a spot in a small open vlei near kopjes in which I failed to obtain any tsetse on a subsequent special visit—but they were definitely regarded by the natives as bad. The same, it may be added, applies to *G. morsitans*. Vleis lined with ilula that Major Murray and myself had traversed in motoring from Tabora to Kahama had provided fairly heavy onslaughts by the latter fly. This was on 3rd May, when the surrounding bush was still full of leaf.

When thickets such as I have described as of the *pallidipes* type bounded a swamp, the presence of more or less numerous tsetse (*G. swynnertoni*) was nearly certain. Such a spot, where there was a severe onslaught by tsetses, is shown in fig. 2 of Plate xiii.

Rivers.—It is curious that in the infected area we failed to take this fly at all definitely in any of the formations which I have described above as "fringing." These were very thoroughly searched where found in order to make sure of the presence or absence of *palpalis*, *brevipalpis*, or *austeni*. The incriminated fly was not even taken in the more open mgu acacia formation prominent on the Duma and lower Simiyu, except as individuals that had followed us in, yet was present in some numbers just outside. *Pangonia*, on the other hand, was particularly abundant in such places.

It is likely enough that the dry season and the fires may drive the fly to the very spots from which we found it to be nearly absent—these fringing formations and the kopjes. Dr. Maclean found on 12th June many more flies on the streams in Msanza Mdogo than between them, and this may have been the beginning of a concentration. Manangwa Masalu, a headman who accompanied me northwards from Nasa to Kalemwa in Msanza Mdogo, informed me that the bush on the small dry streams we crossed here was also, a little later, a concentrating-place for this tsetse. It was composed of *Acacia spirocarpa*, some *Albizzia brachycalyx*, some tamarinds and dense thicket of *Grewia* and other genera.

Fly was taken also at the Mbarangeti and Rowana fords—that is, in secondary fringing forest sandwiched between great open mbugas—by both parties which preceded me, each travelling by the main road. My personal party, which met the Mbarangeti lower and followed the Rowana up from its mouth, searching it slowly and carefully and taking numerous *brevipalpis*, but striking off before reaching the main road, found none. This difference in result was explained, I am inclined to think, by a previous observation on the little Gudama stream.

IX.—AN APPARENT METHOD OF CONCENTRATION.

In the observation just referred to, on the Gudama, Turnbull and I took several flies in a stream-bed thicket at a ford, yet I could find none in similar thickets in the same stream bed anywhere away from the ford, in spite of stays of half an hour in each place tested. In this instance, at the ford, we first took five females fairly

rapidly, then nothing for a long time—till a party of women passed through. On their arrival we at once took a male and two females that had presumably dismounted from them. Two, which definitely came on a messenger, were taken at one of the other thickets.

Meantime two pairs of natives with cattle were kept working up and down, on each side of the stream. Between them they took only one fly, a female, and that was at the ford. The preponderance of females may have resulted from a greater readiness on the part of this sex to dismount at the shadiest places. The conditions for pupae seemed ideal, yet a thorough search by a number of natives revealed none at all.

It is interesting to compare these results with my similar observations in Portuguese East Africa (Bull. Ent. Res., xi)—*morsitans* leaving us at the shadier wooding beside streams rather than in the open bush when the latter was losing leaf (p. 370), *brevipalpis* waiting similarly till suitable cover was reached (p. 357), and *morsitans* usually dismounting on reaching one of its own concentrations (p. 357).

In these observations generally we would appear to see the *modus operandi* of concentration, taking place in a diffuse manner even when the leaves are on the trees, but becoming marked, as a matter of course, when the suitable dismounting places become few and far between.

X.—THE FEEDING HABITS AND SEX PROPORTIONS OF THE FLY.

I have referred to the fact that we found puparia freely under the large rocks of granite kopjes, even to their summits. These were on several occasions in close association with much dung of rock-rabbits (*Hyrax*). It seems most likely that these animals, abundant and sometimes conspicuous in the spots in which such large numbers of puparia were found, contribute to the sustenance of the fly, and certain that baboons must do so very largely indeed. I have myself found tsetse on baboons that I have shot in Tanganyika Territory, and been beset by tsetse on arriving at a spot from which I had dislodged a troop; and the Sultan of Itilima informed me that cattle-owners particularly disliked the incursions of baboons into fields in the margins of the cattle-grazing, as they commonly brought tsetse with them and cases of trypanosomiasis followed sometimes amongst the cattle. This statement bore out what was told me by the natives in Portuguese East Africa (Bull. Ent. Res., xi, p. 336).

Of the game animals—three zebra, six topi, six impala, two Coke's hartebeest and one roan antelope—shot on this safari, all but four were shot in mbugas, and tsetse were found on and about none of those thus killed. Of the four shot in bush, one (a zebra) was seen stamping and driving away flies before it was shot. Two flies were taken on an impala, and the roan and the kongoni showed none. The blood of these animals was examined, and gave negative results. They were too few, in any case.

The fly is a particularly surreptitious and (it would seem) gentle biter, for in the case of no tsetse have I seen so many successful full feeds on man. Again, in the Simiyu area it was the rule to take nearly or quite as many females as males, and the former often preponderated remarkably in particular places or attacks. This seemed to indicate a condition of hunger for man, had it not been that the females often travelled on us, like males, before feeding.

That this was, nevertheless, the correct explanation was shown somewhat later by a little definite experimentation at Ngasamo and Nasa, where in places where game or baboons were present in fair numbers the males far exceeded the females, while in pieces of bush that were being neglected by animals the female proportion was higher. In one experiment catchers who kept entirely in the main bush caught a great excess of males, while others who kept outside it in a mbuga in which were villages and a dearth of animals took, at a tongue of bush extending into the mbuga,

an excess of females. A complicating factor in such experiments was suggested by the fact that on several occasions in the Simiyu area it seemed that females were merely slower to attack than males. Thus in one case the first six flies were all males, but continuing to stand in the same place, our final bag was 11 males and 9 females. A marked excess of males became the rule after we had, at Ngasamo, passed out into the country of unimpeded movement of game. The grass was unburned in this area also, so that it was no difficulty connected with this that caused the flies to be more eager for food in the enclosed area than here.

A striking point about this fly was that it showed no appreciable preference for cattle as against man. My fly-boys also remarked with surprise on this contrast with all their previous experience. On several occasions when I was present the initial attack was on the cattle; the fly then spreading from them to the men around and being mostly caught on the latter. On numerous occasions the natives actually catching at the cattle had no flies on them, while the cattle and the men five or six yards away were attacked, so that it was likely that the cattle acted as some protection to the natives actually working with them; but this, and the possibility that the cattle did tend to induce more flies to leave the bush in the first instance, is the most that can be said, and the tsetse boys themselves considered that the fly liked man better. I was myself much reminded during these observations of my experiments on birds. These, when hungry enough, made no choice between insect and insect when laid down together, but took them as they came, the most "nauseous" species as readily as the more "palatable," except that they preferred the largest.

About Ngasamo, in spots where game was present, boys working with cattle brought in nearly the same large proportion of males as boys working without.

In general, I am inclined to regard this tsetse as having become, under the local conditions, an unusually dangerous fly to man. Mr. G. G. Griffiths also testifies to the savageness of its attacks in the Chinyanga fly-belt.

XI.—BREEDING-PLACES OF THE FLY.

The high grass everywhere made it difficult to find logs, but in the thickets (mainly of a xerophilous type and characterised by *Sansevieria*) a considerable number of puparia were found under leaning trunks or at the bases of standing trees (especially *Albizzia hypoleuca*, Pl. xvi, fig. 1), as well as under woody scrub and the heavy coils of lianas. Most were empty, as on the granite kopjes. In its apparent partiality for thickets as a place of deposition the fly would appear to resemble *pallidipes* and differ from typical *morsitans*, for, in the west of the territory at any rate, few *morsitans* pupae but many *pallidipes* are found in these thickets, while under the logs in the grass outside them the proportions are reversed.

However, even the thickets were by no means more productive of result than the granite rocks. Single great boulders standing out from the base of a kopje would often be found to shelter puparia if they had even a slightly over-leaning side, and in dark places between cleft rocks, or under rocks strongly shelving, the puparia were sometimes most numerous, in sand or vegetable debris (Pl. xvi, fig. 2).

In one place they were found in numbers where this layer was a mere half-inch thick on the surface of an underlying rock. In another, what amounted to a cave sheltered both puparia and numerous Argasid ticks (*Ornithodoros*), though villages which had been near had been abandoned some years before. Under single rocks near Ngasamo as many as 300 and 400 puparia were taken. The conditions were always dry, and in some cases ant-lion pits were present also. In the case of the log shown in Pl. xvii, fig. 2, no shade at all was present. This I have found to be not infrequent in the case of *G. morsitans*. Puparia were also taken immediately round individual sleeping-sickness villages.

XII.—THE FOLLOWING-DISTANCE OF FEMALE FLIES.

The length of distance that a female tsetse will "follow," travelling on man or on animals, is a most important question in relation to the possibility of checking the advance of a fly-belt by means of a barrier clearing.

In my past experiments (with cattle and man and using *brevipalpis* and *pallidipes*) 820 yards was the greatest distance covered by any female fly. It was obvious from an early date that the present fly was behaving quite differently, and that considerable "followings" by females were taking place.

I took the first opportunity to test this view by awaiting my carriers near the opposite side of a completely open mbuga and catching and sexing the flies on them when they had been travelling for twelve minutes (half a mile) in the mbuga. Six of the flies were females—resting on the men's backs, not feeding—and ten were males.

Again, at Zagayu, with Mr. Tully's help, marked females were tried, and I myself saw followings of a mile and a quarter on walkers and (one marked female) on a carried cloth screen. Mr. Tully obtained a considerably longer following by using his bicycle for part of the way, but it was known already that female *G. morsitans*, at any rate, will travel for great distances on fast-moving cars and bicycles.

The females travelled quietly, without (so far as I saw) constantly flying off the walker's back and returning to it as did the males, and, apart from size and colour, it seemed possible to distinguish the sexes in this way. Also they usually settled down to feed in the end, which the males did not, and then left their carrier. It may have been a coincidence, or it may not, that the females of the Zagayu experiments tended to begin to feed as the rest-house and huts, the first conspicuous object since leaving the bush, were approached.

The full distance that will be travelled has yet to be ascertained, but a barrier of a mile and a half and probably very much more would have to be cleared to obviate the likelihood of females crossing it, even on natives—at any rate when the fly was specially feeding on natives, as it seemed to be doing here. The experiment was useful also as indicating the special danger of leaving patches of bush standing near dwellings or segregation camps within following range.

A point best mentioned here, though it follows naturally on the concluding remarks of Section X (p. 332), is that my observations on this safari tended to convince me finally that while many tsetses leave a party entering open ground, those that are once carried well out into unsuitable country do not readily leave their carriers till cover is once more reached. The conclusion extended to the female of the present species, and is of importance in relation to the idea of a barrier clearing.

XIII.—DISTANCE OF ATTACK AND PROTECTION OF ROADS.

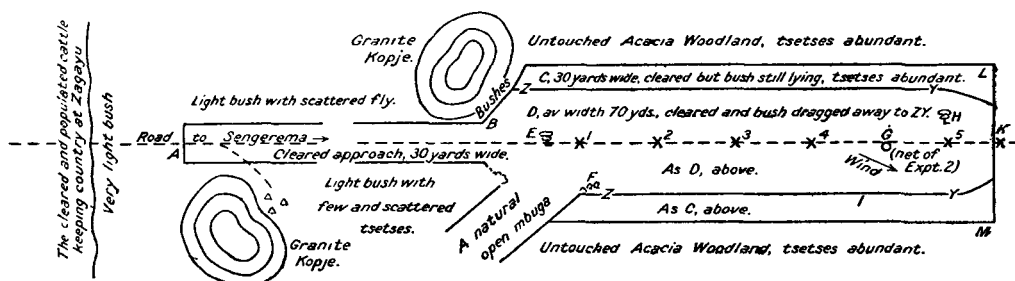
The provision of cleared high roads at the points where these are most required was one of the most urgently needed measures for the protection of the population from the infected fly. Experiments were therefore attempted with the object of ascertaining the necessary width of clearing. In order that the work should not be wasted and that no additional natives should be exposed to possible infection, they were carried out on a piece of road (Zagayu to Sengerema) that was about to be cleared by these people in any case as part of the scheme of control.

Experiment I.—Range of Attack across Cleared Ground.—It was planned to clear first to 50 yards on each side of the road and test, then to increase the width and test again, and so on till a conclusion should be reached. Owing to the miserable native tools it was impossible to complete this in the time at my disposal, and the actual experiment was as shown in the text figure.

From A to B, about 900 yards through lightly infested bushes, was cleared to a width of 30 yards to minimise the chance of picking up tsetses in travelling to the

experiment with numbers of natives and cattle. It proved useful, and an inspection took place at B to remove all remaining tsetse (I think one only was present). From B to K, the actual experiment, was 600 yards in length, a stretch of road on which tsetses had been abundant. The width of complete clearing (D) varied from 53 to 80 yards. E and H were solitary large acacias left uncut, each with a good clear stem. G was a large, white, conspicuous mosquito net in use for the second experiment I shall describe.

From two to three natives and two cattle were placed at each station shown above (E, G, H, K, and X, X, X). There were seven pairs in all, the last pair working X⁵, H and afterwards K. E and G cattle stayed where they were, but the X's occasionally moved to each other up and down the road or took up intermediate stations on it, some of them with a clear view to the bush owing to the grass having been destroyed by the dragging away of trees and shrubs, others in long grass.



Result.—The results at the stations varied in the most interesting manner. At E, a conspicuous mgongwa acacia just 80 yards from the nearest bushes (of the granite kopje on the one side and a few slightly out-jutting acacias at F on the other), flies of both sexes were taken steadily all day to the total number of 77. Yet X¹ close by, and sometimes moved closer, saw not one.

The catchers stationed at G, the conspicuous white mosquito net, also took flies steadily all day, as did acacia H and (in much greater numbers) post K on the road where it left the clearing. Yet X², X³ and X⁴ took none at all when stationed in long grass and only half a dozen in all when in view of the bush.

The fact that natives were working in the bush (though in two compact and localised parties) complicated the experiment by rendering it possible that they drew off or fed a number of flies that might otherwise have been attracted to the road, and the line of dragged-off trees (X to Y), while containing numerous tsetse, was obstructive to vision from the bush behind, but it seems likely even from this incomplete experiment :—

(1) That a clearing even of 70 yards on each side of a road would afford great protection when the grass is long, but is likely to be much less useful when it is short.

(2) That the period of long grass is probably for the fly a period of relative difficulty in finding food-animals. Here we have some slight experimental confirmation of a point to which Fiske and Duke have drawn attention.

(3) That both sexes of this tsetse range to some extent, flying to conspicuous objects such as isolated trees and (probably) rocks at a distance of not less than 80 yards in cleared country, perhaps much more. It follows from this that no trees, however clean-stemmed, must be left in a road-clearing. Also that the high, black-green euphorbia hedges that make the villages so conspicuous may be a disadvantage when the village is within one or two hundred yards of bush.

Experiment II. Range of Perception.—A wide mosquito net was erected at E and more than 300 flies turned into it, of both sexes. The idea was to pass a large number of men and cattle to windward and note up to what distance the tsetses would fly to that side of the net on receiving their scent.

Difficulty occurred owing to the fact that the tsetses persisted in congregating on the windward side of the net. Apparent reactions occurred at all distances from 30 to 150 yards when the party passed exactly to windward of the fly and no reaction at 200 yards, but I am not describing the experiment in detail, as I do not regard it as reliable, and I had, unfortunately, no opportunity of repeating it.

Against the indication that the fly attacks from far may be set the conditions at some of the watering-places of native cattle; for example, right up against tsetse-infested bush at Mtukuza and in the mbuga just north of Mount Sansui, though in each case with a sixty-yard fringe of open mgu trees with only occasional flies between the water and the mhali-and-thicket that really contained the tsetse. The natives stated that they dare not traverse this further distance with their cattle.

Distance of Attack through Bush.—Yet another set of observations suggested that attack may take place from quite a distance in bush, at any rate under the conditions of hunger apparently prevailing here. In my previous experiences of tsetses the few men at the head of the safari have had nearly all the flies. This by no means happened with the present tsetse, for on many occasions the middle or even the hindmost men had more tsetses than the leaders, and it seemed very much as though the flies were coming to us from considerable distances and, arriving late, swerved and followed up, alighting on the first man they reached. This was suggested also by the fact that in country in which we picked up merely occasional flies we often, by standing for some time, drew in tsetse after tsetse until the total for that one spot reached quite a large figure. All this was in bush, not mbuga, and there was nothing, therefore, to indicate what the distance might have been. On one occasion when I was standing in a mbuga 150 yards from the nearest bush two flies came to me, but there were a few small bushes in the mbuga that may have harboured them.

XIV.—MISCELLANEOUS NOTES.

1. Settling Habits.

The fly resembles *G. morsitans* in the fact that individuals move along in front of the traveller, settling before him on the road. In open spaces the flies on his back tend, when he halts, to distribute themselves on the ground about him.

2. Relation of Game and Cattle.

At the Mtukuza mbuga, two miles broad by possibly twice as many in length, which we worked to get an idea of the position at these natural open spaces haunted by game, occasional flies were taken up to 500 yards out in the ilula-clumps—more or less connected by a few bushes and small clumps with the main bush containing fly—but none at all in the open, though we put up topis, zebra and roan antelopes, and at once worked along, men and cattle, in their tracks. No puparia could be found at the water-hole, at which the game drank, in a small patch of acacia that included one or two large and shady trees. In this mbuga there are four small herds of cattle, living safely, their owners state, and those I saw certainly looking well, in close contact with the game and much attacked sometimes by Tabanids. The game is regarded as coming out and living—and sleeping—in the mbuga to escape the attentions of the tsetse in the bush, and the tsetses are said not to follow them into the mbuga unless in one and twos, as they “fear the hot sun.” The game retires to the shade of the clumps in the heat of the day.

From this and other evidence I judge that the danger to cattle from game wandering on to its pasture out of fly-infested bush will not be great, provided that the clumps of bush on the pasture are cleared or the cattle kept away from them.

While at Mtukuza I was told of two fly-surrounded mbugas near the Duma, at one of which (Inyamageni, stated to be much smaller than Mtukuza) cattle, it was alleged, had been kept in safety for many years; while at the other (Magerani) small losses were always taking place. At Manangwa Masalu's, on the Nasa littoral,

cattle were being farmed in a mere mile-wide strip, some of it going back to bush as the result of a reduction in the number of cattle. The position between the Mbarangeti and Rowana is still more curious, for here a very narrow clear strip exists between the Lake and a submarginal strip of fine mhali wooding, sheltering thickets in which *brevipalpis* is present and in which occasional *swynnertoni* appear. Yet cattle are kept there permanently, it is said, without loss, and looked well.

Instances occur also elsewhere in the territory of fairly successful cattle-keeping in diminutive, fly-surrounded open spaces. Safe water, avoidance of too close approach to the bush and avoidance of much-frequented paths and villages would seem to suffice; and it seems to follow from this also that the fly does not venture uncarried into open country unless to conspicuous objects within a limited range.

3. Banishment of Tsetse by Partial Clearing.

At Kilalo I saw the interesting phenomenon of the riddance of fly by *partial* clearing. Small areas of wooding were still present, but they were mostly in the valleys and cut off from each other by cultivated hill-tops and upper slopes. Several herds of cattle were present, and only occasional tsetses were said to be met with. It was said that twelve years ago the position with regard to the tsetse over most of the area was the reverse of what it is now. That is, the cultivated fields instead of the bush patches were the islands, and tsetses still inhabited this bush, which was also then more widely connected with the main infested wooding. In Tshasama's country also small areas of bush cut off from the main areas had become free of tsetse. At Kilalo *G. swynnertoni* is concerned, at Tshasama's *G. morsitans*.

4. Test of a Tsetsefuge.

Garlic, suggested by me previously (Bull. Ent. Res., xi, p. 380), was tested for me very fully on cattle by Mr. Tully, and proved a failure. An interesting point that came out well in the watching of the cattle used on this expedition and to which Mr. Tully drew attention was that, quite apart from considerations of colour, individual cattle are far more attacked by tsetses than are others.

5. Protection against Bites.

I dressed my more permanent tsetse-catchers in white clothing with long trousers. It was soon remarked by themselves and their companions that they drew few flies, and it was a matter of daily observation, when on the march, that dark colours and khaki attracted far more flies than white. Long trousers in themselves are not an absolute protection for the legs. I was bitten inside my helmet, through my clothes, and once by a fly that, in the tent at dusk, introduced itself into my trousers at the ankle and bit me inside the thigh. Again, white clothing becomes less protective when no alternative is present for the flies to go to.

A veil was tested on one or two occasions, but discarded as obscuring vision. It was a protection, but a discomfort.

XV.—THE KNOWN INFECTED AREA AND THE TSETSE APPARENTLY RESPONSIBLE FOR THE SPREAD OF THE INFECTION.

The infected section of the Usukuma fly-belt, in so far as it was known at the time of my departure, was bounded on its west and south-west by the western margin of the tsetse-infested acacia woodland area from Nyalikungu to Nung-hu, and on its east by the settled Zagayu-Luguru-Uhiro arc, with some infected villages outside of it. On the north it extended across to the Duma and crossed it, the Ngasamo-Kilalo-Nasa road being roughly the boundary here. An isolated small outbreak was reported from Bukumi just south of Ikoma, but I judge from an incidental reference in a letter that this proved not to be trypanosomiasis.

The infected section thus includes a considerable length of each of the two rivers mentioned and this, with the distribution of some of the cases, gave rise to the suspicion that the infection might be carried by *G. palpalis*. The people did much fishing, and it was possible that, meeting at the rivers in the course of this occupation, they were much bitten there by tsetses and infected. Certainly some small focus of this fly may exist on some reach of one or other river that has been missed by Maclean's search and mine, but this is unlikely, and it could not in any case account for the position. The villages in the tract between the rivers and many miles from either were infected with the rest, and the history of the epidemic, as given by the natives, showed that it travelled from village to village irrespective of any relation to rivers. It would also not account for the infection of women and children at a great distance from the rivers, and still less for the case of the young man I shall refer to below. He was blind, and there was every reason to credit the statement made of him that he had never previously left the neighbourhood, which was a considerable number of miles from the Simiyu.

Experimental evidence was still lacking when I left, but the circumstantial evidence was strong in favour of the view that *G. swynnertoni* was the responsible species. It was, as I have said, taken by my fly-boys in thousands in the paths and villages of the infected section, and was the only species of *Glossina* that could be found there at all.

XVI.—TYPES OF SLEEPING SICKNESS VILLAGES.

Village completely in the Bush.—A small triangle formed by native paths through high weeds. At each of two of its corners a hut, at the third two. A diminutive and dirty open space before each hut and a shade-tree at two of them. The general thorn forest—mgongwa and mhali acacias, with some *Albizzia hypoleuca* and much *Commiphora* thicket—extending right up to two sides of the triangle. The third side abutting on a limited open space of grass and weeds representing old cultivation, itself surrounded by the bush. A path leading through this and then through mgongwa-with-thicket wooding, past a granite kopje, in which we found puparia, to a water-hole in the bush. Another bush-path leading to the main piece of cultivation some distance off in the bush in another direction.

Fly fairly abundant in the thorn-bush near, but less so than in the village. Here it seemed concentrated and greatly at home. An old woman who appeared was accompanied in all her movements and domestic duties by tsetses of which she took little notice. A dozen or more at a time would be perched on her leather garments and her skin. A number followed her into her hut and remained there. One of my fly-boys went in and captured six. About and between the huts we were much attended, and a few fed successfully. Unfortunately it did not at once strike me to keep this catch separate or count the flies, but, out of five boys, one that counted from the start captured 35, and from the very late moment at which I ordered a separate catch, over 70 were taken. The total will not have been less than 200. A few *Haematopota* and *Tabanus* were present also.

One of the solitary huts was deserted. The woman had died of sleeping sickness and her husband, the headman, had gone; apparently it was not known whither, or whether he was infected. Of the four remaining inhabitants one man still well was away accompanying one of the others, a young man with sleeping sickness, to Dr. Maclean's nearest hospital; the old woman has been mentioned, and a younger woman "had been ill with malali but was now better, and had gone some days before to visit in Igombe." I found her bed had just been slept in—a probable case of concealment.

There is only one thing to be done with the inhabitants of a village of this kind. They are attended in every occupation of the day by tsetses—in their village, inside their huts, going to water and hoeing their fields. Let one of them become infected,

and he is bound in the course of a four to eight months' illness to infect many hundreds of tsetses ; and the infection of his fellow-villagers and the neighbourhood generally is only a matter of time and possibly of a very short time. Evacuation is necessary.

Village in a Mbuga.—A more compact village of several huts, some of them surrounded by a tall euphorbia hedge, the whole much cleaner and less overgrown than the last, standing a quarter of a mile from the bush in an open grassy mbuga. Other euphorbia-circles in the mbuga, some of them still containing villages. The mbuga surrounded by tsetse-haunted thorn bush. The river, in which much fishing is done, not far away, and the village itself close to the borders of the better game country. One of the outermost of the infected villages.

My first visit was by moonlight and no tsetses were seen. On my second, with Dr. Maclean, two tsetses were caught in the village, perhaps carried in by ourselves. It was stated that sometimes many tsetses are carried in from the bush, and from one result of the clearing experiment described above, it would seem that occasional tsetses might range out from the bush to so conspicuous an object as a large, black-green euphorbia hedge. The conditions in the village itself, however, are not ideal for direct transmission.

Three people, perhaps four, had already died of sleeping sickness in this village, and four others were sick, one of whom had come there sick from another village. One of the four, a little girl, was dying, and died next day, but was replaced at the second visit by her brother, who showed symptoms sufficiently suspicious to warrant an injection. Visits to a neighbouring infected village (further from the game and in the bush) were regarded as the source of the infection.

It would probably take comparatively little clearing to protect the people of a village of this type (of which there are many) from tsetse, if only they would then keep to the cleared area and cleared paths ; but the bush is all round, the temptations of the river and the game at their door are too great, and they are too far away from everyone for supervision.

Village in Cleared and Closely Settled Country.—A lane, more than half a mile long, flanked on both sides by a tall euphorbia hedge ; small millet fields up against it on the outside. At intervals on either side small openings leading directly into sub-villages, which are themselves surrounded and sometimes subdivided by similar shady euphorbia hedges reinforced closely with dry thorn to make them impervious to cattle and goats. The whole standing in cleared and open country. Several cases of sleeping sickness present, and a number of deaths already. *Ornithodoros* ticks and mosquitos present, but the possibility of direct transmission through these negated by the fact that except in one instance the cases were scattered, single members of families being infected and (except in the one instance) no hut-fellows. No tsetses could be found.

At its narrowest point the completely cleared country seemed to be half a mile wide, counting from the nearest end of the lane, itself nearly half a mile nearer than most of the cases. A large millet field belonging to the village then separated the grazed strip from country in which bush was beginning to grow up on the site of old occupation. In this was another village belonging to the same headman. There was much visiting between the two villages, one on each side of the millet and open ground, and tsetse were present in small numbers in the young scrub. A considerable distance farther on came the real thorn forest, with more numerous tsetse and an earlier infected village. The patients there had also been much visited by the members of the village I have described, and its infection was attributed to this, though the bush was visited also for firewood and building material, and doubtless for other purposes.

A few tsetses would be carried back on these occasions, but the scattered nature of the cases, referred to already, suggests that these tsetses carried into the villages

would have been a less important factor here than in (at least) the first village type I described, and that the victims probably became infected independently in visiting the area containing infected tsetse. It was hardly a "village epidemic."

The distance from the bush is here probably sufficient for future purposes in view of the fact that the country about is cleared and settled and supervisable, and that the highly infective bush villages will have been removed. The further remedy lies in the prevention of visits to the bush, the abandonment of fields that lie in the margin of the tsetse country or wide and complete clearing beyond them, and, possibly, the cutting back of the euphorbia hedge to a height at which it will still be serviceable for cattle but will not give shade.

Probably many of the villages to be evacuated will afterwards occupy the position of this village in relation to the bush, owing to congestion further in, and the prevention of the natives from visiting the bush is, temporarily, a matter of importance.

XVII.—DURATION AND COURSE OF THE INFECTION.

Possible Date and Original Locality.

There was a regular passage of natives for trading purposes between the now infected area and the Mori, Shirati and even Kavirondo before the war—that is, with areas involved in the original great *gambiense* outbreak—but the evidence to the time of my leaving Musoma seemed to place the beginnings of the Simiyu outbreak at a later date. The natives everywhere, as well as Messrs. Zimmerman and Buttler, of the Ngasamo Mine, stated that they were certain that the disease was not present before the war. Manangwa Salim, of Basheshi, who was with Von Lettow till the armistice, told me that subsequently to his return there was increasing talk of cases of "safula," or ankylostomiasis, for which the natives till lately mistook it, though the first cases of the present disease that he is himself sure of were observed three years ago at Igombe, where last year deaths were already particularly numerous.

Questioning of the chiefs elicited references to alleged early cases. Thus a Msikuma disbanded at the end of the war after serving first the Germans, then the British, is said to have then come straight to Luguru already showing sleeping sickness symptoms and to have died. He may have contracted infection on his way from Mwanza. At the beginning of 1919 a man from Kilehiji, four miles north of Luguru, on the edge of the bush, was taken to hospital in Mwanza by Sultan Mwanilanga with symptoms that, according to the Sultan, were completely identical with those of the present outbreak. The disease, however, does not seem to have been recognised as sleeping sickness in Mwanza, where he died shortly afterwards, after an illness that had lasted in all eight months. A man named (or from ?) Yikiji was said at Luguru to have contracted the disease four years ago and died two years later. Sultan Tobias, of Usmao, about fifty of whose people have died this and last year, spoke of the death last year, with sleeping sickness symptoms, of a woman who had been ill for three years. Several natives—and this seems much more important—stated that the first cases of what was then called "safula" (hookworm), but is now recognised as "malali" (trypanosomiasis), coincided with the end of the great famine of 1918.

Naturally, native diagnosis cannot be relied on, and some of these may not have been cases of trypanosomiasis, but the more prominent symptoms—the oedematous feet, dry skin, large appetite, distended stomach and growing emaciation—were a combination that is readily remarked and was always quoted, so that if no evidence to the contrary has been obtained since I left, the epidemic would appear quite likely to have started from five to six years ago. That it had already started at the beginning of 1918 is shown by the one really reliable piece of evidence available. Dr. A. Balfour tells me that in Mwanza, on 2nd April 1918, he found unusual numbers of trypanosomes—as numerous nearly as the red cells—in a slide made from the blood of a patient from Usmao who had died shortly before, which was submitted to him for confirmation by Capt. J. Currie.

Except for an old man who insisted that cases occurred even earlier in Usmao—just across the Simiyu from Igombe—natives everywhere regarded Igombe, near the Simiyu, as an early focus of the disease—"The first news came from Igombe"—and they traced its passage thence from village to village, naming each, until it came to their own neighbourhood, when their detailed account of its local course was simply a replica of the example I shall give below. I am rather impressed by the possibility that the infection occurred first in Usmao because the infested wooding there is on the border of a well populated piece of country. There were many people near its margins to come into contact with the tsetse, and, there being many people, the game would have been particularly heavily reduced, so that the tsetse might have been brought into exceptional dependence on man. It seems possible (and the special intensity of the infection may favour this view) that Capt. Currie's case (from Usmao) was amongst the earliest that occurred. The exact locality is, however, a mere matter of detail, for game had been greatly reduced throughout the area between Usmao and the Duma.

Mode of Spread of the Outbreak.

It was always easy to trace a sequence between any case and preceding cases. Thus a woman sick with "malali" came from Ndagalo and stayed at two villages near Nyasambi, at the second of which she died. Her presence was closely followed by cases at each village, and the people from neighbouring villages who regularly visited and sat with the sick, and attended the mourning, fell sick next and introduced the disease into their own villages, in which further cases then occurred. One of these cases taken to a clean village to be nursed introduced the disease there, and the occurrence of a beer-drink at that village, with many tsetses present, passed the disease on farther. This was the story everywhere.

Going to see the sick, and taking the sick in, seem to have been the commonest sources of infection recognised by the natives. One woman sick with "malali" in the Igombe area was said to have wandered for long from village to village, more or less demented, and at last to have died in the bush, having probably first infected numbers of tsetses and several villages. Business claimed its victims; a woman who went to a sick village in a neighbouring Sultanate to inspect some ground-nuts contracted the disease. After her return six other persons got it, and, of the seven, six were dead at the time of my visit to her village. Going to work—or stay—in Sengerema or Igombe was said to have brought the infection to several places to the south and west of them, and at least some of the Sengerema infections were said to have been due to the fact that many Igombe people, getting frightened, shifted over to that Sultanate.

Two native doctors at Turasi, practising among the victims, were stated to have contracted the infection themselves and died. Their methods were long series of incisions down the inside of the legs (of which we saw examples), massage and medicine by mouth.

Contact with the sick in villages was thus fully recognised by the natives as a mode of infection, though they had not realised the part played by the fly. In addition to these infections in villages there must have been many infected tsetses travelling with the natives on the paths and, if cyclical infection plays its part, present in the bush also.

Whenever a narrative came to a patient who migrated to a village well inside open country it stopped—"No one else got sick there."

Nevertheless, an exceptional number of cases had occurred apparently along the margins of the populated areas, such as that of the cleared strip of Luguru; no doubt, chiefly because it was here that the largest number of people were in contact with the fly. It may very well have been due also to the fact that game was scarcest there and the fly most dependent on man.

There was no indication of new and independent infections. Every case appeared traceable to contact with sick persons in the presence of tsetse. Man seemed now the sole reservoir, however the first infection arose.

The outbreak seemed already to have halted in its northward course at the time of our visit. Yet the northern barrier against the game, with which the check coincided, was, unlike the eastern, by no means of a nature to check the disease. Concealment (of which we obtained no evidence) and areas of more open woodland with fewer tsetse were two possible explanations of the fact that the disease had not appeared in villages into which, on the analogy of its previous history, it might already have been carried again and again; but it was strange that cases should be concealed more here than elsewhere. The check did, however, coincide with two other changes: game was present in fair numbers and baboons were numerous, and (a consequence of this) an equality in the sexes of the tsetse, with local excesses of females, had been succeeded by a general great excess of males. In any case (*cf.* the footnote on p. 351, and the instance of the Luangwa valley) there is no reason why odd cases should not occur in game country, and these will doubtless yet be found.

XVIII.—THE FACILITIES FOR DIRECT TRANSMISSION.

Comparison with the Conditions under which Direct Transmission spreads Nagana.

For the spread of trypanosomiasis in a herd of cattle by means of direct transmission a heavy infestation by the flies appears necessary (as in the great October–December outburst of *TABANIDAE*), combined with close contact amongst the cattle; and the result, as I have seen myself, varies from no or few infections to heavy infection. Chambers records (*Vet. Review*, i, 1917, p. 222) an instance in which 280 cattle out of 300 died as a result of the introduction of three infected beasts in tsetse-free country.

With the flies few or the temperature low it may be that the cattle resist the occasional trypanosomes injected, but under the October–December conditions, with hundreds of flies, constantly disturbed, to every animal, individual beasts, few or many, may even through dint of sheer repeated biting receive some approach to the number of trypanosomes that, after cyclical development, fill the proboscis of a tsetse.

In view of Duke's most illuminating suggestion (*Parasitology*, xi, 31st Oct., 1919) that direct transmission by *G. palpalis* may play a very important rôle in human epidemic trypanosomiasis of the *gambiense* type, it is interesting to enquire whether the conditions under which mechanical transmission produces outbreaks in herds of cattle ever exist for man in relation to infection that is carried by flies of the *morsitans* group.

The *TABANIDAE* may, I think, be ruled out at once as an important factor. They attack man but seldom in anything approaching the numbers in which tsetse very ordinarily come to him, and they also relatively seldom succeed in sucking blood. The same, in somewhat less degree, applies to *Stomoxys*.

On the other hand, the tsetse *G. morsitans* and *G. swynnertoni* do attack man—seldom, unless he is on a bicycle or a car, quite in the numbers in which the October Tabanids swarm on cattle, yet often in very considerable numbers indeed. They have fewer individuals among whom to divide their attentions than have the Tabanids in the cattle-kraal, and they are individually exceedingly persistent, so that even half a dozen of them, not feeding seriously or often driven off, might transfer many trypanosomes directly in the course of half an hour from a sick person to a friend sitting chatting beside him, or as between the members of a party travelling. Tsetse, again, tend to be present in greater or less numbers for many more months than the *TABANIDAE*, and the fact that an infected person takes a few months to die will bridge any ordinary gap.

Conditions under which Tsetses of the *morsilans* Group concentrate on Man.

Observations here and elsewhere in the territory show that concentrations, large or small, of tsetses that are indicated by the proportion of the sexes to be concentrating their attention on man are caused by the relative absence of game and by nothing else. With game absent, they may take place at villages, particularly perhaps near primary or secondary centres, and along paths, on travelling parties, and at the more suitable patches of bush crossed by the paths, as at water-holes, streams, and particular thickets and vleis; for at such places (as we have seen, p. 332) flies are apt to leave their carriers, at such places they tend to persist in smaller or greater numbers throughout the year, and at water-holes and streams the natives themselves (each party carrying in an accession of flies) break their journey to drink or cook their food or to rest, and sit with other natives who have preceded or followed or met them there, while all are bitten repeatedly by the same tsetses. In game country concentrations of the particular kind referred to do not take place, except very temporarily or incompletely. Thus tsetses may attach themselves specially to passing man for a week or two only, after a grass fire, or when, near the end of the long grass period, game is attracted away to early "burns." At the long grass season natives leave the paths less and so probably come into contact with far fewer tsetses, but those flies that once come to them may tend to remain on the paths and in the villages owing to the fact that, with the grass long, they will not easily detect other prey by sight. That they may detect them otherwise was suggested by the way a succession of tsetses would sometimes find their way to us singly, until a large number had collected, when we stood still for long in one place. I think that these minor types of concentration may be disregarded, except where actual sleeping sickness or conditions specially favourable to it (such as famine and game destruction) are present. Here they might act as accentuating factors. Most of the cases of sleeping sickness enumerated by natives were described as having taken place either "at hoeing time" (two months after grass-burning), or when the crops were sprouting (temperature rising and flies abundant), or at "Ramadhan" (the date of which, retrogressing each year, has probably travelled during this outbreak from September to May). It is interesting to note also that of the first two dates referred to, the first coincides with and the second shortly follows the usual climax of the beer-drinking season.

This brings me to the point that, whatever small part may be played by the game, no one who has observed the habits of the natives can well regard man as other than the chief or only reservoir in any human trypanosome infection. Sick natives—even very sick natives—spend much of their time outside the huts with children playing near them, women stamping grain or grinding and preparing food beside them, men sitting about (sometimes for hours) occupied or idling. People drop in from neighbouring villages or (particularly on a main road) pass through in travelling and—an important habit from South Africa to Tanganyika Territory—they stop, sit down with the inhabitants, and give their news and receive that of the locality over a platter of food that seems always ready for production and round which the men of the village also crowd, each person dipping in his hand in turn while the same tsetses bite all. This habit of stopping to exchange news—indulged in always, even on the open road—is one main factor. Another is the beer-drink, which, in great part, and in some tribes more than others, takes place outside the huts and in the day-time. Travellers tend to stop at a village in any case, but if a beer-drink should be taking place there or in a village near (and it can always be heard from a distance), they stop often for hours or for the period of its duration, which may be three days, and, crowded densely round the beer-pots, come into intimate and continuous contact with the population of all the villages round—invited wholesale to assist in the hoeing of his garden that has constituted the owner's object in brewing the beer. The same thing happens at the next village and the next, for the hoeing season (at and following which, according to the

above information from the natives, so many infections took place) is often simply a round of beer-drinks, with the same tsetses biting all partakers at each. Beer-drinking recrudescens later when the new crop is felt to be such a certainty as to justify the use for beer of the store-grain, gains force with the final harvesting of the crop (that is, in July), and shortly afterwards again attains its maximum intensity with the arrival of the hoeing season. In real famine there are no beer-drinks, but I have myself seen them become all the rage when the first crop after a famine or semi-famine was reaped. People then simply gave themselves over to them. And this, with infection well established through the aid of the famine, is the very time that is critical as regards its further spread in localities in which the tsetses are concentrating on man. A third meeting-place is the water-hole, at which members of many surrounding villages tend to congregate when drawing water, washing, or carrying out some parts of the process of preparing beer. Water-holes and fords on roads have been referred to as a factor elsewhere. A fourth important factor is the caravans, travelling closely in single file, with one member perhaps infected or the tsetses from an infected village they have passed through accompanying them. A fifth, important only on lakes and large rivers and usually unimportant as regards flies of the *morsitans* group, is one to which Duke has drawn attention—canoes and landing-places. Finally, there are such occupations as hoeing and threshing. Here, as at the beer-drinks and round the food-dish, the participants are crowded as closely as cattle in the cattle-kraal. The flies may be switched off frequently, but settle again at once on somebody, and a highly occupied man or woman, and particularly a drunk or fuddled person, takes little serious notice of them.

People who are not yet very sick take part in the ordinary occupations of the community. The very sick—except those in the last stages of weakness—spend, as I have said, much time in sitting or lying outside, near the other members of the village if they are present, being specially visited and sat with by their friends and relations of the surrounding villages and by passers-by, who are brought to see and discuss their symptoms and (in the Usukuma outbreak) to prod the oedematous parts. This last quaint point was volunteered by several of the natives I spoke to in the sleeping sickness area and appeared almost to be regarded by some of them as a cause of the infection. Also the sick take part in, or lie near, the crowded beer-drinks. And the tsetses, in an infested bush village, enter the huts. My experience, extending over more than twenty years, of the habits of the sick African in his home is concerned with other diseases than sleeping sickness, but I saw nothing amongst the relatively few sick I found still in their villages during my visit to make me regard sleeping sickness patients as an exception and heard much which showed that they were not, and I wish to lay particular stress on this usual relation of the sick to the well, and on the resulting fact that every case, through much of its course, of *rhodesiense*, as of *gambiense*, may form an important reservoir of the disease.

Famine vastly increases contact both within a given area and as between that area and those surrounding it. In the one considerable famine of my own experience even the decrepit and nearly dying struggled through the country trying to buy, beg or work for food, and inhabitants of villages from far around would meet at spots in which wild yams, mushrooms, certain wild vegetables or the fruits of *Uapaca* were specially to be found, and they might be seen sitting and digging together at the clumps of yams.

The concentration of the flies in the village I described first in Section XVI was somewhat heavier than at any other bush village I entered, and distinctly heavier than in the bush around, but it was sufficiently typical, and it is obvious that there was every possibility of direct transmission between the inhabitants, and between the sick and their visitors from neighbouring villages, who would often sit with them for hours; and that the relations between man and tsetse were everywhere such that direct transmission might quite well have played an important part in this

epidemic. The danger of direct transmission of human trypanosomiasis is, as I saw clearly, by no means limited, however few the trypanosomes in the peripheral blood—and in some of the cases examined by Maclean while I was with him they were numerous—as, I understand, is the rule in infection with *T. rhodesiense*; and it seems easy to understand how, under conditions so favourable to intensive direct transmission, the pathogenicity of the trypanosome might mount rapidly and bring about the well-known special virulence of early cases, taking place before any diminution of the fly, recovery of the game, extension into areas in which game was to some extent present, or more orthodox attenuating factors came into play.

The presence of abundant mosquitos in the settled country, combined with the alleged absence there of infections, might seem an argument against mechanical transmission. On the other hand, I know of no cases or records from which it seems likely that mosquitos have transmitted nagana of cattle, and it is possible that for mechanical reasons, or (perhaps far-fetched) as a matter of temperature, the night-biting mosquitos that alone were present in number may be less efficient transmitters of trypanosomes than the tsetses and Tabanids or than the two day-biting genera of mosquitos (*Stegomyia* and *Mansonioides*) that I believe are especially suspected by French investigators.

A further criticism might be to the effect that the European rarely comes into the intimate contact with sick natives in the presence of tsetses that I have described, and wears clothes, yet cases of trypanosomiasis in Europeans are not infrequent. Against this it may be said that it is not argued that cyclical transmission is not also a factor (and, if the disease is purely human, a highly important one); and, in addition, the question of the relative susceptibility of the races has never been adequately studied. The aggregate sojourn of white men in sleeping sickness foci is infinitesimal compared with that of the natives, yet even where only a rare native becomes ill Europeans have contracted the disease, though their porters have apparently escaped.

XIX.—THE RELATION OF THE GAME TO THE OUTBREAK.

The oedema that was commonly present and the identity of the insect vector suggest that the infection was one of *T. rhodesiense*, and even the rather long duration of the cases that told against this view is explicable on the fact that the epidemic had already lasted some years; but a decision on the point was lacking when I left, and several theories were still tenable as to the origin of the outbreak.

If the Trypanosome is *T. gambiense*.

It seemed to us at the time of our investigation quite probable that the outbreak had been initiated by some infected person or persons with the Belgian or British forces that collected here to attack Neumann in 1917 when he broke back from the south of the territory to Ikoma.

A portion of this force, which included numerous carriers from Uganda who accompanied the Belgians, was landed at points nearer to Ikoma. Another portion was stated definitely by the chiefs and other natives to have passed through and camped in the villages of Igombe, Luguru and other parts of the country now infected “at the time of the ripening of the crops,” and further contact with the inhabitants was established through the fact that the latter also were impressed as carriers and marched with the imported carriers.

On the other hand, the disease may have lingered unknown in some spot in our own territory since the great epidemic on the Victoria Nyanza. There was much movement of the Wasukuma people in 1917 and 1918, as I shall describe below; and this, or the wandering of infected individuals from elsewhere, may have brought them in contact with infection.

The disease has continued to exist in Kavirondo ever since the great outbreak on the Lake. A report by Dr. Johnston, dated 5th May 1922, states that in middle Kavirondo a case or two is present in practically every location, though the majority are in the Lake shore areas, and I was told by himself and others that the position was certainly not better in south Kavirondo. Infection thence represents a third alternative.

Should our trypanosome be *gambiense*, actual or convertible into *rhodesiense*, the fact that the disease can be freely carried by a fly of the *morsitans* group would turn the position in Kavirondo, if it should continue, into a menace to the great territories to its south.

If the Parasite is *T. rhodesiense*.

In this case, which seems more likely, three further theories of origin arise: (a) that it was introduced into Usukuma as a human trypanosome by the movements of man in the war, for example, from the South, in Neumann's incursion, or from the Congo by the Belgians. There is no apparent reason why *T. rhodesiense*, just recorded from the Sudan, should not exist in the appropriate areas in the Congo;* (b) that it had been present all the time as a specific trypanosome pathogenic to man, which, in spite of the distributional evidence to the contrary obtained in the war, is widely spread in *morsitans* areas at every latitude in which temperature conditions are favourable to its development, but tends to be overlooked so long as cases are few; or (c) that it is simply a strain that may arise from *T. brucei* of game, temperature and other conditions being suitable, in any place in which the latter trypanosome is present and heavy and continuous concentration of tsetse is taking place in relation to man.

Whatever theory of origin is correct—and on this I express no opinion—what caused the infection to grow into an epidemic in this particular place?

Duke has suggested that direct transmission may play the all-important part—we cannot perhaps yet say the only part—in producing and maintaining a virulent strain of trypanosome in nature, as under experimental conditions, and I have shown that in this outbreak a position favourable to direct transmission, as also probably to transmission, direct and cyclical, that would be almost confined to man, existed in the fact that the human population was being specially and continuously attacked by *Glossina* as a result, undoubtedly, of a previous destruction of game, and that the greatest destruction, and therefore the greatest concentration, had in all probability coincided rather particularly with the locality (Usmao and Igombe) in which the outbreak appears first to have assumed serious epidemic form. But game destruction and special attacks on man have taken place locally in parts of the territory in which, nevertheless, so far as we know, no outbreak of human trypanosomiasis has followed.

Coincidental factors seem to complete the explanation. Thus in 1917 the bush-dwelling Bagwe (Wasukuma) were brought into contact with the heterogeneous collection of humanity that accompanied the Ikoma pursuit and were much scattered,

* While correcting the proofs of this paper I have been shown by Dr. Newham a war-time report (I believe unpublished) by Wolff, the German investigator, in which the following passage occurs: "The large bodies of troops and porters have carried infection to districts formerly unaffected. I discovered three sleeping sickness patients in Mwanza District among a small number of Belgian askaris who were prisoners of war, and of these one reported that he was infected with his illness and had already been treated for it in the Congo territory. These people had brought their sleeping sickness with them from the Congo and come there in a condition to infect other districts. After this demonstration it must be admitted that a considerable number of the Belgian natives will have carried the disease through a large portion of German East Africa. All prevention and control have ceased since the beginning of the war."

The period of the war at which these prisoners were taken is not indicated (Neumann took Belgian prisoners), nor is anything said of the trypanosome, but the record is valuable and suggestive nevertheless. It also reinforces my argument in Sect. XX.

both as carriers and to avoid carrying, and were also probably exhausted by excessive portage. So, possibly, were some of their fellow-porters who may have been carriers of trypanosomes. In 1918, and probably already in 1917, the Neumann operations having reduced food supplies and prevented hoeing, the people were scattered by a famine for the second time over the face of the country seeking food, and came into fuller contact than ever with surrounding peoples. Influenza also swept through the area, and smallpox through a portion of it. Additional game extermination took place in the neighbourhood of the larger populations in which the game was greatly reduced already.

It is stated by natives that cases with the sleeping sickness symptoms were first noted at the end of the famine (when, to judge from the date of Capt. Currie's observation, they were probably already numerous), and it is probable (a) that a trypanosome or strain of trypanosome actually or potentially pathogenic to man had been introduced from one of the various sources I have indicated above or was already present in the area; (b) that first their other hardships and then the famine had weakened the people's power of destroying the injected trypanosomes (the great Busoga epidemic similarly accompanied a severe famine); (c) that out of several localities in which this trypanosome was present and might have caused trouble had it not been for the fly-diverting, virulence-controlling presence of game, it did actually first spread and establish its full virulence in one of them—eventually for relatively undebilitated man. In that locality, between Ušmao and Ngasamo, game having been greatly reduced, the fly was devoting that special attention to human beings that we ourselves noted in this more gameless area, and that it always does devote to human beings when deprived of other food.

Famine and game destruction appear to be the most dangerous combination. They tend to occur together, for game destruction by natives takes place rather specially during famine, but the destruction in the Simiyu area was probably exceptional. Game destruction was taking place in that locality especially for years before the war; it was doubtless accentuated by the relaxation of attempts at game preservation during the war; it would have been reinforced by the killing indulged in by that portion of the Belgian expedition which passed through this country; wherever I have travelled in the west of the territory, the destruction of game by the Belgian forces has been described to me by the natives as something quite exceptional; and it would have reached its climax finally, in relation to any game that remained, during the famine as the result of hunger and movement. And all this destruction, while it was not entirely confined to the area between Ušmao and the Duma, was exceptionally effective there because this region bordered on the areas of heaviest population, and was with difficulty reached and replenished by the annual game movements. I have shown that the position was very nearly indeed that which would have been brought about had anyone enclosed a piece of country with a nearly game-proof fence and killed most of the game inside it, while leaving the human population exposed to the attacks of the tsetse. The game, it seems certain, had already increased between the famine and my visit, particularly on the Duma, yet, even so, it was very scarce as compared with the game about Nasa and beyond Ngasamo, and this difference was still being strongly reflected in the habits of the tsetses.

Whether *T. brucei* of the game then became converted into *T. rhodesiense* of man, or a human trypanosome that was present in the game or in some human carrier who lived in or visited the area secured vectors and an enhanced virulence, it was clear later that, once the initial catastrophe has occurred, man becomes very definitely the reservoir and the vertebrate disseminator. On the *brucei* view (as modified by Taute's results and Duke's suggestions) a human infect, carrying a parasite that is already virulent for man, must in any case be far more dangerous than a game animal, for the parasites in the blood of the latter would seem likely to require some passages through man, probably by means of direct transmission and perhaps at

first through debilitated persons, in order to attain the same specific virulence and produce the disease. Taute's evidence shows that it is vastly more likely that the Lindi-Kilwa foci were set going by infected man from the Rovuma or Lujenda than that each arose independently from local *brucei* infection. And it would seem perfectly probable, though not necessary, that the Usukuma outbreak itself arose in the same way from man-borne infection.

Density of Fly not in itself a Cause.

- A point that seems clear is that mere density of the fly, as such, has nothing to do with the incidence of human trypanosomiasis. In other places in the territory the fly (to judge from the evidence of the puparia) is just as numerous, yet in these, so far as we know, there is no sleeping sickness. The fly in the latter areas is living largely on game (as the proportions of the sexes show strongly), so that the fly that bites a man now will next bite a zebra, and though males—and many males—may temporarily follow a caravan, there is little intensive feeding; whereas the fly on the Simiyu was quite largely living on man, obtaining feed after feed from man possibly for weeks (as the proportions of the sexes again suggest), because the game in that place had been reduced. From this, on Duke's view, would have followed a development or an elevation of specific virulence, a conquest of man's usual resistance to trypanosomiasis and, if all other circumstances favoured it, an epidemic. It is continuous density in relation to man that matters, and ready feeding, and these depend entirely on the presence or absence of game.

Density of Population unessential.

Nor does massed population seem completely necessary for the propagation of an epidemic—I do not say of a great epidemic, for an epidemic needs fuel in order to grow great. In this instance we had small, family villages scattered through the woodland widely or closely, but not densely. All, then, that is needed apparently in this respect, is that villages, large or small, should lie so near as not to preclude ordinary social contact, and that the fly should, in considerable numbers, be devoting its special attention to man. It is true that where an adequate enforcement of the game laws is absent, great population means great game destruction and special concentration by the fly on man.

In relation to a fly that likes man as well as it likes other animals, a population of man that has locally merely outstripped that of the other food-animals in availability might, without any complete destruction of the latter, attract the fly rather specially to itself. The matter would be relative. This may be the position in relation to *G. palpalis* everywhere or in particular localities, and I am convinced that it could be the position as regards *G. swynnertoni* were it not that population in this case means clearing of bush and reduction of fly. It may, I think, be said that the extent to which a given species will attack man decides whether that species will act as a vector, and, secondly, that the length of time during which a fly that will fairly readily attack man is led by circumstances to concentrate on man will perhaps decide whether, in a given locality, the result will consist in isolated cases and small foci or (with debilitation at first present?) an epidemic. *G. brevipalpis* and *G. austeni* will probably never, in practice, carry human trypanosomiasis. *G. pallidipes*, also, to a vastly greater extent than *morsitans*, is a wild-mammal fly and is unlikely to become of importance, though the relation, if any, of the adjoining *pallidipes* belt to the sleeping sickness outbreak associated with *G. palpalis* on the two rivers in south Kavirondo is worth investigating. *G. morsitans*, with human infection present, will probably produce occasional cases, even where extremely localised game removal, as along a road or as a result of local heavy shooting, makes it concentrate on man, and would produce an epidemic under the conditions

existing on the Simiyu ; while *G. swynnertoni*, now very much a " man " fly, and strains, at least, of *palpalis*, might, theoretically, produce the disease merely where man is so very much more available than the game that it becomes easier to prey on him.

Corroborative Observations from other Sources.

Taute and Huber specially state of the roadside foci of human trypanosomiasis behind Kilwa and Lindi and further south the most interesting fact that they were confined to water-holes and river-banks that were the halting-places for Yao labourers passing from the southern infected foci to the Lindi-Kilwa plantations, and that cases did not occur in the surrounding country ; and they remark that one of them, the Kilwa (Kilimila) water-hole, was not on the main road used by the local population but on a deviation particularly used by these labourers from the infected area. *G. morsitans* is stated to have been abundant at and around the water-hole, and it is likely that we have in each of these instances a case of the introduction of man-borne infection into the main human meeting-places on roads on which the fly was concentrating much on man. Taute mentions also (Minutes of Evidence taken by the Interdepartmental Committee on Sleeping Sickness, 1913-14, p. 231) that the sleeping sickness districts of German East Africa were in general ones that were not very rich in game, and (in another place) he quite correctly lays stress on the fact that *morsitans* is not merely a game fly, but a man fly also, and that it will make man its chief blood supplier after the shooting-off of all antelopes. Shircore, in one of his very excellent contributions to the subject of the tsetse problem, has referred to the concentrations of the fly that in Nyasaland collect round villages in forest and on the paths between villages, " so that the villagers are constantly fed on for the greater part of the year by these flies, both in and every time they leave or return to their villages " (Minutes of Evidence, p. 274). I understand that he refers to the sleeping sickness area.

May (*op. cit.*, p. 214) states, " The majority of cases have been found in the vicinity of main traffic routes (game is generally less abundant in the vicinity of these routes than in many other localities . . . where the disease is absent or rarely found), this lending some support to the view that it is transmitted from man to man rather than that game is the chief reservoir. This occurrence of the disease along the main traffic routes is so marked," etc. Still speaking of Northern Rhodesia, he goes on to suggest that " taking into consideration the scattered nature of the population, the disease might remain for years, if not indefinitely, endemic ; slight local exacerbations from time to time being accounted for by some such circumstances as increased opportunity of infection for the fly " [*e.g.*, by concentration due to game removal.—C. F. M. S.]. He attributes the larger number of cases in Nyasaland " to the much greater density of the native population along the shores of Lake Nyasa and consequent increased opportunity for infection and transmission." That even famine, by itself, will not necessarily lead to the development into epidemic or sporadic human trypanosomiasis of the Nyasaland type is shown by Kinghorn's statement (*op. cit.*, p. 259) as to the trying years 1911-13 in Northern Rhodesia. This might suggest that the disease was endemic in the latter country, but that Usukuma was virgin ground, or, more likely, that the famine in Rhodesia did not coincide to the same extent as on the Simiyu with a marked diminution of the game and a widespread and lasting concentration of tsetse on man. Both May and Kinghorn draw attention to the retrogression of the disease in Rhodesia " although all the conditions favourable to its spread, viz., *an abundant reservoir* " [the game—the italics are mine], " an ubiquitous and plentiful vector and lowered vitality among the natives, have been present " (Kinghorn). May in his evidence before the Committee (p. 211) gives an instance of a traction-engine road (from the Kansanshi Mine into Belgian territory) on which practically no game had been seen for two years, yet tsetse

(*morsitans*) were, day after day throughout the journey, most plentiful and most vicious. There was very extensive traffic on the road, and Dr. May believed that the fly was subsisting on man. In this case no sleeping sickness had resulted, but the elevation was 5,000 feet and over, and the result in this place of the removal of the game would appear to give us the key to all the previously quoted observations.

Passing to *T. gambiense*, we may note that more than one observer mentions the relative lack of game in the sleeping sickness areas of the Congo, and that Roubaud associates the most intense infection with the greatest lack of game and with special concentration on man by *G. palpalis* (*op. cit.*, p. 226). He also suggests the utility of enquiring whether, in those regions in which Nyasaland sleeping sickness is present, *G. morsitans* does not live in closer intimacy with man than it does in other inhabited areas. I would substitute "localities," "roads" or even "villages," for "regions" in an area like the Luangwa valley in which the disease is sporadic. Roubaud suggests the existence of local races of *Glossina* that have become specially sensitive to infection by a given virus—a point to consider in relation to our Usukuma outbreak. Bouffard mentions small endemic centres of the disease in the French Sudan in which game is definitely absent while tsetse flies are everywhere present, but believes that in the vast belts of the Banifing and the Black Volta some wild animal, perhaps hippopotamus, supplies the infection to man. Yet his observations as given, to the effect that the danger of infection, amounting almost to certainty, is confined to the two or three months of the year during which antelopes are precluded from coming to the river and the concentration and eagerness of the fly in relation to man become extraordinary, suggest to the reader that the infection may be brought about by intense direct transmission as between the members of the boat-crews should any one amongst them be a carrier of the trypanosome. Dalziel (*op. cit.*, p. 251) states of the Munshi tribe in Northern Nigeria that they "have not exterminated, indeed, but greatly reduced the number of wild animals. Tsetse flies abound, however, and in certain localities sleeping sickness is endemic." In this particular case partly immune dwarf cattle are regarded as possibly forming a reservoir, but it may be that without them matters would be worse. Finally may be mentioned the records as to the scarcity of game on the shores of Lake Victoria that were devastated by the epidemic. It would be of interest to know whether as the result of the Busoga famine the natives had greatly reduced any important food-animal of the fly and so intensified its concentration on themselves. Mr. Hobley tells me that the dearth of mammals in Kavirondo was extraordinary.

These latter observations refer to a different fly and a trypanosome that is now more resistant to human serum than is *T. rhodesiense*; but the knowledge that man is the all-important reservoir in the west renders it advisable that we should apply the logician's "razor of Occam" to the case of the sister disease before we give weight to alternative hypotheses.

Probable Utility of the Game.

The definitely mentioned failure to find sleeping sickness away from the much-used labourers' route in Taute's foci, the absence of known sleeping sickness on certain roads much crossed by game in Tanganyika Territory—not that this line of evidence can yet be regarded as secure—May's evidence, and the general facts of the Usukuma outbreak, suggest that the trypanosome does not gain and may not keep up its full infectivity for man in places in which the fly does not depend, or ceases to depend, on man for its food; further, that man, at least for all practical purposes, is the only reservoir; and that in either case an epidemic, once started, is likely to cease to spread as an epidemic when it comes into definite contact with a game population that is sufficient to break freely the continuity of the attendance of the fly on man, and reduce its avidity, though very local reductions of the game might

be accompanied by occasional cases* which, as the potential first cases in a possible epidemic and for the cause referred to on p. 345, would be particularly virulent individually.

The presence of game would thus be protective to man. It was impossible to resist this conclusion when, in and north of Nasa, I obtained my final information and evidence on the distribution and movements of the game and a continuance of the striking evidence that was being afforded by the fly itself. I had already seen *G. morsitans* concentrate on man during very temporary absences of game, but the Usukuma evidence suggested a next step, that, in relation to a fly closely allied to *G. morsitans*, man is capable of replacing the destroyed game as a main source of food-supply; and further, that such a position may, in point of fact, lead to an epidemic of sleeping sickness. On propounding this conclusion (as to the utility of the game) in Entebbe, I was most interested to hear from Dr. Duke that he had arrived at the same view as a result of observations in Uganda and had published it in a number of "The Field" which I had not seen. I am glad to have been able to confirm his view, and I think it is of particular interest that the conclusion should have been reached in relation to two very different tsetse-flies, two very different game faunas, two native populations with quite different habits—one of lake fishermen, the other of people with inland pursuits—probably two different trypanosomes, and from the two different standpoints of protozoology and entomology.

XX.—POSSIBILITIES OF SPREAD.

Both the details of the spread of the Usukuma outbreak and those I have quoted as recorded by Taute suggest that sleeping sickness, once set going, is capable, through the agency of human beings who travel or are visited in the presence of tsetse, of spreading and reproducing itself in places and under conditions in which the fly is paying special attention to man, but in which, nevertheless, the disease had never been able to make a first start while it lacked this special infection by man. Further, the Kilwa water-hole focus, infected (it seemed certain) by the travelling Yaos, was, as Taute states, not less than 150 miles from the infection on the Rovuma and much further from what was regarded by the German workers on the Rovuma as the original source of that infection—namely, Mwembe or Kumembe, a thickly populated area of the Lujenda valley. It becomes, therefore, of the utmost importance to study the larger movements of the natives with a view to their judicious control, and to carry out a most thorough search for sleeping sickness through the west and south of the territory.

It is certain that we cannot know the position to-day as regards the distribution of infection. In view (1) of the Belgian occupation of the west of the country during and since the war, with its recorded introduction of infects and its alleged exceptional destruction of game; (2) of the fact that traffic exists between the infected Usukuma area and Uzinza, the fly belt south of Eyasi and elsewhere; (3) of the fact that foci of *T. gambiense* infection existed in the territory itself till fairly shortly before the war, and of *T. rhodesiense* still later; (4) of the general movements of men in the war, and (5) of the fact that Usukuma was not the only area which suffered during the war from famine, heavy portorage and game disturbance and destruction such as might conduce to heightening of virulence in any appropriate trypanosomes present; it will be surprising if we do not find foci of sleeping sickness of one or other kind existing to-day in the great *Brachystegia* belts, infested with tsetse, that extend

* With a trypanosome pathogenic to man already present, any bite from a fly which had shortly before bitten an infected person and picked up trypanosomes might be expected to be capable of infecting a sufficiently susceptible person; and it is possible that such infections, and infections of a cyclical nature, often take place with game present; but the persistent biting by many flies that results from hunger in the absence of game would render infection more likely even for the probably somewhat resistant native by greatly increasing the number of trypanosomes injected.

from west of Mwanza Gulf far south through Tabora to Lake Tanganyika, and in the south. The Usukuma instance and similar instances of undetected outbreaks under the Germans show clearly how easily such matters may be overlooked, and it is known that sleeping sickness increased during the war in the French and Belgian colonies.

Trade and game are the chief factors causing movement from and through the Usukuma infected area, though numbers of natives go also to seek work in Kenya and some to the coast. There is a regular movement to the Uzinza tsetse area to buy hoes, and the natives stay there in the tsetse-haunted bush and work to pay for their hoes. Many go to the south end of Lake Eyasi to dig salt, and they carry this and tobacco not merely to their own country but to Shirati and Ukerewe and elsewhere to sell, to Ikoma to exchange for wildebeest skins and tails, and to the Mbarangeti to exchange for fish. Thither also the Wantusu go to fish.

The hairs of the wildebeest tails are used as cores for twisted wire bracelets for their toughness and flexibility, and are so much in demand that it is said that even natives from Tabora, Chinyanga and Uzinza go to the Ikoma country to buy them from the hunting tribes there, and pass through the infected Sultanates in doing so. They also attract natives from the infected areas of the north, and a capture was recently made near Ikoma of 43 wildebeest tails in the possession of four Wakavirondo from the Kenya border, who had bought them at Ikoma and were taking them home to sell.

A movement of cattle, present or past, was spoken of from Busia in the Chinyanga district to the Masai country to exchange breeding stock for oxen, which were then taken to Tabora to be sold for slaughter. It is interesting that it should be possible to take cattle through Itilima and Ututwa (this being the route indicated) without so many becoming infected as to make the loss prohibitive.

Finally, there are the members of outside tribes who have settled amongst the Bagwe or Wasukuma, and who by their intercourse with each other and the main tribe may spread the disease. The Washashi, with their headquarters in Musoma, are to be found in some numbers throughout, having been scattered, their Sultan told me, by famine. The wild, dwarfish Wahi or Bahi, of south Meatu, are purely hunters; they follow the game in its movements, but they are also said to visit the settlements to their north and those of Chinyanga to their west to exchange rhinoceros horns, skins, tails and honey for food, and they appear (from rather doubtful native statement) to have a branch beyond Eyasi. The Wataturu of the upper Simiyu region are said to have constant intercourse with their branch south of Lake Eyasi and to pass through the fly area near Lake Eyasi.

The movements of the game are of importance both because they are followed by the hunters, who, in this country and particularly perhaps in Musoma, appear to comprise a very large proportion of the native population, and because if the parasite is one that can retain its virulence after passage through game-animals, these may themselves become infected and instrumental in spreading the infection; but of this there is no present indication.

Ikoma may be taken as the local centre in relation to game. A broad colony extends thence eastwards between and about the Rowana and Mbarangeti rivers, and another populates the Serengeti plain southwards. It is said that the headwaters of the two rivers just named dry up, as do the waters of the Serengeti plains, and that the Duma and Simiyu headwaters and the Ngasamo stream do not do so to the same extent. This leads to a dry-season movement of the Mbarangeti-Rowana game eastwards along the two rivers and south-eastwards (through Masanza-Mdogo and even Nasa) to the Lake, and southwards through Ututwa to the Ngasamo and Duma. At the same time a proportion of the Serengeti game comes eastwards through Kanadi to the Duma and Simiyu headwaters.

From this may be deduced the movements of the hunters also to and from the borders of the infected area and the points at which the game from divers quarters intermingles. Also the localities (abutting on population) in which the game is liable to the greatest destruction and that particular locality (inside and west of the cleared Luguru arc and extending to Usmao) in which it appears to be least capable of being replenished by the annual movement to water.

To summarise: Tsetses alone are unlikely to spread the disease far, even if it is propagated through cyclical transmission, owing to the considerable breadth of the barrier round the main Usukuma belt. Game, on present evidence, does not seem likely to spread it, and I know at present of no great movement of game between the main Usukuma belt and the tsetse belts about it. But an infected man going out, passing through or having entered for one of the many purposes I have enumerated may subsequently sit down and talk in a village or road-side halt in any tsetse belt in the territory in a locality in which man is for the time being the centre of attraction for the tsetses that he was in the Simiyu area during our visit, and start a case or two or an epidemic. It is improbable that the last will come about in any place about which game is present abundantly.

XXI.—IMMEDIATE LOCAL MEASURES.

I have not heard what were the recommendations that were finally made by the Acting Principal Medical Officer and adopted, but there can be no harm in stating that the urgent local desiderata when I left seemed to us to be these: to finish the delimitation of the outbreak and of the tsetse area; to segregate the sick in fly-free country, and, for the reasons to be stated below, to evacuate the remaining population immediately the crops should be harvested; to protect people who must still, after evacuation, pass through the woodland either to water or during essential travelling; so far as possible to prevent entry into the infected wooding for any purpose whatsoever; to prevent, for as long as might prove to be necessary, all passage of people between infected and uninfected tsetse areas in our territory or across the Kenya border; if at all feasible (cyclical transmission being presupposed and infected persons having been removed already), to hasten the decease of the tsetse already infected—pending evacuation; again, if possible, to prevent the infection of the game with the trypanosome in case the latter should be capable of maintaining its pathogenicity for man after having been transmitted to the animals.

These would be emergency measures. I was myself anxious, and we thought it distinctly useful, that the continued presence of workers and of natives in the area should be utilised for observation of the primary centres of the fly during the dry season already commencing and for such further acquirement of knowledge regarding a new and highly dangerous tsetse as would help us to initiate later an effective campaign against it such as might assist early resettlement and enable us to utilise the latter to the best effect for the final eradication of the fly. To such a campaign the evacuated, barrier-encircled Simiyu-Duma area would rather particularly lend itself.

Here I ought to say that the problem as regards native co-operation appeared to be very different from that which I believe confronted the British East African authorities when the evacuation of Kavirondo was, long ago, in question. We had conferences with the Sultans, and I was most struck with these hereditary native rulers of the district, with their information and outlook, their apparent ability and hold over their people, their ready grasp of the matter in hand and their shrewd suggestions, and their keenness to support the Government in an effective tackling of the outbreak.

The local measures that (in final consultation between them and the Senior Commissioner) were decided to be useful and, with good supervision, sufficiently practicable, and with regard to which they promised their hearty co-operation, were complete evacuation of the woodland sections of the infected sultanates; the

people evacuated and all gardens to be nowhere less than half a mile from bush ; no entering of it for any purpose except on cleared roads ; all cutting of wood, etc., to be on the edge of the bush—an approach to the fly that it was impossible to avoid in a country clear of wooding but that would result in a steady invasion of it ; the road to be cleared from Luguru to Sengerema and from Maswa to Nasa to provide for the main traffic of the country, also another road (already for the most part clear) following the Lake shore through Nasa to Mwanza ; a path to be cleared (where necessary) to water from each group of villages ; some general effort to be made to keep bush from growing up within cleared areas ; and burning of the bush areas (by then evacuated) to be postponed each year to a given date, the cattle-owning population meantime continuing its custom of protecting its grazing by burning around it an early fire-guard that should not be allowed to spread.

The necessity for some adequate control of the hoe traffic or its discontinuance, for the continuance of the salt traffic only through cleared villages and under such safeguards as might be possible, and for clearing round bush villages immediately surrounding the evacuated areas, was also recognised. Some details with regard to the measures mentioned may be of interest.

1. Evacuation.

With direct transmission as the only factor in the spread of human trypanosomiasis a completely successful segregation, or successful treatment alone, of all infected persons should, theoretically, suffice to clear an area rapidly of the disease, and treatment is the line on which the French are working in their colonies. But (a) concealment of cases may take place ; (b) detection of all infects cannot be expected even when there is no intentional concealment ; (c) the problem of evacuation was, in this case, exceptionally simple, a fraction only of the population living in the bush, cleared country being present close by in each Sultanate to move to, and the co-operation of the more responsible natives being assured ; (d) direct transmission as a sole factor, though attractive as a working hypothesis and just possibly true, is unproved, and should cyclical transmission play any great part and long-lasting infection of the fly and of the game be present, the area would be in the highest degree dangerous, and it was important to evacuate it at once ; (e) the position otherwise also was unique and possibly full of danger ; here, for the first time, was a very definite epidemic of human trypanosomiasis carried by a fly of the *morsitans* group ; it was in a territory more than half of which is infested with *morsitans* flies and which adjoins great territories similarly infested ; and it was in a fly-belt that was connected, both by the “stepping-stones” of the Chinyanga-Kahama belts and by a constant native traffic, difficult or impossible to control, with one of the most extensive and important *morsitans* belts in the territory ; and (f) an immediate decision was necessary, as otherwise it would be too late to hoe for crops in the new locations.

In the face of such considerations we had no hesitation in recommending evacuation. The measure is a sound one also from another point of view. Instead of dissipating their energies, scattered through the woodland in unselected spots, clearing nowhere enough to have the smallest effect on the tsetse, the people evacuated would swell the numbers of those living outside the fly area, who by the mere fact of settlement are tending to destroy the infested bush from its outskirts inwards.

It will be completely impossible to prevent these people from re-entering the bush from their new villages without the employment of much vigilance, a considerable staff and an Administrative Officer in special control, and it was recommended that these should be employed ; for even a marked check on such movements will be useful, and Uganda experience shows that in moderation they will do no harm once the main conditions for an epidemic are removed. With their villages all in clean country as the result of evacuation and the real danger—the bush village—extinct, the chances that infects will be able to spread the disease to the extent of causing a renewed epidemic will be very greatly lessened.

2. The Protection of People who must pass through the Bush.

Here it was a question of the minimum width of clearing. In order to safeguard the travelling population adequately, while exposing for as short a time as possible the large number of natives who would be engaged in making the clearings, it was urgent to find this out. It was particularly important in relation to a fly that had already shown itself to possess habits of movement that had been recorded hitherto for no other tsetse.

While for the reason I have stated (p. 334) I had to leave the completion of my experiment at Zagayu to Dr. Maclean and Mr. Tully, I was not prepared to recommend a clearing of less than 150 yards on each side of the road, and I think that when the grass is short more will be required for complete protection. But it will be well to push through a somewhat narrower clearing in the first place in order the more rapidly to confer some measure of protection on travellers.

Fords especially and other halting-places should be cleared, at the very least, to twice or three times this width, as it is here that natives halt long enough for belated flies to come dribbling in (p. 336) and that, with bush present, the flies leave their carriers and form dangerous concentrations. Also the natives themselves at such places move about in search of wood, and the smaller the clearing the greater the number of flies they will bring back to the shelters. The scattered bushes and trees round water-holes that have no effect on the conservation of the water should be cleared also.

Whatever clearing is made it should be thorough. All trees should be cut, and they should be cut near the ground, at once chopped up and piled on the stump. When dry (in three or four weeks in the dry season) they should be burned and the remnants repiled and burned out finally. This kills many of the stumps, and may help to some extent to prevent that dense regrowth which in two or three years becomes more acceptable to tsetse than the uncleared bush and which must at all costs be prevented.

3. The Prevention of the Passage of Infected Persons to uninfected Tsetse Areas.

In the German agreement with the Territory's northern neighbours it was arranged : (a) to take such steps as might be practicable to prevent natives of the respective territories who are suspected of being infected from crossing the border ; (b) to detain or segregate natives coming in and found to be infected ; (c) to prevent natives from crossing into areas declared infected ; (d) to lose no time in notifying infected areas ; (e) to establish segregation camps at adjacent points on either side.

This is purely an administrative and medical problem and I will not discuss it here. The dangers and difficulties have been indicated in Section XX, and, in the map, I have thought it interesting to show (over a small patch only) some of the native paths to illustrate further the difficulty of preventing natives from crossing the border or of otherwise controlling their movements.

4. Clearing round Villages.

The measures already enumerated, and particularly the effective segregation and treatment of the sick, constitute fairly full prophylaxis in themselves. An additional measure that seemed to us advisable—and Maclean was specially anxious for it—was the clearing of the bush round all villages and gardens in the areas surrounding the evacuated country. This would comprise the villages most likely to contain undetected infection and most likely to be visited with any frequency by infected people, and though the measure would not free the villages completely of tsetse, it would at any rate prevent the very wholesale infestation I have described and to that extent lessen the chances of infection.

It seemed that even a larger measure would be on the safe side, namely the clearing of villages throughout the tsetse-infected areas surrounding that of the outbreak, and particularly along such routes as that to the salt at Lake Eyasi, but where game is abundantly present clearing may be quite unnecessary, and one does not wish to harass unduly people whose co-operation is essential to the success of our more necessary measures. The measure I suggest on page 367 might suffice.

5. The Hastening of the Extermination of the Tsetses already infected.

Destruction by fire.—It is probable that a large number of tsetses in any case fail to survive the hard conditions of the height of the dry season, and these conditions would be intensified by thorough burning.

The question arose whether we should sacrifice the anticipated effect of a really late fire on the bush and the more exposed puparia and try to produce an early effect on the fly on the wing—which, if cyclical transmission were an active factor, might, in thousands, remain capable of infecting people or perhaps the game. The matter was really decided by the certainty (confirmed by information from the Senior Commissioner, Tabora, to the same effect) that it would be impossible this year to preserve the grass after the end of August. Evacuation was to take place in August, and it was decided that the grass should be kept unburnt, if possible, till the 31st August. I have since heard that it was not possible to do this even till August.

I have always foreseen that it will take three or four years fully to convince the natives generally that the Government is in earnest in this matter and to secure their co-operation.

Catching the flies with nets.—It seemed likely that with man as the special object of their continuous attention, the majority of the infected flies should at a given time be found about infected villages in the bush and on the bush paths between them. Smart local natives were engaged and, having been trained to catch flies, were returned to catch in their own localities in specified places until after the fires or up to evacuation. It was hoped that a system of rewards would ensure their carrying out the work with some thoroughness and that the large crop of infections which (on native information) appeared to take place "at hoeing time" might even be to some extent anticipated. At any rate, in view of the considerable captures made by the natives with myself at one or two such spots of flies a great many of which should have been infected if cyclical transmission was present, it seemed well worth attempting this disinfection of the village flies now that the accomplished segregation of infective persons would have removed the source from which the flies crowding in to replace those caught might have drawn fresh infection.

The use of limed screens.—This method was also considered, and Mr. Ralph, the Public Works foreman in Mwanza, made me an excellent revolving screen on the lines long ago suggested by Dr. Shircore (Trans. Soc. Trop. Med. & Hyg., London, ix, Jan. 1916, pp. 101–103). Life-sized silhouettes of men were painted in hartebeest blood, which dried brown, on each of the four vanes (three would have moved better) and the effect as these turned was most striking. From a short distance and partly concealed by bush it looked like an endless succession of natives turning a corner. Mr. Tully and I caught 17 tsetses off it in about 20 minutes, near Zagayu, but the impossibility of obtaining good bird-lime prevented its proper trial. That referred to took place in a spot where the flies were not at the moment abundant and, while it is possible that we with our scent assisted to attract them, they went to the screen rather than to ourselves. I tried it both with and without a loin-rag, freshly removed from a native and placed on it, but could not decide that it made a difference. The dry blood attracted house-flies in great numbers, but the tsetses settled as freely on any exposed woodwork; they avoided the white background. The screen was finally smeared with indifferent lime and set up on Mugasiro island, but, the bird-lime having dried on the way over, caught three flies only (*palpalis*). A small simple

stationary screen composed of a square of khaki stretched between two sticks at 4-6 feet from the ground caught six in the same time. The figures are too small to be a guide, but I had found earlier by watching it that flies were attracted to this stationary screen and, only because it is so much simpler and cheaper to make, this may be the best to use where many screens are required. The use of screens necessitates a thoroughly reliable native in charge, and one who is not interested in the catching of birds, to renew the lime frequently, and the latter substance has to be put on so thickly that, even were it good, it would probably be uneconomical as compared with commercial fly-gums. The use of the latter substances is indicated, and the screens may prove a useful reducer of tsetse in bush villages and (as Shircore suggested) on main paths—the two places in which continuously man-feeding tsetse would most abound.

The probable value of propaganda was also fully realised. With the native once well convinced of the danger of being bitten, the distribution of small nets amongst the villages might be the best remedy against the "direct transmitter."

6. To prevent the Game generally from becoming infected with the Human Trypanosome.

In first reporting on this investigation I was impressed by the risk that the trypanosome might retain its acquired virulence for man even after cyclical passage through the fly and transmission to the game, and by the fact that, as little game was probably infected as yet, and that mostly between the Duma and Simiyu, we might utilise the impending evacuation to place the natives in such a way as to complete by a broad strip of settlement the Maswa-Luguru arc of cleared country, round by Ngasamo and the Kilalo clearing to the Lake at Nasa or Masalu's; and, in the opposite direction, either (shorter) to the open country of Nung-hu or (longer) along the road that it was proposed to clear from Luguru to Sengerema. This would make nearly game-proof the barrier of settlement that already stands in the way of the annual southward and westward migrations and (on the hypothesis stated) prevent more game from becoming infected and from carrying the infection far and wide. I recommended that the natives should be so settled, if possible, and there can be no doubt that this will be a useful measure either to meet such a situation as I have just suggested or as a part of the policy, of which I shall shortly say more, of breaking up the fly-belt so as to allow us to attack it in detail, isolate future outbreaks, and check the movements of the fly. It could also serve as a base for invasion inwards by reinforced native settlement should that be our eventual measure, and anything approaching an absolute barrier against the game might enable interesting periodical investigations of the trypanosomes in its blood to be carried out.

If, on the other hand, the trypanosome loses its virulence for man on passing into the game, the measure would still be useful in the other connections I have mentioned. Yet, on this same view, it might be a very great pity to place any obstacles in the way of flooding the area with game.

XXII.—A CAMPAIGN AGAINST THE FLY.

The following remarks on measures refer rather to the Territory at large than to the Mwanza district only, but they are for the most part as applicable to the latter as to the former. Measures against tsetse fall into two categories—wholesale (or catastrophic) and precise. In the first I include such things as general late grass-burning, wholesale clearing of bush and game destruction. In the second, I include highly localised measures against, for example, the primary centres of the fly, these having first been carefully located.

Each of these categories is sub-divisible into (a) special and usually expensive measures—such as special clearing, the breeding and release of parasites (least expensive), the provision of artificial "trap" breeding-places, or game destruction

by paid men; and (b) incidental measures, consisting in the mere diversion into channels hostile to the tsetse of some process or agency already at work in the country and costing little or nothing to divert or to organise.

Wholesale Measures.

Game Destruction.—The destruction of game animals over any great area by men specially employed is too expensive to contemplate, and unless the area or a broad barrier round it is at once fully settled it will gradually fill with game again.

Game destruction carried out by means of arming the natives and allowing unlimited shooting might succeed in decimating the nobler game over areas of savannah forest that are nearly devoid of thicket (though probably not, for such areas are also poor in natives), but in most areas would leave the bush-pigs (which are probably quite inexterminable) and other small animals. These live in the thickets that result from the coppicing effect of the native's method of cultivation aided by his usual untimely burning of the grass, and appear to be keeping the fly fed to-day in certain areas on the coast from which the bigger game has gone; so that when the native later invades the cleaner savannah forest areas that we have, let us suppose, cleared of fly by killing the animals, his thickets, with their pigs and *their* fly, will accompany him, and we shall have gained nothing, ultimately, by killing the game. This sort of position actually exists to-day in much of the territory in which there is a fair native population. It takes a very large population of men and of cattle combined to produce, in what is normally a bush country, the temporary freedom from bush and fly that exists in parts of Tabora and Mwanza. In such a case the clearing of the bush automatically eliminates the tsetse and there is no need for further measures against the game.

Game—it is true of certain kinds in particular—would seem capable of carrying tsetses into cattle-pasture and so causing small outbreaks of nagana, but our study of the position at Mtukuza, where four herds of cattle were running in apparent and alleged safety in a limited open space closely hemmed in by tsetse in which the game from the surrounding country also congregated, was illuminating in this connection. Several head of game were shot here, but the only flies found either on them or in the mbuga generally in spite of special search were occasional individuals in the small clumps of trees. Shircore has also recorded that tsetses are not found on game shot in dambos except when near the fringe of forest harbouring the fly. This, with the observation that flies once carried well into an open space tend to dismount on reaching bushes or trees, shows that the real protection against this danger lies in most cases in the clearing of the bush in the endangered pasture. Similarly, bushes and trees standing near huts and gardens in clear country near the margins of tsetse areas should be cleared for protection against flies brought in by baboons, and the danger thus reduced to that which may still result from the few flies that will leave the baboons for the crops or the huts. Occasionally, as to-day near Namanyere, the bushes and trees are too many to be cleared, and steps have to be taken against a particular herd of the "wandering" section of our game animals.

Game destruction will not merely, in most cases, be useless for the production of such eradication of the fly as will enable cattle to be kept in what is now tsetse country, but is even highly dangerous to man. I have already said so much in evidence of this fact that I need not labour the point here. It is obviously by no means a policy to be undertaken light-heartedly.

Bush Destruction.—It is interesting to divide our secondary bush formations into three categories: (a) the relatively open savannah forest that tends to accompany an absence of human population; (b) the savannah forest intermixed with or replaced by thickets that accompanies the appreciable presence in the past of natives (or, in places, elephants); and (c) the country clear of all bush that accompanies continuous, intensive native settlement or intensive grazing by game and by cattle,

Such clear areas in the Mwanza district and the smallish open spaces that carry cattle surrounded by fly offer abundant proof that clearing of the bush effectively banishes tsetse. But wholesale clearing by means of paid labour resembles wholesale game destruction by the same means in being prohibitively expensive. Can we divert any natural agencies to this work?

Open ground in the African bush is due (a) to seasonal flooding or swampiness; (b) temporarily, to clearing by natives for cultivating or for firewood and building material, and (c) temporarily, to browsing by game and such intensive grazing by cattle as leads to browsing by the latter; it is also (d) maintained, and in many places is capable of being gradually brought about, by regular late grass-burning. I will discuss these factors, though not in this order.

Clearing by Flooding.—This would in most cases entail engineering and expenditure, but opportunities to flood cheaply should be watched for. The dead trees standing in the overflow "lake" of Kidete on the Central Railway show what its effect would be on the existing bush, and its ultimate drying out would remove the attraction to tsetse that the damp margins of the flooded area might temporarily constitute. I am not aware at present that cheap seasonal flooding is applicable to any part of the Usukuma fly-belt.

Gradual Clearing of Bush by the Annual Grass Fires.—Simultaneous grass-burning on a great scale in an unevacuated sleeping sickness area, or in a famine area in which game is not present in sufficient numbers, may conceivably be dangerous. Our observations on the Simiyu showed that some species, at least, of the *morsitans* group, will concentrate and maintain themselves continuously on man when other foods fail, and special observation is now needed to show whether such fires are less or more dangerous than the ordinary early fires that (themselves expelling game) leave patches of shelter dotted everywhere in which the flies can maintain existence better than in well-burned areas and from which they concentrate on passing man. Pending the result, we might omit areas of this kind from any scheme of large simultaneous burning.

For other places with sufficient grass, late burning and (within strict limits) simultaneous burning will be especially useful, and it is particularly necessary in the evacuated Simiyu-Duma block. This lends itself well to grass fires, the growth of the grass, except in places (as near Nasa), being very fair. Also it especially demands late burning, for everywhere amongst the grass are now present numbers of young thorn trees of several species, some of which are already growing up and forming thickets admirably suited to the apparent needs of the fly, while others are still young enough for this to be prevented by late burning (*cf.* p. 323). The fly breeds greatly in the thickets, and to this extent late grass fires may gradually attack the pupae; but where these are deposited under the rocks of the kopjes they are protected from the fires. Also it is a measure the carrying out of which does not necessitate the presence of large numbers of natives in the infected area.

The one real difficulty is the administrative one. I drew attention to this difficulty (which has been overcome in the past) in my report to the Mozambique Government in 1918 (Bull. Ent. Res., ix, pt. iv, p. 384). A method of fixing responsibility in order to control the fishers, hunters and honey-seekers who fire the grass is necessary.

Clearing by Native Settlement.—It will be noted that I have included in the map figures representing (as I understand) only the taxable males of each Sultanate in Usukuma, as given me by the Senior Commissioner. It will be seen that the population of this kind of the Sultanates west of Usmao and Nung-hu, inclusive, totals 341,806, in an area of about 3,115 square miles, or roughly 109·7 to the square mile, and that this country, except for a margin on the Simiyu, is practically all cleared of bush. It will be seen, further, that the population (of this kind) of the eastern Sultanates totals only 100,720 in an area of about 8,762 square miles, or 11·5 to the

square mile, and that it inhabits chiefly enclaves in a great sea of bush. I include here Sengerema, which is mostly bush, and exclude Nung-hu and Mwagala, in which Sultanates such wooding as remains is mostly much broken up by settlements. Nyamhanda, a little Sultanate (968) that is not shown in the map, is included in the clear country. A multiplication of the figures stated by three would give, I believe, an approximation to the total populations. This crowding of the population into that portion of Usukuma which lies farthest from the Masai, and the consequent existence of the great Usukuma tsetse belt, inhabited by one-tenth of the number of people to the square mile that exists in the wholly cleared area, is said by the natives to have been due very largely to the raids of the Masai, extending in the past as far as Seke.

A third point to note is that of the well-populated fly-free Sultanates some carry a much larger population to the square mile than do others—a population, that is, which, after making allowances for uninhabited mbugas, etc., would appear to be unnecessarily large for the purpose of keeping the country clear of tsetse. To make the calculation complete we should know the numbers of cattle also; but that they, too, are in some of the areas far too numerous is shown by the fact that it has been stated of the cattle-keeping Sultanates of Tabora that 10,000 cattle die there annually of poverty. Whether this figure is correct or not, a condition of overstocking must obtain in greater or less degree in the more congested Sultanates generally.

From every point of view, therefore, it will be a pity if the unnecessary surplus of population cannot, to its own great advantage, be encouraged to clear new homes for itself in the borders of the fly. As it is the aim of every chief to have many subjects, it would hardly, I take it, be politic to offer direct inducements to people to leave particular Sultanates, but the popularity of the woodland areas might be increased. I have been informed by the Sultans that popularity has much to do with the fluctuations of population that are even now taking place between the different Sultanates. When Mwanilanga was a youth the clear, cattle-keeping area at Zagayu did not yet exist. People came to it from the surrounding Sultanates. Tshasama (Sultan of Msalala Mdogo in Uzinza) has received, so his son informed me, much reinforcement and re-cleared much country that had previously in turn supported populations of tsetse, man and tsetse again, as the result of his own popularity and the unpopularity of one of his neighbours. So that it is certain that people can be induced to move, and now that the threat from the Masai has been reduced to a minimum the fly-ridden Sultanates might be further popularised by (let us say) the remission of tax for a limited number of years, or by any alternative methods that the Senior Commissioner may be able to recommend as useful and desirable in order to get the movement started. Growing pressure of cattle in their own localities will make people the readier to accept opportunities offered in new areas. Under this scheme we could prevent such things happening as are occurring to-day in Chinyanga. Here, as the Senior Commissioner of Tabora, Mr. H. C. Stiebel, informs me, Sultan Wamba ten years ago had a population of 30,000 with large herds of cattle. To-day, owing to their abandoning their country in face of the fly, he has only 5,000 people and proportionately reduced herds. Young wooding is allowed to spring up, and "the encroachment" (Stiebel writes) "is so gradual that the natives do not realise it until too late, and then the job of cutting back the bush is too big." The right measure in such a case is to reinforce, and not to abandon. The reinforcements are already waiting a mere dozen or twenty miles away, but through lack of any organisation *ad hoc* they remain unused. Mere timely reinforcement of the cattle would often suffice.

In Mwanza, as elsewhere in Tanganyika Territory, cattle are kept only in areas that are free from tsetses of the *morsitans* group,* so that the problem, so far as cattle

* An exception, south-east of Shirati, has been reported by Dr. Davey (v. p. 328 of this paper). It might repay investigation.

are concerned, is not the direct protection of the existing herds (except in the matter of providing fly-free cattle routes), but (1) the effective invasion of the adjoining tsetse areas *pari passu* with the increase of the cattle so as to obviate the great losses that now apparently occur through overstocking ; (2) the prevention of the invasions by bush, entailing invasion by tsetse, that take place as the result of losses anywhere or of temporary removals of cattle from the margins of clear country. The former point is of great practical importance. In the Tabora district alone, according to Stiebel, there are " 40,000 square miles of country, and of this probably only one quarter, at the outside 33 per cent., is actually free from fly, and that carries over 600,000 head of large stock in addition to small stock and a population of a quarter of a million agriculturists. It is a simple sum to calculate what the district could carry if we could eliminate fly. At any rate it should carry the best part of two million large stock." The immediate importance of this wasted grazing lies of course in the fact that, without the tsetse, it would save the great numbers of animals that are stated to die annually from overstocking.

I have referred to " 2 " already. At Masanza Mdogo, just north of Nasa, the bush is now growing up in parts of the still occupied area, the fly has come in in ones and twos, beasts are being lost, and the people discouraged, as the ultimate result of the reduction of the live-stock below its bush-controlling minimum through a Masai raid that took place before the war. In an area in Ututwa the same thing has happened as the result of partial human depopulation through another Masai raid. In Chinyanga, according to Stiebel, fly has crept into country where there is scarcely a bush more than six feet high—much as at Masanza Mdogo. Mr. E. D. Browne, the Senior Commissioner of the Arusha District, which adjoins the Usukuma area on the east, writes, in a letter dated 14th September 1921, " There is no possible doubt that tsetse-fly has spread into inhabited areas since March 1916, when I first came to Arusha. In the case of the Masai it has caused complete abandonment of certain areas, and in the case of agricultural natives an abandonment as far as they are concerned of the areas formerly used for grazing purposes ; such latter abandonment inevitably leads to the eventual complete abandonment of the areas encroached upon, because no native will willingly for protracted periods live far from his cattle, nor can he conveniently do so for family reasons." Mr. Browne refers, of course, to tribes that have been accustomed to keep cattle, and the fact, stated by him in another letter (10.ix.21), that the fly areas in his district are practically uninhabited bears out his view. To return to the Tabora District, " Twenty years ago Urambo area was open grass country carrying huge numbers of stock ; to-day it is one tsetse-infested bush."

One or two other instances like that of the fly-free bush near Musoma may still exist in the territory, but, in general, *G. morsitans* at least has filled up the areas in which it can exist, and in nearly every case of which I know the details it is an invasion not of game but of bush that spreads it farther. The position appears to be quite serious, and the remedy for this insidious invasion is not game-destruction, which will be completely without effect, but (a) such measures against the growth of the bush as I am recommending in this paper, and (b) protection of the cattle against cattle diseases generally ; for it cannot be emphasised too strongly that appreciable losses in a cattle area which anywhere adjoins fly means invasion somewhere by the fly, and that everything which fosters the cattle industry will reinforce our own invasion of fly areas, so that a strong Veterinary Department is, indirectly, an important measure against tsetse.

In the great, clear, populated areas of the Mwanza and North Tabora districts it is the cattle, very largely, that keep the country clear. Everywhere are stumps that, with less heavy stocking, grow up at once and form bush that harbours tsetse. On the other hand, cattle can do nothing against trees already grown, and gradual special clearing could easily be undertaken by the owners who abut on tsetse, or by

the communities, as some increase of their grazing that is not obtainable otherwise becomes necessary.

Goats are valuable for their browsing habits, and the keeping of them should be organised in tsetse areas in which they can survive. In parts of the territory it is the presence of great numbers of leopards that prevents their better survival. Game is most valuable in the same way as cattle and goats, and, where it remains in sufficient numbers, it is to-day producing the same discouragement of the bush and of tsetses as are cattle. The open-plains game in particular should be encouraged in this connection in order that it may assist us to preserve the open plains through the dry-season feeding-down accomplished by its countless herds. Once let the woody growth get beyond the power of game or cattle to reduce and tsetse will appear, and we shall be faced with the difficulty (of reducing established woodland) that exists already in two-thirds of the territory.

But even the game of the woodlands, powerless though it is to reduce the bush effectively without the initial assistance of clearing, is to be regarded as a potential ally. Elands, through their size and their preference for feeding on shrubs and trees, are the very best of the large game as potential bush-reducers. An attempt to capture and domesticate elands for farming and transport in fly-areas is being initiated, as this animal has many good points for the purpose, is very easily tamed, and can be captured more easily in great numbers than any of the other game animals; and any temporary special attraction of tsetses to the neighbourhood of a village herd would very soon be reversed through the influence of the antelopes on the lower shelter of the fly, and, with close stocking, the position with regard to the ultimate destruction of the bush that I hope to attain similarly in places by means of late fires would come about with the end of the rotation period of the older growth. The *situngas* are stated to have cleared whole islands in Lake Victoria of undergrowth and left the trees bare to a level height like trees in a park with cattle, and by doing this to have banished the fly (*G. palpalis*) quite largely from those places. This has been rendered possible only by the removal of the human population, but eland farming would combine with human population the activities of a first-class browsing animal. Naturally, presuming our trial of the animal to be a success, it will take a good many years before we can establish any widespread eland farming even in a single large fly-area, but this delay will itself be useful in meeting a temporary difficulty very soundly suggested to me by Mr. C. W. Hobley, namely, that it may take time for the native to admit the eland into the "gold currency" that is represented for him to-day by cattle. This is in any case not quite the position. The elands are mainly for native tribes that to-day possess no animal currency.

Meantime we shall be unable to invade the bush from within in this particular way, but by nursing the territory's stock, judiciously relieving congestion by encouraging movement to the margins of the woodland, stimulating the definite clearing of those margins in places in which we can at once place ample stock on the cleared strip, reinforcing communities that are for the moment being invaded themselves, encouraging the starting within the fly-areas of such new clearings as those from which Zagayu, Luguru and Kilalo grew, and, in general, making the margins of fly-infested areas the objects of a particular solicitude, we shall gradually drive these back, if we can also prevent the occurrence of such epidemics of cattle-disease as would lessen greatly our material of invasion. I have been interested to note that Taute also, evidently knowing the conditions well, recommends the systematic clearing of large expanses in tsetse borders in lieu of the present haphazard native methods. I have indicated the least expensive and most effective method of clearing them.

No measure is universally applicable in its entirety, and this one will be found less workable in relation to some tribes than to others, and be modified or abandoned in conformity with local conditions. My experience in Tanganyika Territory has

confirmed the conclusion at which I arrived in Portuguese East Africa—that special study and special measures or modifications of measures are needed for each separate locality.*

Effect of Clearing on Water.—In reply to the criticism that clearing (by whatever method) for the eradication of tsetse will dry up the natural water-supply, the facts observed in the Usukuma area may here be cited.

It was most interesting to note that in the great areas that have been completely cleared by native settlement there is nowhere insuperable difficulty over water, and people are able to live anywhere. Moreover, the poor savannah wooding that constituted the shelter of the fly appeared to have little or no influence in conserving the water. The streams both in it and in the cleared country outside of it dry into pools in August, and the only difference, as Sultan Mwanilanga said, was that in the cleared areas water was more abundant because there were more people and they dug more water-holes.

Naturally the clearing of primary forest, in districts in which this still exists, would have a very different effect.

Precise Measures.

The measures I have described above are widely applicable measures amounting, in effect, to a general policy in relation to the tsetse of the territory. If we can make them successful—and, given the human material and the cattle, this should be merely a matter of organisation and watchfulness—they will both prevent the serious invasion of cattle areas by tsetse and enable us to take over from the fly all the ground we more urgently require for the accommodation of the increase of the cattle of the territory, as such increase takes place. Under such a policy the fact that tsetses carry trypanosomes acquired from the game will be a matter of supreme indifference to us, for we shall have all the tsetse-free land we can use, and the rest is a matter of careful herding.

But situations may still arise that will demand a rather more rapid elimination of the tsetses in a particular area than can be accomplished by means of our gradual invasion of the fly-belts. It would certainly be well if we could to-day eliminate the Chinyanga fly-belt and at least the eastern side of the Usukuma belt, and it is for a problem of this kind that what I have called “precise” measures may be useful. Such measures entail an exhaustive preliminary study of the locality. Primary centres of the fly, breeding-places, water-holes, streams and swamps must be located; areas of bush particularly affording egress from the centres to the main woodland sections served by them may usefully be searched for, as Shircore long ago suggested; lines of open mbuga that might be connected with advantage by clearing in order to split up the fly area should be noted, and other points of attack observed. Finally, on the data collected, the real campaign can be planned. The most important line of attack will again be clearing measures, but the clearing here will be discriminative—directed solely against the strongholds that enable the fly to maintain its hold on the country generally. These in some belts will be prohibitively abundant, in others fewer and more easily dealt with.

* Mr. C. W. Hobley, C.M.G., who has had exceptional experience of native administration and was also in charge of the Nyanza Province during the great epidemic on the Lake, has very kindly read the proofs of this portion of the paper with a view to criticism. He regards the scheme as being on sound lines and suggests, for country in which the streams dry up, the inducement that would be offered by the erection of a few dams and, beside open “mbugas” in which the people would be settled first, the sinking of wells. Goats would be farmed first. Cattle would follow when it was perfectly safe for them to do so and the clearings would eventually coalesce.

This adds useful detail to the idea of “large locations” as centres from which to invade the surrounding tsetse-country, and it is possible that the settlement of little more than the mbugas alone would, as I have suggested under “Precise Measures,” at once banish the tsetse.

Clearing Measures.—It should not be necessary to employ paid labour, and, if it were, the cost would be great. The resettlement of the evacuated Wasukuma, when they are allowed to return to their old area, will offer a good opportunity for the application to the Simiyu-Duma problem of the control of tsetse by judicious native settlement. A yet finer opportunity might be afforded should we find ourselves in a position to utilise the surplus population as I have suggested on page 360. Instead of leaving it to attack the woodland indiscriminately (as there suggested) from the margin inwards and from such clearings as those of Zagayu, Maswa and Kilalo outwards, we would offer our inducements to those who would settle in and clear the spots indicated by us. These spots would be the main "strongholds"—the primary centres—and by concentrating on them we should make the best use of our human material.

But it is essential that the scheme should be organised soundly and with care from the agricultural standpoint also. It should, if possible, be of such economic importance agriculturally to the country that it will not lack special fostering, and so profitable to the natives concerned in it that after the first brief period of special inducement their numbers will be swelled automatically. What, apart from food-stuffs, should be the crop? This, naturally, would be settled by the agricultural experts, but it is already likely that amongst the strongholds of the fly will figure the borders of many of the small open mbugas that are scattered so freely through the woodland, and that the soil at these places, as well as in some of the thicket areas, is suited to cotton. Native settlements here for the large-scale planting of cotton might thus at once go far to control the tsetse, and cotton is the crop the cultivation of which it is most wished at this time to promote amongst the natives of the territory. Organisation of transport, a guaranteed price for the cotton, good entomological control of its pests by a man stationed on the spot, and, for produce generally, access without prohibitive duties to the Kenya market, would encourage the cultivation of the area, which, with its water transport to the railhead at Kisumu, is a peculiarly suitable one for treatment in this way.

We should still discourage the one-family bush village. Enough people would be stationed at each centre to ensure its proper clearing and to make it capable of carrying cattle at an early date, and these cattle in their turn would assist in the consolidation of each focus as it grew. Again, the reopening and extension of the gold-mining industry of the district, if that should happen, would lead to more clearing for timber round the mines themselves and, by creating a local market for agricultural produce, lead indirectly to much other clearing.

Cleared Barriers.—The effect of breaking up the belt in the way referred to on page 363 is worth investigating in practice. Thus, a tongue of bush extends into the more open Nung-hu country, and it is stated that in it the tsetses are few. By broadly cutting through the comparatively narrow neck that is stated to connect it with the more heavily infested bush nearer the Simiyu, it is possible that it will be completely cleared of flies, and the possibility of doing this elsewhere also should be borne in mind. Where much-frequented paths cut across a barrier, the latter may be less effective; for though many or most flies leave a person who enters cleared ground, others follow right across it, just as flies will accompany a canoe till it lands. Where it is a case of a barrier to check the advance of a fly-belt (and here I speak of general principles rather than of the Mwanza-Tabora problems) advantage might be taken on any much-travelled path that crosses it of the flies' tendency to dismount at the first piece of shade after traversing much open ground. A few bushes or huts only (p. 334) could be left at some point on the path, together with two or three resident natives whose business it would be to clear passers-by of flies. In such a place as this a few limed screens might find their best use.

Other Measures.—Certain other control measures that have been proposed are very well worth investigation, such as the breeding and releasing of the fly's enemies

and the interchange of parasites in different parts of Africa. I understand that Dr. W. A. Lamborn is working on this in Nyasaland, with considerable prospects of success, and that he will shortly be in a position to supply large quantities of the parasites of the pupae. The release of the parasites would take place in the chief breeding centres of the tsetse, and it would be well, when it became practicable to do so, to carry out a trial in a selected portion of the Simiyu or Chinyanga areas.

Asilid flies of one or more species were called by the Wasukuma the "Lion of the Tsetse," and a Sultan in the Tabora district is said to have reported that a whole area had been cleared of tsetse by these flies. Unfortunately their breeding, even if they should specialise in tsetse to the extent reported, is likely to offer insuperable difficulties.

I saw relatively few drongos and fly-catchers in the fly area, and the local natives are great bird-catchers and eaters of nestlings. Possibly, as Mr. Turnbull suggested, the evacuation of the infected area may help the birds a little. Guinea-fowls, of which also I saw but few, might be particularly useful in relation to a fly that is so partial to breeding in thickets, and seeing that birds hand on their traditions to their young, the release of guinea-fowls that had been accustomed in captivity to scratch up the pupae of Muscid flies under logs and in other typical breeding-places might possibly be of use. Unfortunately any bird that had been domesticated would be at a disadvantage in relation to carnivora and man.

XXIII.—GENERAL PROPHYLACTIC MEASURES.

The Perpetuation of Areas once Fly-free.—One of the most striking things about the cleared, populated areas is the number of small thorn trees kept right down by the cattle and goats or cut for firewood if they should grow beyond them, that stud the ground, lying in wait to renew the forest and reintroduce the tsetse as soon as any of the land is abandoned. Abandoned settlements growing up first into scrub, then into bush, and already harbouring tsetse in some numbers are to be seen on the borders of the fly, or (as at Ndagalo) in the wooding, and I have given on page 361 instances from three districts which show how serious and pressing a matter this is in relation to our cattle areas. But it is not only in the cattle areas that it is important to prevent this regrowth. The extent of country that is covered in Tanganyika Territory by old cleared ground and gardens, native and European, that have gone back or are going back to bush is enormous, and I was specially impressed in the Namanyere sub-district by the indications of extensive former occupation in country that is now entirely given up to fly. Had it been the custom of the native and the European thoroughly to stump all shambas, a large amount of fly-infested land would now either be free or require but little additional work to make it free. I, myself, by merely stumping for ploughing, cleared many acres of ground in Rhodesia from a pestiferous woody *Parinarium* that always springs again in native fields and forms thickets after their abandonment.

In the clear areas in the Mwanza district the stumps are neither over-large nor too densely growing, and it would be a matter of very small trouble in these thickly-settled parts, while they still remain thickly settled, for the natives to remove the stumps and so make their tsetse-free areas more permanently tsetse-free. They have doubtless much work to do this year in connection with their road clearings and the moving of their villages, but it has already become very necessary, as a sleeping sickness measure, that they should keep the scrub about their villages from growing up, and it is to be recommended strongly that from next year on they should be encouraged to do this not by the work of cutting back, which has to be repeated laboriously year after year, but once and for all by stumping.

It should also be a rule that any native living in a tsetse area *anywhere* shall stump his garden, and, when the moment is opportune, legislation might enact the same contribution to our campaign from the European owner of shambas. But it may be

admitted that the supervision of a general measure might be difficult, as it is not easy to see at a glance if the smaller stumps and roots have been eradicated in cultivated land under crops or weeds or lately hoed. It is easier in the case of well-stocked grazing country, as at Mwanza, for the sprouts from the stumps show up well, and at least in these circumstances (where, also, it is more immediately needed) consideration should be given to the possibility of enforcing or encouraging what will prove an invaluable measure. When we cease to give back to the fly what we have gained from it, our final conquest of it will at last have begun—through this systematic consolidation of all ground won.

The Prevention of Human Trypanosomiasis.

It is probable that the cost of fighting successive outbreaks like that on the Simiyu will greatly exceed the cost of detailing three or four officers for a time to sleeping sickness survey and of the small preventive measures that the survey may in various localities show to be necessary; and more than possible that in further outbreaks we shall not find evacuation the easy matter it was on the Simiyu. On the other hand, success in the trial of new drugs that is now proceeding will render evacuation unnecessary in the future. In case it should be agreed that an investigation is necessary it is interesting to note that the lesson of the Usukuma outbreak seems to be that such a survey should consist:—

(1) In the usual search for infection. Even if it should reveal no real outbreaks this will help to show us the distribution of one of the three factors, all three of them important, that seem likely to contribute to the creation of a danger-focus.

(2) In a close survey of the tsetse and of the game. The latter would include a study of the seasonal movements of the game, the reasons for them, and the length of absence of game from particular places; an enquiry as to the extent to which game is being reduced by the natives in the neighbourhood of population living in woodland; a record of the roads from which it has been driven away to such an extent as to cause unduly prolonged concentration of the fly on man; and (in the tsetse survey) any other factors that might locally cause such long-lasting concentration.

(3) In a study of the meteorological and agricultural history and conditions of each area with a view to determining the liability to failure of crops from natural causes.

The combination, in an area containing many tsetse, of game reduction with a liability to famine and the presence, in or near it, of infection (or, for that matter, if *brucei* be convertible into *rhodesiense*, the first two factors alone) would constitute the area a danger-focus. In such a danger-focus game protection should be well enforced (though without prejudice to the protection of the crops), a vigilant eye kept on the welfare of the crops generally, and distress caused by their failure anywhere relieved promptly; but it should be relieved by other means than throwing the game open to unrestricted killing. It would appear from this that the expert Departments, both in a properly organised sleeping sickness survey and in the scientific prevention of sleeping sickness, would be the Medical, Game and Agricultural. The location of scattered infects in a vast bush country would be assisted by a knowledge of the distribution of the conditions under which infection is likely to be present, and such a survey would indicate also the localities which must be carefully watched in the future.

The presence of a herd of domesticated elands at a village would probably be the greatest safeguard against sleeping sickness. If any success attends the experiment that the Game Department is now trying to initiate in this direction, that condition may some day come about. As regards the more general question of game protection, it may be said that the present Game Ordinance of Tanganyika Territory provides

for the control of dangerous game generally and for the protection of native gardens in particular, and that this last, in practice, covers the killing by natives of a moderate supply of meat. The Ordinance also gives resident and visiting sportsmen a generous schedule. Otherwise than in these respects, it protects the game. It would seem likely now that this reasonable degree of protection is not only in the interests of the game, of science, of sport and of posterity, but that it represents a policy that must be continued for the safety of the human inhabitants of fly areas. The mild killing that is already permitted may, in general, be useful in preventing so large an increase of the game near man as to leave a particularly large population of fly stranded if anything unforeseen should happen to the game, but even this danger would be robbed of much of its sting by the adoption of the simple measure I shall suggest next.

For the purposes of this paper I have practically taken the view that *T. rhodesiense* and *T. brucei* are convertible, the one into the other; for if man's resistance requires to be overcome by transmission through man, I do not think that even the last of Taute's daring experiments has disproved this alternative. On the other hand, neither has Taute's view been disproved, and a single infective person may easily have started the Usukuma outbreak. Natives have travelled in the war nearly from one end of tropical Africa to the other and, from the most widely-separated parts of it, have visited the infected region of Portuguese Nyasaland, so that *T. rhodesiense* infection as such may have been carried almost anywhere. Even on this view, the action of the game in preventing such concentration of the fly on man as will facilitate transmission and enhance virulence must be most valuable, and its adequate preservation is still the best prophylaxis against sleeping sickness.

The Utilisation of Cultivation.

The following suggestion of a measure that would be simplicity itself and yet of great use seems worth emphasising. Native villages may be divided into three categories: (a) villages surrounded by cultivation; (b) villages standing beside their cultivated fields or (c) completely separated from them. Except perhaps, where trees and shrubs are present in a village of the first category, it is only in villages of the second kind that large concentrations of tsetse will tend to take place, and, as I have seen myself, in investigating demands for the destruction of game, it is especially the third type of village that is liable to suffer from a large destruction of crops by wild animals. These people, with their gardens and even some of their corn-bins some hundreds of yards from protection, are wantonly exposing them to attack by the game and themselves to attack by the tsetse, and it should be a sanitary rule, to be enforced as strongly as such rules are enforced in the townships, that every village in tsetse-infested wooding anywhere should stand in the middle of its cultivation and be free from bush. This means of utilising for partial protection clearing that already exists is very simple, and it will be the cause of no discontent amongst natives, who often do surround themselves with their cultivation. Villages the main crop of which is rice are likely to be the only necessary exception.

But this is only a first step. The policy in tsetse-areas should (in my opinion) be directed to the gradual elimination of the small "family" bush village and the encouragement of the "large location." The large village, or the fairly compact group of villages, will protect itself from at least epidemic trypanosomiasis by surrounding itself with really extensive cultivation; it will be able, when the clear space is large enough, to keep cattle, first one small common herd, then, as operations extend, several herds; it will be able to use its numbers for a better protection of its crops and even (against animals other than simians), co-operate in such special measures as the trench that the closely-settled Watshaga of Kilimanjaro have interposed between their cultivation and the elephants and pigs of the game reserve; and it will also render the general task of administering the natives incomparably easier.

School Propaganda.

Propaganda on these subjects is, relatively speaking, useless in respect of the adult native, except in connection with a danger that has been brought home to him, as sleeping sickness has in relation to some of the Wasukuma; yet even here propaganda should not be neglected. But school children are far more receptive, and opportunity will doubtless be taken of the fact that schools have been opened or are being opened all over the territory to teach the children, amongst other matters of hygiene, the danger of the tsetse-fly, the advantages of cattle-keeping, the circumstances under which sleeping sickness may arise, the methods of preventing it, and the ways in which the natives can contribute to such prevention and to the conquest of the fly. A brief circular of my own on the subject of tsetses has been translated by the Director of Education (who is keenly interested), and will, I understand, be distributed, and oral teaching will be still more useful. Such teaching will help us greatly to obtain the intelligent co-operation of the native in this furtherance of his own interests as years go on.

XXIV.—CONCLUSION.

Apparent Lessons of the Outbreak.

1. The area covered by the epidemic coincided with remarkable closeness with a section of the fly-belt in which game was markedly scarcer than elsewhere, and in which, as the evidence shows, it had been scarcer still earlier in the outbreak. More factors than contact with the game helped to confine the outbreak, but all observation indicated that the fly was here concentrating greatly on man, and that in the game area it was not; and it was difficult to doubt that this concentration, the result of game destruction, had constituted a main factor in the production of the epidemic, the other being famine. Further, on page 349 I have quoted evidence from other parts of Africa to show that (apart from sporadic cases) it is quite usual for sleeping sickness to be associated with a local lack of game and a consequent concentration of tsetses on man, and that in Rhodesia famine alone did not suffice to turn sporadic cases into an epidemic.

2. It is for protozoologists to demonstrate the rôles and relative importance of cyclical and direct transmission in human trypanosomiasis, sporadic and epidemic, but my observations demonstrated that conditions strongly favouring direct transmission are present in the normal relations of man to flies of the *morsitans* group that have been led to concentrate on him.

3. It was clear from the evidence that the infection in Usukuma, once set going, was with much regularity carried from man to man, and, while it may yet be clearly shown that *Trypanosoma rhodesiense* of man is capable of arising from *T. brucei* of the game in places in which the fly has been forced to concentrate on man through the destruction of the game, Wolff's record of the capture in this very district, by the Germans, of three Belgian native soldiers suffering from trypanosomiasis, one at least of whom was alleged to have been treated for it already in his own country, shows that there is at any rate no final necessity to resort to another explanation than the presence of an infective person for the first origin of the Usukuma epidemic.

Local Measures against Tsetse-flies.

In my Mozambique report (*op. cit.* pp. 382-385) I made late grass-burning my main recommendation, while I also laid stress on the advantages of judicious native settlement—settlement, that is to say, that would be confined to the points that are essential to the continued occupation of the area by the fly (p. 381). For the Usukuma-Chinyanga area, while I still insist on burning, I make judicious native settlement, reinforced locally by release of parasites or any other sufficiently cheap measure that may commend itself, my main recommendation. I do so because it appears

likely to be unusually feasible in this area (1) through the fact that we shall in three or four years have a native population that will be anxious for resettlement, and (2) because beside the fly-belt lies a densely populated area from which it should prove possible to attract recruits. We could gain experience and begin to remove the dangerous link between the greater belts by attacking first the small belt of Chinyanga, and then lay our detailed plans for the area between Usmao and the Duma in time for the return of its population. This last is a golden opportunity for such an experiment and should not be neglected. My immediate recommendation, if the Senior Commissioner of Tabora should regard the scheme as locally applicable and if Dr. Duke's findings are such as to render it inadvisable to re-people the Simiyu for some time, would be that officers of the Medical, Veterinary, Game and Agricultural Departments should, with the Senior Commissioner, study the Chinyanga belt and the resources that could be diverted to it, and draw up a plan which would then be put into effect.

I will here reiterate my conviction that the time has arrived when we can learn most about the control of tsetse in relation to man and cattle by definitely taking in hand particular problems—whether fly-areas or infested roads. I would expect much from either of the two experiments I have suggested.

General Policy.

Development, not retreat, is the right general policy with regard to fly-areas. Where through lack of urgency or for other reasons we do not, or cannot, put into effect what I have termed "judicious" settlement, the development should take place mainly as an invasion from the borders of the cattle areas, beginning in the localities in which the cattle pressure is greatest and the human material therefore most needing assistance, and also most likely to be anxious itself to assist. Our ability at once to stock fully the country reclaimed will then keep pace with the work; the latter will concern at any time chiefly natives who already know fully the advantages of cattle-keeping, and of whose keen co-operation we shall therefore be assured, even should it sometimes come to localised measures of hand-clearing; and it will least dissipate the energies of our keen but small Veterinary Department, whose ability to take its full share in the carrying out of the measure is most essential to the success of the scheme. Government encouragement to agriculture, *e.g.*, to cotton growing, should be concentrated whenever possible in places on the margins of fly-areas or along roads that it is wished to make safe for cattle, and settlement generally should be attracted to these places by any suitable means.

The general feasibility of directing any surplus, present or future, of men and of cattle to the organised invasion of tsetse belts should be carefully examined in each cattle-keeping district, for the ultimate alternative is inevitably heavy overstocking and loss and, in places, retreat; and even the fact that we have not an adequate market for the territory's cattle need not be regretted if we can utilise the animals thus saved to us for the conquest of the tsetse.

At the same time, by overcoming the difficulties in the way of late grass-burning, by the release of parasites, by the formation of large locations instead of the family village and by starting eland farming, we should organise an invasion of the fly-belts from within. The result of a successful application of the principle of late grass-burning would consist in an ultimate opening to cattle farming of great blocks together that it might be impossible to stock heavily at once, but in which cattle would run safely in scattered herds with unstinted grazing and under the best conditions for rapid increase—in contradistinction to the other type of invasion which would have to be maintained by continuous heavy stocking accompanied by some liability to loss through insufficient pasture in the dry season. We may also find it possible, in places in which the primary centres of the fly are somewhat scattered, to reduce large blocks at a time by such measures as I have referred to under "Local Measures against Tsetse-flies."

I have here summarised the policy and some of the measures by which the fly-areas of Mwanza, of the territory generally, and possibly the *morsitans* areas of any other territory, may gradually be eliminated. A continent-wide problem must be met, not by scattered measures, but by a broad, firm and persistent policy, refusing the aid of no measure which locally or generally may accelerate the attainment of its purpose. The process will be slow, but it will also be sure. It is probable that there is no other way and that an administration that is not in a position to put this policy in motion will not get rid of its tsetse. I believe that we are now in a position to make a start. The first step will be to examine in every district the position in regard to the present feasibility of the policy. The second step will be to put it into operation where it is already feasible, with such modifications of detail as the local conditions may demand, and to prepare the ground for it where it is not, by means of propaganda, the special fostering of the cattle industry, the encouragement in fly country of large locations and the organisation of their expansion, or any other measure that is locally indicated.

Human Trypanosomiasis.

The occurrence of human trypanosomiasis in severe epidemic form in association with a *morsitans* fly, together with the considerations I have stated in Section XX, suggests the utility of a survey of the west and south on the lines suggested on page 366.

As regards measures, atoxylisation of infects and "screens" of immune pigs appear to be the simple but comprehensive combination favoured by the French. On the prospects of a measure equivalent to the first I am not competent to express an opinion, but the wild game animals, with eland farming in fly country ultimately superadded, would with us play the part of the French animal screens. We appear to be arriving at the same conclusions on both sides of the continent. I would add the utility of making the native live on a clean site in the middle of his cultivation and not in the fly-infested bush beside it or away from it. The disappearance in this way of the thoroughly dangerous and obnoxious bush village, described on page 338, and responsible, as I consider, for the major portion of the Usukuma epidemic, will safeguard the natives very largely from any untoward result that might arise from local reductions of the game through epidemics, unlawful killing or failure of pasture. The game must be reasonably but adequately protected. There can be little doubt but that such special concentration of fly on man as does very definitely and strikingly result from the driving of the game from the neighbourhood of real bush villages and much frequented bush roads is very likely to lead to cases of human trypanosomiasis if infects carrying the pathogenic strain of trypanosome should be present. Whether such pathogenicity for man of the game trypanosome can arise in the first instance from game destruction only, without the aid of a human infect and of famine or hardship to enable the earlier trypanosomes to survive in the blood of successive persons long enough to secure retransmission might be shown by such an experiment in game destruction as has been much advocated. But to exclude these two factors is difficult, and to carry out the experiment in the face of an adaptable fly and trypanosome and of the possibility of a failure of crops before it is concluded—for man must be present, preferably in numbers, for the experiment to be of use—is to court disaster, and to risk, further, the filling of all the surrounding country with a more highly combustible material than it now contains. For it would seem at least possible that the scattered, sporadic infection of the south is merely the still radiating remnant of what was once an overlooked conflagration like that of the Simiyu, but is now, like a grass fire that has arrived amongst leaves, smouldering and flickering and working its way tortuously with the movements of persons, but virulent still and ready to blaze again should it anywhere find the dry grass of a prolonged and extensive local reduction of the game. The events in Usukuma have shown us what is liable to happen when game destruction takes place under natural conditions, and suggest why sleeping sickness bulks largest in those areas of Tropical Africa in which game is relatively scarce.

