UNIVERSITY OF IFE NIGERIA

Inaugural Lecture Series 40

THE TSETSE FLY AND TROPICAL AFRICA

by R. A. Balogun

UNIVERSITY OF IFE PRESS

THE TSETSE FLY AND TROPICAL AFRICA

by

R. A. Balogun
Professor of Zoology

Inaugural Lecture Series No. 40

Inaugural Lecture delivered at the University of Ife
on 24th April, 1979

University of Ife Press

I decided to choose the topic, "The tsetse fly and tropical Africa", not just because my own work has been involved with the insect in the last twelve years but that the subject is, in its own right, of particular importance to the economy of Nigeria, and of tropical Africa, today. Nash (1969), a distinguished entomologist (glossinologist) of this century, wrote on this notorious insect as follows:

> "The tsetse fly lies at the centre of a vast biological complex—an intricate web whose strands extend across the 4½ million square miles of tropical Africa, destroying man and his animals and stifling the economy. Tsetse have been for centuries among the most dangerous animals in Africa, and still are. Early in this century a sleeping sickness epidemic on the shores of Lake Victoria killed over 200,000 people, while the tsetse-borne 'nagana' of domestic cattle is responsible for much of the malnutrition in Africa today."

The tsetse fly replaces the spider in the centre of this web, whose strands insect scientists have tried to unravel for many years.

Tsetse flies and the trypanosomes which they carry are partners in widespread crime against the people of tropical Africa. The presence of tsetse and trypanosomiasis has worked against the rearing of livestock and the development of a settled, non-nomadic cattle-producing industry in many parts of Africa. In Nigeria, for example, the problems of animal trypanosomiasis are enormous. In coastal and forested areas of southern Nigeria accounting for approximately 30 per cent of the country, tsetse flies are ubiquitous almost all the year round. Under such conditions the large Zebu cattle of the northern states of Nigeria, which are susceptible to trypanosomiasis, cannot be kept. Their place is taken by much smaller dwarf varieties of cattle, such as the Muturu and N'dama, which have developed some degree of tolerance to trypanosomiasis but which, when exposed to heavy trypanosomiasis challenges, also succumb to the disease (Baldry & Riordan, 1967). Apart from cattle, all classes of mammalian livestock are susceptible in varying degrees.

Tsetse are blood-sucking flies. Although specimens of this insect have been reported from Southern Arabia by Carter (1906) and fossil

flies attributed to the insects were reported from Colorado in North America during the Oligocene period (Cockerell, 1919), they are at the present time confined to Africa south of the Sahara in the Ethiopian Zoo geographical region. It has been suggested that the extinction of prehistoric horses and camels in North America may have been caused by trypanosomiasis carried by these flies.

Tsetse flies belong to the genus *Glossina*, a name derived from the Greek word 'glossa' meaning tongue, and refers to the conspicuous proboscis which sticks out in front of the insect's head. They belong to the order Diptera (true flies) and to the family Glossinidae, which are closely related to such insects as house flies, blow-flies and stable-flies. The smallest species are about 13 mm. long and the largest about 19 mm. The ground colour of tsetse is dark brown or yellowish brown and this is suffused with varying patterns of black. It is easy to determine the sex of a tsetse fly. On the underside of the tip of the abdomen, the male has a button or a hard convex structure called hypopygium in the centre of which is the anal orifice. The female has no such button.

Trypanosomes, the parasites which tsetse flies transmit, belong to the group of microscopic unicellular animals called the Protozoa. They are slender, elongate protozoans which possess at the anterior end, a thin, whip-like process called the flagellum. They belong to the genus *Trypanosoma*, a name derived from two Greek words, 'trypanon' meaning drill and 'soma' meaning body. The name is appropriate in that if a drop of fresh, infected blood is viewed under the microscope, the trypanosome can be seen boring and lashing its way with its flagellum through the large number of blood corpuscles. Nash (1969) wrote, "Once, having spent an hour trying to convince some villagers that the tsetse carried the micro-organisms of sleeping sickness, one of my African assistants who was dissecting the mouth-parts of recently killed flies shouted: 'Positive!'. I beckoned one of the audience forward and told him to look down the microscope and see for himself that I had been telling the truth. He looked and exclaimed: 'Allah!' Never have I seen so many fish."

The disease caused by trypasonomes is referred to as trypanosomiasis. When a tsetse fly feeds on a host infected with trypanosomes it may itself become infected and can then transmit the organisms to man or his domestic animals; both sexes of the fly are carriers of the disease. Human trypanosomiasis affects the central nervous system causing the affected person to feel drowsy and sleepy, and hence the

term, 'sleeping sickness' is given to it. Infection may result in acute disease, with symptoms of severe acute toxicity which often culminate in death after only a few months. Animal trypanosomiasis results in the infected animals becoming languid, they lose flesh, swell at the eyes which give a discharge and the animals ultimately die. The disease is referred to as, 'Nagana'.

There are about 30 described species and sub-species of tsetse fly to-date. All of them can probably carry nagana but only five species are known to transmit sleeping sickness.

History of Tsetse Flies and Trypanosomiasis in Tropical Africa

Man has undoubtedly been aware of tsetse flies and their haematophagous associations with him and his livestock for a long time, but it was not until 1830 that these insects received zoological recognition (Wiedemann, 1830). Even so, it was nearly another 70 years before it was demonstrated that trypanosomes were responsible for nagana and that the tsetse fly, *Glossina morsitans* Westwood, was the carrier of the disease (Bruce, 1895, 1896). Later, Bruce et al. (1903) reported that tsetse flies also transmitted sleeping sickness from man to man.

The name 'tsetse' is derived from a Botswana word which refers to 'a fly destructive of cattle'. Major Verdon, a colonial administrator, was the first man to take a scientific interest in tsetse. Aware of the existence in certain districts of Botswana of plants poisonous to cattle and suspecting that some herb might be the cause of the mischief ascribed by the Africans to the fly, he put the matter to test by riding his horse into a tsetse-infested locality without dismounting or allowing the animal to feed. The horse subsequently died! Verdon sent specimens of the flies to Professor Westwood, who in 1850 described and named the species *Glossina morsitans*. In a letter to Westwood, Verdon wrote, "I have ridden up a hill and found 'setse' increasing at every step, till at least forty or fifty would be on my horse at once. The specimen you saw cost me one of the best of my stud. He was stung by some ten or dozen of them, and died in twenty days."

In 1857, David Livingstone focused the attention of the scientific world on the ravages caused by the tsetse. He mentioned an occasion when he lost forty-three of his oxen, and was puzzled because 'not a score of flies were ever upon them'. At this period, the role of insects as carriers of disease was unheard of; everyone thought that the tsetse flies injected a poison.

Kirk (1865), in an interesting paper to the Linnaean Society, pointed out that the tsetse-disease was not contagious and he quoted various people's estimates of the number of flies sufficient to kill an ox. In the ensuing years scientific opinion accepted the idea that insects might carry parasites pathogenic to man and his livestock.

In 1880, Evans announced the discovery in India of a trypanosome, later named *Trypanosoma evansi* in the blood of horses and camels which were suffering from a disease known as 'Surra'. By this time, clues to the understanding of the nagana problem were available for the first time, but it was not until 1895 that those partners in crime—the tsetse fly and trypanosome were incriminated.

In Zululand, in 1895, Surgeon Major Bruce of the Army Medical Service found trypanosomes, later called *Trypanosoma brucei,* in the blood of cattle suffering from nagana. In his experiment on mechanical transmission of infested tsetse to healthy dogs, he was able to prove conclusively that nagana is carried by tsetse flies. Bruce introduced the nama 'nagana' – a Zulu word which signifies 'a state of depressed spirits'.

The early historical references to human sleeping sickness originated from the western part of Africa and undoubtedly refer to the Gambian form of the disease in which the late stages are often characterised by sleepiness. In those days, the cure was thought to lie in the rousing of the patient from his lethargy.

One of the early signs of sleeping sickness is the presence of enlarged lymph glands in the neck. Certain tribes in Africa have long recognised this symptom and some used to cut the glands in the belief that this would effect a cure. Slave traders, however, appear to consider these tumours as a symptom indicating a disposition to lethargy and they either never buy such slaves or kill them as soon as they observe any such appearance.

Throughout the last century, doctors reported many cases of sleeping sickness along the West coast of Africa from Lobito Bay to Dakar, but more especially from the Congo where it has been recorded that this disease caused about half a million deaths from 1896 to 1906. Until 1902, no one had any idea of what caused sleeping sickness although a number of theories had been put forward such as various bacteria, a type of malaria, sunstroke, hookworm, bad water and beriberi.

The preceding historical account of tsetse flies in relation to trypanosomiasis has been given to highlight how baffling the problem must have appeared to scientists at the end of the last century as no clues could be obtained from the Africans. In 1902, Forde a Colonial Surgeon, discovered trypanosomes in the blood of a man; the trypanosomes were described and named *Trypanosoma gambiense* by Dutton. Castellani (1903, quoted by Nash, 1969) reported that he found trypanosomes in the cerebro-spinal fluid of 70% of sleeping sickness cases. In the same year Bruce, working in Uganda, confirmed his colleague's findings that *T. gambiense* was the causal organism of the disease and the *Glossina palpalis* Robineau-Desvoidy was the vector.

The presentation of the whole problem, for future generations to solve, was almost complete. But one important discovery was made in 1909 when Hearsey recorded the presence of sleeping sickness in districts where *G. palpalis* did not occur and he suggested that there were two different types of the human disease. In 1912, Stephens and Fantham (quoted by Nash, 1969) described a trypanosome from a patient in Rhodesia which was rather different from *T. gambiense* and which they named *Trypanosoma rhodesiense.* This new trypanosome was also found to be more virulent to man than *T. gambiense* and is the causal organism of Rhodesian Sleeping Sickness. *G. morsitans* is the main vector.

History of Tsetse Research

The history of tsetse research is a long one. Austen (1903) produced a monograph of the tsetse flies and Swynnerton's (1936) book on the tsetse flies of East Africa was regarded by the tsetse fraternity as the bible of their cult. It was followed in 1955 by Patrick Buxton's authoritative and encyclopaedic work on the natural history of tsetse flies, often referred to as the gospel according to St. Patrick. Glasgow's book published in 1963 on: "The distribution and abundance of tsetse flies", was a later addition to the general works on tsetse flies but was different from the earlier books in being relatively less voluminous. Apart from these general works there are a number of books on special aspects of tsetse fly and a multitude of scientific papers. The scientific literature on tsetse has increased tremendously in the last four decades that one can confidently state that very few insect species can rival *Glossina* on point of scientific documentation.

In spite of the large volume of information on the biology of the tsetse fly which has been gathered since the turn of the century, with the main objective of facilitating its control, the insect seems to be holding its own pretty well. In making this remark, I intend no disparage-

ment of the efforts of Tsetse Control Units, Departments and Institutes in various parts of Africa; indeed, without them the situation could have been worse.

The distribution of Tsetse Flies in Africa

The genus *Glossina* is distributed over 7 million square kilometres between latitudes 15°N and 28°S on the mainland of Africa and some outlying islands, including Zanzibar (Glasgow, 1963).

The limits of the distribution are determined primarily by the climate, and secondarily by the vegetation, which can often mitigate against the severity of climate. The distribution is closely related to the area of the rain forest, surrounded by savannah, ending in desert or the sea.

The genus is subdivided into three main systematic groups namely, the *palpalis* group, the *morsitans* group and the *fusca* group. These subdivisions are based on texonomic characters of the genital armature which I need not bother you about in this lecture.

The distributions of the *palpalis* group and of the rain forest, are consistent with the view that this is primarily a creature of the rain forest, which by means of certain adaptations, succeeded in extending its range to cover an area greater than the rain forest. The most important species in this group is *G. palpalis*, the great vector of Gambian sleeping sickness. It has an enormous distribution, having adapted itself to many different climatic and vegetational conditions. *G. tachinoides* is also a very important carrier of this form of disease, especially along streams which traverse areas that are too hot and dry for *G. palpalis*. These two species are responsible for most of the sleeping sickness in Africa.

All species of the *morsitans* group are associated with the savannah country which extends from the forests' edge to the desert or the sea. Of all species of tsetse, *G. morsitans* is the greatest scourge. Its vast range through the woody grasslands of West, Central and East Africa enables it to transmit nagana on a colossal scale; it is also the main vector of Rhodesian sleeping sickness (Nash, 1969). The distribution of the *fusca* group is very little different from the sum of the distributions of the *palpalis* and *morsitans* groups. All species of the group probably carry animal trypanosomiasis.

Of recent, the Organisation of African Unity (O.A.U.) with the financial assistance of Nigeria has published, in colour, maps of Africa showing the distribution of species and sub-species of the *palpalis*, *morsitans* and *fusca* groups of *Glossina*.

The Tsetse Fly and the achievement of Independence of its Environment

Tsetse flies are biological peculiarities (Tobe and Langley, 1978). Their peculiar mode of reproduction provides a good example of what I consider to be the achievement of a partial independence of environment.

The female is most willing to mate about three days after emerging from the pupa. In the field, it is common to see a female borne to the ground by more than two males, and thereafter, a struggle ensues in which the victor flies off mounted on the female's back. Pairing may last several hours, but insemination does not take place until just before the couple separate. Once inseminated, the female remains inseminated for life, as the male sperm is stored in two orange-coloured sacs called the spermathecae.

The female has two ovaries which are served by a common duct which leads into the uterus. The ovaries develop single eggs alternately throughout the female's life, but reproduction is by adenotrophic viviparity; that is, the female tsetse fly does not lay eggs, but carries its fertilised egg inside her, in safety, until the young larva is fully grown when the mother literally gives birth. Second and subsequent larvae are deposited at about ten-day intervals. The larva attaches itself to the uterus and draws nourishment from the milk glands of the pregnant female. The larva has the appearance of an ordinary white maggot, characterised by two conspicuous black and hard lobes at its posterior end which play a part in intrauterine respiration. When the larva is finally deposted by the female on the surface of the soil, it burrows to a depth of a few centimetres, contracts to a barrel shape and its skin immediately starts to darken and harden to form a sac called puparium inside which is the pupa. After the period of subterranean development which varies from 20 to 100 days, depending on the temperature (Bursell, 1968), the young tsetse fly emerges from the puparium.

I have described the reproduction of the tsetse fly in some detail because it illustrates clearly what one can consider to be a great feature of tsetse biology, namely, the attainment of a high degree of independence of the environment. The peculiar mode of reproduction, based on far-reaching morphological and physiological specialisations, constitutes an almost complete withdrawal of the developmental stages from the environment.

Some aspects of Advances in Tsetse Research

In this section, attempts will be made to highlight some of the latest research findings which are helping us to get more insight into the workings of this great biological complex.

(i) Rearing and maintaining *Glossina* in the laboratory.

An abundant supply of tsetse flies is an essential requirement for many aspects of research itself. In the last ten years, successful laboratory colonisation of tsetse has been achieved with a number of tsetse species using living host animals as sources of food (Nash et al. 1968;. Nash et al. 1971; Azevado et al. 1968; Mews et al. 1972). The living host animals used for blood meals are goats, guinea pigs and rabbits.

The Tsetse Research Laboratory, University of Bristol at Langford, England, is one of the few laboratories that has developed an effective breeding of *Glossina* at production levels of several thousand individuals. Collaborative efforts in tsetse research have been in existence since 1972 between the Bristol Laboratory and our own laboratory here at Ife. A self-sustaining colony of *Glossina morsitans morsitans* Westwood was established at Langford in 1967 with puparia sent from Rhodesia. Originally, the colony was fed on goats which are excellent hosts for feeding large numbers of tsetse.

In our simple set-up at Ife. with no insectary equipped with special facilities fro controlling weather parameters such as temperature and relative humidity, we have been able to maintain a small colony of *G. morsitans* and *G.* palpalis in an incubator and to feed the flies on lacal rabbits. Although we have achieved good survival rate with this technique, it has only enabled us to maintain a stock of *Glossina* for small-scale experimental work.

Nash et al., (1971) have succeeded in establishing optimal *in vivo* rearing conditions for two tsetse species, *G. austeni* and *G. morsitans morsitans* at the Tsetse Research Laboratory in Bristol, utilising goats and rabbits as the living host animals. This laboratory has thus been able to fulfil its primary objective of meeting requests for large numbers of uninfected flies for experimental work from research workers in the United Kingdom and, embarrassingly, from African countries. The goat-fed colonies of *G. austeni* and *G. morsitans* in Bristol were getting too large by 1972, when I worked in the laboratory as a Visiting Scientist, that they had to be destroyed to reduce the self supporting colony to manageable proportions!

Two other laboratories located in Europe and which have large colonies of tsetse include the Laboratory at Maisons-Alfort in France and the Joint FAO/IAEA Laboratory at Seibersdof, Vienna, Austria. In Africa, laboratories at Kaduna in Nigeria, Nairobi in Kenya and Tanga in Tanzania breed smaller number of tsetse, although the laboratories at Tanga and Kaduna are planning increases in their output.

Although many workers have attempted to feed tsetse flies *in vitro* through a variety of natural and synthetic membranes (e.g. Roubaud, 1917; Lestler and Lloyd, 1928; Cockings, 1961; Mews and Ruhm, 1971; Rogers, 1971; Langley, 1972; Mews, 1972; Mews et al., 1976) only limited success has been achieved using diets of defibrinated cow blood. But very recently, Mews et al. (1977), at the Tsetse Research Laboratory, Bristol, reported a successful techique for the large-scale rearing of *G. morsitans morsitans* and *G. austeni* using exclusively *in vitro* methods and a diet of defibrinated pig blood. This substantial advance in *in vitro* feeding technique for tsetse flies is relevant to large-scale rearing for sterile male control projects, and has implications concerning fundamental research on the physiology of haematophagous arthropods.

The flies are fed under aseptic conditons through membranes made of silicone rubber or of agar and Parafilm overlying blood pools, poured onto grooved glass plates. A hot water circulation system with horizontal glass radiators provides the necessary warmed surfaces at 35-37°C upon which feeding plates and membranes are made.

In our laboratory at Ife, an *in vitro* feeding technique has been successfully developed to maintain *G. palpalis*, and *G. morsitans*. The membrane employed is the wing of the African fruit bat, *Eidolon helvum* kerr and the blood meal is defibrinated bovine blood (Balogun, 1975, 1977). Good survival has been achieved with vigorous aseptic breeding precautions. Because of the ease of preparation, good keeping-quality (if stored in a refregerator) and re-useability of the bat's wing membrane, the technique is considered to be a promising complementary method for the economically large-scale rearing of tsetse flies in the particular context of tropical Africa. Moreover, the bats are available in large numbers at little or no cost.

(ii) Tsetse physology and behaviour

A short review of progress in tsetse physiology was given by Bursell (1963a). In the last 10 years in particular, tsetse flies have been successfully reared in the laboratory and so become available to physiologists in Europe, America and Africa (Langley, 1977a). As far as can be judged. studies have shown that laboratory-bred tsetse are able to res-

pond normally when released in the field. Their reproductive performance is excellent and their behaviour is similar to that of the wild flies (Dame et al. 1975; Vale et al. 1976). This suggests that they are normal flies from the point of view of some aspects of their physiology. In vitro feeding systems clearly broaden the scope for physiological studies which involve manipulation of the diet. In additon, the maintenance of large colonies of blood-sucking insects for use in sterile insect realease programmes is now feasible. Development of synthetic diets is the next logical step as this would eliminate the need for living host animals (Langley, 1977b).

It may be said that the study of tsetse physiology is a modern pursuit. Since the advent of such techniques as immunological assays, paper and ion-exchange chromatography, electrophoresis, autoradiography and isotopic labelling, we have been able to increase our knowledge of tsetse physiology (Balogun et al. 1969a; Balogun, 1969b, 1974a; Moloo et al. 1974).

The active principles from the male accessory glands have now been isolated from several dipterous insects (Tobe and Langley, 1978) and are protein or peptide in nature. Such paragonial substances have not been clearly demonstrated in *Glossina*. However, Balogun (1974b) has reported the presence of a sex-specific ninhydrin-positive compound in the male accessory gland of *G. morsitans* and *G. palpalis;* but the nature of such a paragonial substance and its role in the reproductive physiology of *Glossina* are yet ot be elucidated. Work is in progress at the international Centre of Insect Physiology and Ecology (I.C.I.P.E.), Nairobi on some aspects of the reproductive and salivary gland physiology of tsetse, particularly *G. morsitans*. Sehlein and Lewis (1976) have already shown that immunoglobulins can cross the gut wall of tsetse fly to exert an antibody effect, which has obvious implications for control.

Nitrogenous excretion in tsetse has received deserving attention. The main components of the semi-solid excreta produced by *G. morsitans* are uric acid, arginine, histidine, haematin and a fluorescent pigment with minor components such as urea, ammonia and amino acids other than arginine and histidine (Bursell, 1965). Balogun (1974c) has shown that *B. palpalis* is similar to *G. morsitans* in that its excreta contains similar proportions of arginine and histidine, and a variety of other amino acids occur in the excreta of both species in small amounts.

Gee (1975) has shown that the production of urine by tsetse fly is

controlled by a diuretic hormone which can be extracted from the thoracic ganglion, and the hormone has been shown to induce urine production when injected into flies that are starved. Identification and synthesis of this hormone might have implications for the development of a control technique.

Studies in Rhodesia by Bursell (1963b) and at Ife by Balogun (1974d) have provided information on some aspects of the metabolism of certain amino acids in the tsetse flies, particularly *G. morsitans* and *G. palpalis*. In resting flies the proline content is high and the alanine content low, but during flight, the proline drops sharply while the alanine shows a proportionate increase. It is suggested that proline plays the part of a readily mobilizable energy reserve for flight.

While our knowledge of pheromones has rapidly increased of recent, a deeper understanding of this topic in relation to tsetse flies would be very relevant to the development of new approaches to control. Langley et al. (1975) discovered a sex pheromone gland in the female cuticle of *Glossina* which has led to studies on the physiology of mating behaviour. Pheromones have potential application in mass trapping, population assessment and confusion by disorientation.

PRESENT AND FUTURE STATUS OF TSETSE CONTROL

The main purpose of tsetse control is to reduce the incidence of trypanosomiasis in man and in domestic animals which serve as a major human food source (IDRC, 1974). The success of the destruction of the tsetse vector depends on a realistic assessment of socio-economic and ecological factors in infested regions. The complete eradication of tsetse is at present possible only in limited areas, and elsewhere the advantages of periodic control campaigns should be weighed carefully against their cost (Jordan, 1978).

It is now widely accepted that the tsetse and animal trypanosomiasis problem should be seen as a problem of land use. The strongest possible efforts should be made for the close integration of tsetse control or eradication proposals with planned land development, taking due cognisance of traditional agricultural and livestock practices. Additionally, there should exist local administrative political authorities to enforce agreed land usage proposals.

At present, nearly all methods employed for tsetse control in various parts of Africa depend on the use of insecticides. Techniques such as the clearing of vegetation, on which tsetse depend for shelter, and the

destruction of game animals, on which they depend for food, were widely used in the past, but are now rarely employed. Ground spray techniques with DDT have been extensively used against *G. fuscipes*, *G. palpalis* and *G. tachinoides* in East and West Africa (Glover et al. 1960; Kernaghan, 1961). Techniques for the aerial application of insecticides have been undertaken in Zambia (Park et al. 1972) against *G. morsitans* with treatment of ultra-low-volume endosulfan. Le Roux and Platt (1972) applied dieldrin emulsion to dense thicket habitats of *G. pallidipes* in Kenya. Much more extensive operations using helicopters, primarily against *G. morsitans* have been undertaken in Nigeria with success (Spielberger and Abdurrahim, 1972).

In the current climate of concern for protection of the environment from such pollutants as DDT and dieldrin, there is a need for alternative, but equally effective, insecticides for use in tsetse control programmes. Some of these have already been tested against *Glossina* in both the laboratory and in the field (IDRC, 1974). Although a number of possible alternatives to insecticides are being proposed for the future, it is my considered view that insecticides will still be a main method of tsetse control for many years to come, unless serious resistance problems develop.

The very low reproductive potential of *Glossina* makes it in theory to be particularly vulnerable to control by genetic methods. The sterile male release method relies on the establishment of large productive colonies of tsetse and their releases in large numbers into the natural environment of the same species, after sterilising them with either high energy ionizing radiation or mutagenic chemicals. Both puparia and young adults can be sterilised. The released insects then compete with their wild ones for mates, and since they are sterile they effectively reduce the numbers of offspring produced in the next generation. Successive releases of sterile males can progressively reduce an insect population to the point at which extermination is assured.

The advantages of the technique are that it does not appear to have harmful environmental effects and, unlike other methods of insect control, it is most effective when the density of natural population is low. Its disadvantages include its specificity – if more than one species is to be controlled, more than one species have to be reared and released. The initial costs of colonizing such an insect with low reproductive potential are high. To date there have only been one field assessment of the sterile insect release method with *G. morsitans morsitans* in Rhodesia (Dame & Schmidt, 1970). Puparia which had

been dipped in 5% tepa were released on an island in Lake Kariba and 98% control was obtained in nine months. The population had first been reduced by two aerial applications of dieldrin. If field trials in Tanzania (Williamson, 1974) and Upper Volta (Itard, 1974) prove the efficacy of the technique it may ultimately be possible and desirable, to integrate the release of sterile male *Glossina* with other control methods –perhaps particularly to "mop up" small residual populations after aerial applications of non-persistent insecticides (Jordan, 1974, 1976).

In this connection, it is relevant to mention the cooperative project between the Federal Government of Nigeria and the International Atomic Energy Agency (IAEA) based in Vom, Nigeria which aims at investigating the advantages, efficacy and economics of the sterile insect technique for control or eradication of riverine species of tsetse flies. The implementation phase of the project, according to the IAEA Newsletter No. 24 of December, 1978, became operative from 1st January, 1979. While I feel that the collaborative project is desirable, I would like to suggest to the planners to be aware of the fact that the success of the project among other factors, even at the experimental stage, depends largely on the capacity to rear and sustain *Glossina* at production levels of several million individuals for sterilization.

Tsetse control programmes involve what is now termed a "pest management" or "integrated control" approach – which calls for the combined use of chemical, biological, mechanical and other measures, applied against a background of adequate ecological knowledge of the problem.

Before more practical steps to use other biological control techniques can be employed, there is an urgent need to make an inventory of and characterise the parasites, predators and pathogens of tsetse flies (IDRC, 1974).

Work is in progress in a number of laboratories in Europe and Africa on characterising the effects of juvenile hormones, ecdysones and diuretic hormones, but the formulation of a hormonal insecticide for use against tsetse flies is still speculative. Denlinger (1975) injected juvenile hormone analogue and ecdysterone into pregnant female *G. morsitans morsitans*, and observed that the normal 9-day pregnancy cycle of the flies was disrupted and abortion was induced. The discovery of a sex phenomone in *G. morsitans* by Langley et al. (1975) may have potential for development as an attractant for male flies in the field.

Sulphonamides, which are not normally used as insecticides have

been shown to cause reproductive abnormalities in tsetse flies if they are fed to their hosts (Jordan and Trewern, 1976). Very recent studies in our laboratory at Ife on the effects of samorin, a prophylactic trypanocide on *G. morsitans* showed that samorin affected adversely the survival of the flies at 0.5 mg/kg dose injuected into rabbits on which the flies fed (Oladunmade and Balogun, communicated). The possibility of using samorin in conjunction with strong attractants to control tsetse flies, especially on cattle ranches where fly-livestock contact is high is suggested.

In the light of the above discussion, I believe there is considerable justification for support for physiological research on tsetse flies, the thrust for which will probably continue to be the prospect of developing new insecticidal techniques. Due credit must be given to those who pioneered laboratory–rearing techniques for tsetse, because these have allowed physiologists and experimental biologists who are not involved in control peogrammes, access to tsetse fly as a research animal. This has contributed to the recent increase in our knowledge of tsetse physiology and hopefully with continue to improve our understanding of the biology of this notorious pest in tropical Africa.

INTERNATIONAL COOPERATION IN TSETSE RESEARCH AND CONTROL

There is an increasing awareness of the international nature of the problems associated with tsetse flies. As a consequence of such awareness, it is now being accepted that tsetse problems can only be tackled through large-scale international effort.

It is appropriate to mention, in this connection, the significant and positive role that external agencies such as the Ministry of Overseas Development (O.D.M.), U.K., the Food and Agricultural Organisation (F.A.O.), and the World Health Organisation (W.H.O.) are playing. The O.D.M. already has programmes on tsetse reasearch and control in Nigeria, Sudan, Botswana, Tanzania, the Somali Republic and Zambia. The F.A.O. has launched a continent-wide programme for the control of tsetse in the open savannah, while the W.H.O. has started a Special Programme of Research and Training in Tropical Diseases, one of which is African trypanosomiasis.

At this juncture, I would like to commend these international agencies, research centres, laboratories and University Departments of non-African countries for their contributions to the solution of the problems of tsetse and trypanosomiasis in tropical Africa.

The Organisation of African Unity has, during the last decade or so, through its International Scientific Council for Trypanosomiasis Research and Control (ISCTRC), arranged international conferences and seminars where entomologists, medical doctors, veterinarians, chemists, biochemists and physiologists met to exchange views on current advances in tsetse and trypanosomiasis reasearch and control. The O.A.U. initiatives on the tsetse problem are most welcome and one would hope that such efforts will be intensified not only in the coordination of control projects against *Glossina*, but also in the provision of financial support for tsetse and trypanosomiasis reasearch in tropical Africa.

All African countries affected by the tsetse and trypanosomiasis problem should accept the fact that major projects on tsetse research would stand a better chance of success if they are based in African research centres, where a close integration between field and laboratory work can be sustained. In this connection, I would like to state that it is high time that African countries affected by the tsetse menace provided funds for the establishment of at least one or two tsetse large-scale rearing centres within Africa. Such centres would ensure adequate and sustained supply of tsetse puparia to tsetse research scientists in Africa for experiemental work. The centres could be based at the International Centre of Insect Physiology and Ecology (I.C.I.P.E.) in Nairobi, the Nigerian Institute for Trypanosomiasis Research (N.I.T.R.) Kaduna, the East Africa Trypanosomiasis Research Organisation (E.A.T.R.O) in Uganda, etc. It is embarrassing to note that tropical Africa, which is plagued with the tsetse and trypanosomiasis problem really has no such fundamental facility for tsetse research.

In practice, the entomologist concerned with tsetse flies knows that although conditions differ locally, there is a large amount of entomological knowledge which applies throughout the tsetse-infested areas of Africa. It seems important, therefore, to exchange information, personnel and experience in technical advances relating to tsetse and traypanosomiasis control.

In the light of the above, I would urge all member states of the O.A.U. which are faced with the problems of tsetse and trypanosomiasis to:

(i) provide increased financial support to centres involved in research on tsetse and trypanosomiasis control;

(ii) increase the number of indigenous personnel at all levels involved in the control of human and animal trypanosomiasis;
(iii) organise a system to provide short and long-term training in different parts of Africa for personnel involved in tsetse work;
(iv) intensify inter-African co-operation in research and the control of tsetse and trypanosomiasis through joint projects.

CONCLUSION

Today sleeping sickness is no longer the scourge it used to be in many parts of tropical Africa; thanks to the work of medical doctors, scientists, control officers, and to their middle level field personnel. However, there are still many such endemic foci where the disease needs to be controlled urgently.

Under the present situations, animal trypanosomiasis (nagana) is of far greater economic importance than sleeping sickness in many parts of tropical Africa. It is of much greater medical importance, if the broad view is taken that a deficiency in animal protein among the masses is far more important than a specific disease among the few. According to the National Research Council of the United States of America the normal intake of protein should be 80 grams per day, of which 30 grams should be animal protein. Nicol's frindings in the tsetse-infested middle belt of Nigeria show a total intake of 70 grams, with only 5 grams taken as animal protein (Nash, 1969).

But for nagana both the meat and milk yields of African cattle could be considerably improved by crossing with European breeds. Unfortunately, the latter are highly susceptible to trypanosomiasis. According to the F.A.O., if tsetse and trypanosomiasis could be controlled, it would be possible to increase the cattle population of Africa by 125 million head.

Finally, Vice-Chancellor, distinguished guests, ladies and gentlemen, as we look to the future, one can see new events and an ever widening role for glossinology in the service of mankind. We have tried, during the last seventy-five years, to grapple with the problems of tsetse and trypanosomiasis in tropical Africa. But we cannot yet despair of losing the entire battle. We will continue to co-exist with tsetse flies using an increasingly sophisticated range of techniques. With our present knowledge of tsetse biology, physiology and behaviour, with financial support and efficient co-ordination among the countries concerned, it should be possible within the next decade to reduce considerably the widespread crime committed against the people of tropical Africa by the tsetse flies and the trypanosomes which they carry.

References

1. Austen, E.E. (1903). "A monograph of the tsetse flies (genus *Glossina* Westwood) based on the collection in the British Museum." London: British Museum (Nat. Hist.).
2. Azevedo, J.F. De, Pinhao, R., Santos, A.M.T. Dos and Ferreira, A.E. (1968). "Studies carried out with the *Glossina morsitans* colony of Lisbon. I. Some aspects of the evolution of the *Glossina morsitans* colony of Lisbon." An. Esc. noc. Saude publica e Med. trop. *2:* 19-42.
3. Baldry, D.A.T., and Riordan, K. (1967). "A review of 50 years entomology of insect-borne diseases of veterinary importance in Nigeria, with special reference to tsetse flies and trypanosomiasis." Proc. ent. Soc. Nigeria, 43-55.
4. Balogun, R.A., Hanniman, F., and Chen, P.S. (1969a): "Separation of free amino acids and derivatives in the tsetse fly *Glossina palpalis* (Diptera) by ion-exchange chromatography." Experentia *25:* 93-95.
5. Balogun, R.A. (1969b). "Amino acids in pupa of tsetse fly (*Glossina palpalis*)." Comp. Biochem/Physiol., 30: 785-787.
6. Balogun, R.A. (1974a). "Studies on the amino acids of the tsetse fly, *Glossina morsitans*, maintained on *in vitro* and *in vivo* feeding systems." Comp. Biochem, Physiol., *49A:* 215-222.
7. Balogun, R.A. (1974b). "A sex-specific ninhydrin-positive component detected in the accessory glands of adult male tsetse flies (Deptera, Glossinidal)." Nigerian J. Ent. *1(1):* 13-16.
8. Balogun, R.A. (1974c). "Amino acids in the excreta of the tsetse fly, *Glossina palpalis.*" Experientia *30:* 239-240.
9. Balogun, R.A. (1974d). "Some aspects of amino acid metabolism in the tsetse fly *Glossina palpalis.*" Nigerian J. Ent. *1:* 17-19.
10. Balogun, R.A. (1975). "Bat's wing membrane for artificial feeding of tsetse flies." Nigerian J. Ent. *1(2):* 181-183.
11. Balogun, R.A. (1977). "Maintenance of *Glossina palpalis* fed through bat's wing membrane on defibrinated blood." Acta Tropica, *34:* 321-325.

12. Bruce, D. (1895). Preliminary report on the tsetse fly disease or nagana in Zululand. Bennet and Davis, Durban, 28 pp.
13. Bruce, D. (1896). Further report on the tsetse fly disease or nagana in Zululand. Harris and Sons, London. 69 pp.
14. Bruce, D., Nabarro, D., and Greig, E.D.W. (1903). "Sleeping Sickness." J. trop. Med., *6:* 358.
15. Bursell, E. (1963a). "Tsetse Physiology. A review of recent advances and aims." Bull. Wld. Hlth Org. *28:* 703-709.
16. Bursell, E. (1963b). "Aspects of the metabolism of amino acids in the tsetse fly, *Glossina* (Diptera)." J. Insect Physiol., *9:* 439-452.
17. Bursell, E. (1965). "Nitrogenous waste products of the tsetse fly, *Glossina morsitans."* J. Insect Physiol., *11:* 993-1001.
18. Bursell, E. E. (1968). "A prospect of tsetse flies." Inaugural lecture given in the University College of Rhodesia. 26 pp.
19. Buxton, P.A. (1955). The natural history of tsetse flies. Lewis, London.
20. Carter, R.M. (1906). "Tsetse fly in Arabia." Br. Med. J., *2:* 1393-1394.
21. Cockerell, T.D.A. (1919). "New species of North American fossil beetles, cockroaches and tsetse flies." Proc. U.S. natn. Mus., *54:* 310-311.
Cockings, K.L. (1961). "Laboratory maintenance of *Glossina pallidipes."* Rep. E. Afr. Trypan. Res. Org. 1960, 32-33.
23. Dame, D.A. and Schmidt, C.H. (1970). "The sterile-male technique against tsetse flies, *Glossina* spp." Bull. ent. Soc. Amer. *16:* 24-30.
24. Dame, D.A., Birkenmeyer, D.R., Nash, T.A.M., and Jordan, A.M. (1975). "The dispersal and survival of laboratory-bred and native *Glossina m. morsitans* Westw. (Diptera, Glossinidae) in the field". Bull. ent. Res. *65:* 453-457.
25. Denlinger, D.L. (1975). "Insect hormones as tsetse abortifacients" Nature, Lond. *253:* 347-348.
26. Gee, J.D. (1975). "The control of dieuresis in the tsetse fly *Glossina austeni:* a preliminary investigation of the diuretic hormone." J. exp. Biol., *63:* 391-401.
27. Glasgow, J.P. (1963). The distribution and abundance of tsetse. Pergamon Press, Oxford.
28. Glover, P.E., Le Roux, J.G. and Parker, D.F. (1960) "The extermination of *Glossina palpalis* on the Kuja-Migori river systems with the use of insecticides." ISTCR, Brussels, 1958, 331-342.
29. IAEA/FAO (1978). "Radiation techniques and their application to insect pests." Information Circular No. 24, December, 1978.
30. International Development Research Centre (1974). "Tsetse control: The role of pathogens, parasites and predators." Report of a Scientific Advisory Group, St. John's, 1974.
31. Itard, J. (1974). "The present state of colonies of *Glossina* at Maisons-Alfort (France)." Proc. 3rd Int. Cong. Parasitol. Munich, 1974, 940.
32. Jordan, A.M. (1974). "Recent developments in the ecology and methods of control of tsetse flies (*Glossina spp.*) Dipt., Glossinidae) – a review." Bull. ent. Res. *63:* 361-399.
33. Jordan, A.M. (1976). "Tsetse control–present and future." Trans. Roy. Soc. trop. Med. Hyg., *70:* 128-129.
34. Jordan, A.M. and Trewern, M.A. (1976). "Sulphaquinoxaline in host diet as the cause of reproductive abnormalities in the tsetse fly (*Glossina* spp.)" Entomologia exp. appl. *19:* 115-129.
35. Jordan, A.M. (1978). "Principles of the eradication or control of tsetse flies." Nature, Lond. *273:* 607-609.
36. Kernaghan, R.J. (1961). "Insecticidal control of the vectors of human trypanosomiasis in Northern Nigeria." J. trop. Med. & Hyg., *64:* 303-309.
37. Kirk, J. (1865). "On the tsetse fly of tropical Africa (*Glossina morsitans* Westwood)." J. Linn. Soc. (Zool.), *8:* 149-156 (IIa).
38. Langley, P.A. (1972). "The role of physical and chemical stimuli in the development of *in vitro* feeding techniques for tsetse flies *Glossina spp.* (Dipt., Glossinidae)." Bull. ent. Res. *62:* 215-218.
39. Langley, P.A., Pimley, R.W., and Carlson, D.A. (1975). "Sex recognition pheromone in tsetse fly *Glossina morsitans."* Nature, Lond., *254:* 51.53.
40. Langley, P.A. (1977a). "Physiology of Tsetse flies (*Glossina spp.*) (Diptera: Glossinidae): a review." Bull. ent. Res. *67:* 523-574.
41. Langley, P.A. (1977b). "Tsetse Physiology." Trans. Roy. Soc. trop. Med. Hyg. *71:* (1) 5-6.
42. Le Roux, J.G. and Platt, D.C. (1972). "Application of dieldrin invert emulsion by helicopter for tsetse control." ISCTR, Bangui, 1968, 219-229.
43. Lestler, H.M.O. and Lloyd, L. (1928). "Notes on the process of digestion in the tsetse flies." Bull. ent. Res. *19:* 39-60.
44. Mews, A.R. and Ruhm (1971). "Maintenance of *Glossina morsitans* Westwood fed through an artificial membrane on defibrinated blood." In sterility principle for insect control or eradication 283-293, I.A.E.A., Vienna.

45. Mews, A.R. (1972). "Supplementing the diet of membrane-fed *G. morsitans* by feeding on rabbits' ears once per week". Trans R. Soc. trop. Med. Hyg. *66:* 306-307.
46. Mews, A.R., Offori, E., Baumgartner, H. and Luger, D. (1972). "Techniques used at the IAEA laboratory for rearing the tsetse fly *Glossina morsitans* Westw. In ISCTR 13th Meeting, Lagos, 1971, 243-254.
47. Mews, A.R. Baumgartner, H. Luger, D. and Offori, E.D. (1976). "Colonisation of *Glossina morsitans morsitans* Westw. (Diptera, Glossinidae) in the laboratory using *in vitro* feeding techniques." Bull. ent. Res. *65:* 631-632.
48. Mews, A.R., Langley, P.A., Pimley, R.W. and Flood, M.E.T. (1977). "Large-scale rearing of tsetse flies (*Glossina* spp.) in the absence of a living host." Bull. ent. Res. *67:* 119-128.
49. Moloo, S.K., Langley, P.A., and Balogun, R.A. (1974). "Amino acid synthesis from glucose-U-14C in *Glossina morsitans."* J. Insect Physiol. *20:* 1807-1813.
50. Nash, T.A.M., Jordan, A.M., and Boyle, J.A. (1968). "The large-scale rearing of *Glossina austeni* Nowst. in the laboratory IV.—The final technique. Ann. trop. Med. parasitol. *62:* 336-341.
51. Nash, T.A.M. (1969). Africa's bane the tsetse fly. Collins, London.
52. Nash, T.A.M., Jordan, A.M. and Trewern, M.A. (1971). "Mass rearing of tsetse flies (*Glossina* spp.): recent advances. In sterility principle for insect control or eradication, pp. 99-110. I.A.E.A., Vienna.
53. Oladunmade, M. and Balogun, R.A. (1979). "Effects of samorin on some aspects of the biology of *Glossina morsitans* Westwood." Nigerian J. Ent. (Communicated).
54. Park, P.O., Gledhill, J.A., Alsop, N. and Lee, C.W. (1972). "A large-scale scheme for the eradication of *Glossina m. morsitans* Westw. in the Western Province of Zambia by aerial ultra-low-volume application of endosulfan." Bull. ent. Res. *61:* 373-384.
55. Rogers, A. (1971). "Preliminary observations on an apparatus for the artificial feeding of tsetse flies." Ann. trop. Med. Parasit. *65:* 409-413.
56. Roubaud, E. (1917). "Histoire d'un elevage de *Glossina morsitans* a l'Institut Pasteur de Paris." Bull. Soc. Path. exot. *10:* 629-640.
57. Schlein, Y. and Lewis, C.T. (1976). "Lesions in haematophagous flies after feeding on rabbits immunized with fly tissues." Physiol. Ent., *1:* 55-59.

58. Spielberger, U. and Abdurrahim, U. (1972). "Pilot trial of discriminative aerial application of persistent dieldrin deposits to eradicate *Glossina m. sub morsitans* in the Anchau and Ikara forest reserves, Nigeria, 1971". ISCTR, Lagos, 1971, 271-281.
59. Swynnerton, C.F.M. (1936). "The tsetse flies of East Africa. A first study of their ecology with a view to their control." Trans. R. ent. Soc. Lond., *84:* 1-579.
60. Tobe, S.S. and Langley, P.A. (1978). "Reproductive Physiology of *Glossina,"* Ann. Rev. Entomol. *23:* 283-307.
61. Vale, G.A., Hargrove, J.W., Jordan, A.M., Langley, P.A. and Mews, A.R. (1976). "Survival and behaviour of tsetse flies (Diptera, Glossinidae) released in the field: a comparison between wild flies and animal-fed and in-vitro fed laboratory-reared flies." Bull. ent. Res. *66:* 731-744.
62. Wiedemann, C.R.W. (1830). "Aussereuropaische zweiflugelige." Insekten pt. II: 253-254.
63. Williamson, D.L. (1974). "The biology and mass rearing of *Glossina morsitans* in Tanzania." Proc. 3rd International Congr. Parasitol, Munich, 1974, 941.