BIBLIOGRAPHIC DATA SHEET

1. CONTROL NUMBER
PN-AAH-531

2. SUBJECT CLASSIFICATION (695)
NS00-0000-G110

3. TITLE AND SUBTITLE (240)
Tsetse and trypanosomiasis control; a strategy for the future in Africa

4. PERSONAL AUTHORS (100)

5. CORPORATE AUTHORS (101)
Interafrican Bureau for Animal Resources

6. DOCUMENT DATE (110)
1979

7. NUMBER OF PAGES (120)
60p.

8. ARC NUMBER (170)
AFR616.9363. I61

9. REFERENCE ORGANIZATION (130)
IBAR

10. SUPPLEMENTARY NOTES (500)

11. ABSTRACT (950)

12. DESCRIPTORS (920)
Africa
Tsetse flies
Trypanosomiasis, Bovine
Trypanosoma
Veterinary medicine
Disease control
Vaccines

13. PROJECT NUMBER (150)
698013500

14. CONTRACT NO.(140)
AID-698-001-T

15. CONTRACT TYPE (140)

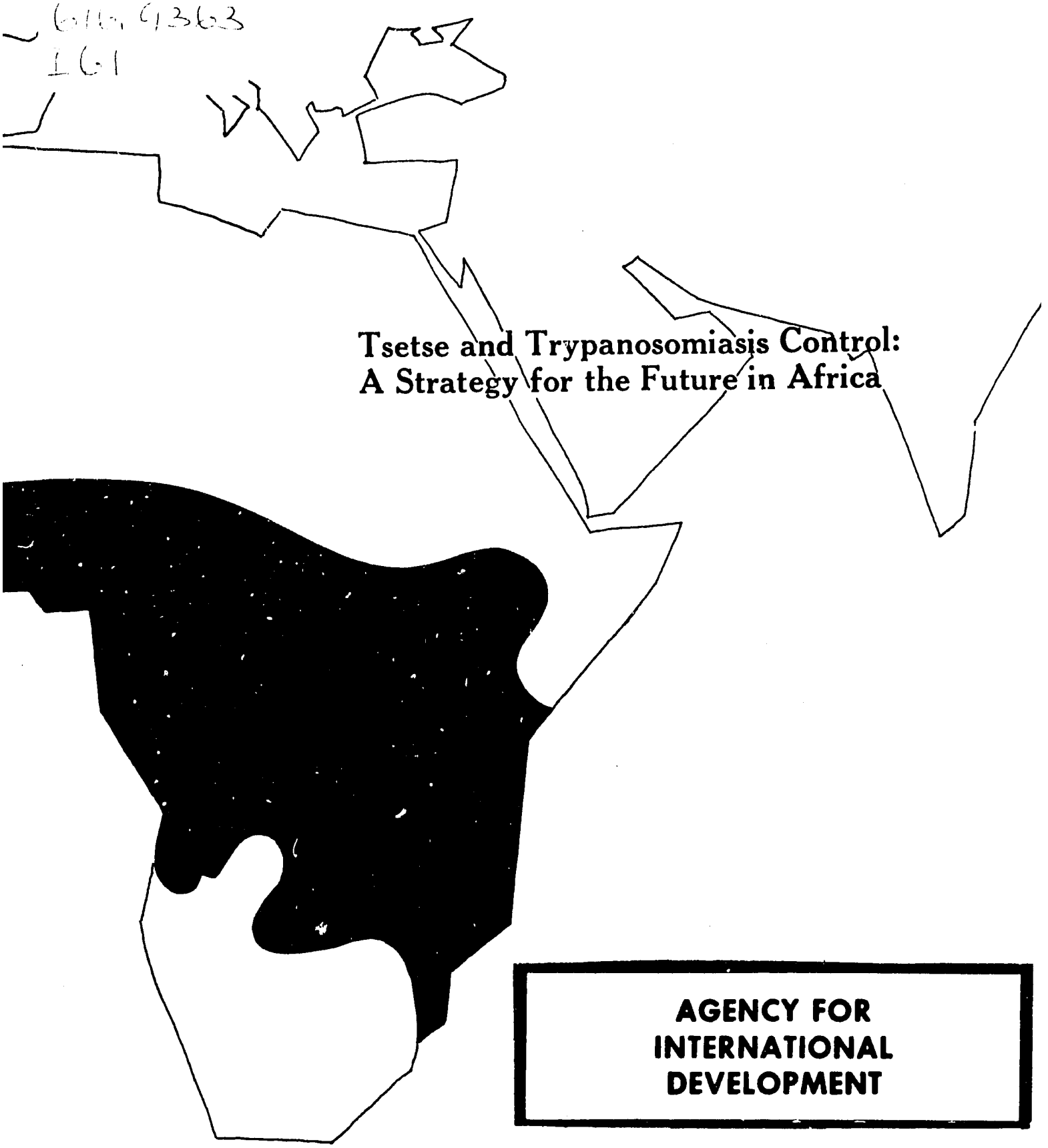
16. TYPE OF DOCUMENT (160)

AID 590-7 (10-79)

HTR
6116 43363
161

PN-AAH-531

Tsetse and Trypanosomiasis Control: A Strategy for the Future in Africa



AGENCY FOR INTERNATIONAL DEVELOPMENT

Organization of African Unity

Interafrican Bureau for Animal Resources

TSETSE AND TRYPANOSOMIASIS CONTROL:

A STRATEGY FOR THE FUTURE IN AFRICA

Based on

the Deliberations of

an International Task Force

Under the Auspices of IBAR

and

Sponsored by USAID

Organization of African Unity

Interafrican Bureau for Animal Resources

Printed in the United States of America

This publication was produced for IBAR by
The Rockefeller Foundation, 1133 Avenue of the
Americas, New York, New York 10036.

CONTENTS

Illustrations v

Preface and Acknowledgments vii

Task Force Members xi

The Charge of the Task Force 1

The Problem and Its Magnitude 2

Tsetse and Their Habits 3

Trypanosomiasis 6
In Animals
Human Sleeping Sickness

Goals and Strategies for Trypanosomiasis Control 12

Goals 12
Economic and Social Development
Effective National and Regional Tsetse/ Trypanosomiasis Control

Strategy 14
Improving National Capabilities

Basing Future Initiatives on Current Activities 35

Conclusions and Recommendations 43

Additional Reading 48

Acronyms 51

ILLUSTRATIONS

Tsetse fly: trypanosome carrier causing sleeping sickness in man and trypanosomiasis in livestock 2

Structure of the trypanosome 4

Zebu infected with trypanosomiasis 6

Sleeping sickness in man 10

PREFACE AND ACKNOWLEDGMENTS

Tsetse flies and the trypanosomes they transmit, which cause sleeping sickness in man and nagana (trypanosomiasis) in livestock, have plagued the livestock industry and the people of the African continent since long before recorded history. They will continue to do so far into the future. In historical times, men and their beasts could move freely to avoid the habitats of the fly and the ravages of the disease, but today on the continent of Africa, man-fly and livestock-fly contacts are ever more frequent and in many cases unavoidable. More than 100 years of investigation and at least 75 years of careful research on tsetse and on trypanosomes have given us the wealth of information and experience that underpin today's action programs and research. Among tropical diseases, the literature on tsetse and trypanosomiasis is probably second only to the literature on mosquitoes and malaria in volume and in its contribution to science. Any modern investment in the management of the fly and the control of the disease must use the materials and tools fashioned from the experience gained in previous years.

This task force on tsetse and the trypanosomiases affecting human beings and domestic livestock originated in a need for advice and counsel that the United States Agency for International Development (USAID) felt crucial for advancing its own action and research programs in relation to the many other projects and programs African governments and bilateral and multilateral donor agencies sponsor.

The organizational committee of the task force met on February 7-8, 1978, in Nairobi, Kenya, at the Interafrican Bureau of Animal Resources (IBAR) headquarters, where it produced a tentative outline of activities, settled on the initial issues, and considered the composition of the task force. On June 15-16, the chairman and the secretary of this committee met informally with representatives of the Food and Agriculture Organization of the United Nations (FAO) and the World Health

Organization of the United Nations (WHO) at FAO headquarters for further discussion. The task force as then constituted met at Bellagio, Italy, over June 21-26, 1978. Members attending discussed the subject matter thoroughly, outlined and drafted sections of the report, and established a steering committee. At Heathrow, England, on September 21-22, the steering committee reworked the outline of the report, planned future activities, and recommended additional experts to be included as task force members. It also recommended that the report be previewed by prominent veterinary scientists and policy makers of African governments. From November 28 through December 1, the task force met in Nairobi at the International Laboratory for Research on Animal Diseases (ILRAD) to deliberate over the draft report and submit suggestions and criticisms.

Subsequently, on June 20-24, 1979, the steering committee met in Bellagio, where it discussed the comments and suggestions of task force members which emanated from draft material following the Nairobi meeting. The steering committee reached general agreement on the text of the final report. It authorized the chairman to put the report in final form, giving due consideration to the comments and suggestions registered by the members and to the agreements reached at this meeting. On September 5, 1979, the chairman mailed to each task force member the final version of the report; a roster of task force members is set forth herein. The report was then presented to IBAR for publication under its indicia. Simultaneously, the chairman transmitted the report on behalf of task force members to USAID and to the Organization of African Unity/Scientific, Technical and Research Commission (OAU/STRC). IBAR is to distribute it to African governments and to international organizations and agencies.

The task force is comprised mainly of experts from African governments, universities, veterinary and health departments; from the international organizations FAO, WHO, the United Nations Development Programme (UNDP), OAU; from the institute ILRAD, supported by the Consultative Group on International Agricultural Research (CGIAR); from the

International Centre of Insect Physiology and Ecology (ICIPE); and from donor agencies. To these experts and to other individuals, all who served in their professional capacities, the chairman and sponsors are grateful. They have been essential to the completion of the work and the production of this report. The task force thanks The Rockefeller Foundation for the use of its Bellagio Study and Conference Center, where crucial meetings took place in the development of its work; OAU/IBAR for its liaison with African governments and institutions and its services as a contracting agency; ILRAD for making available its conference facilities with simultaneous translation; USAID for its financial support; and the task force staff for their unflagging diligence.

TASK FORCE MEMBERS

Dr. John J. McKelvey, Jr., Chairman*

Dr. Protus G. Atang, Secretary*

Dr. T. Allison
Dr. H. Buyst
Dr. Albert M. Challier
Dr. David A. Dame
Dr. Peter deRaadt*
Dr. Pierre Finelle*
Dr. Howard C. Goodman
Dr. J. Gruvel
Dr. Jacques Hamon
Dr. Albert A. Ilemobade
Dr. Anthony M. Jordan*
Dr. K. M. Katondo
Dr. G. L. Kazyumba
Dr. Nels Konnerup*
Dr. G. C. Labrecque
Dr. Cliff W. Lee
Dr. J. G. LeRoux
Dr. K. J. R. MacLennan
Professor Ian McIntyre*
Mr. William A. C. Mathieson
Dr. S. K. Moloo
Professor D. H. Molyneux
Dr. Max Murray*
Dr. Harry Mussman
Dr. B. K. Na'Isa
Dr. Adriel R. Njogu
Professor T. Odhiambo*
Dr. Ordway Starnes*
Dr. Andre M. V. Van Der Vloedt

Participants
Task Force Meeting - November 1978

Dr. M. Abdillahi
Dr. G. I. Akafekwa
Dr. G. Duvallet
Dr. Y. Houba
Dr. B. N. Touray

Staff

Ms. Avis Berman
Ms. Selina Coelho
Ms. Cynthia Grenafege
Ms. Rita Lipsky
Ms. Mary Siedenstrang

*Steering committee member

THE CHARGE OF THE TASK FORCE

USAID, in seeking its best operational and research efforts for helping to combat tsetse and trypanosomiasis, asked the task force to deal with the following issues:

1. How appropriate are proposed tsetse/trypanosomiasis control programs? How effective are existing ones?

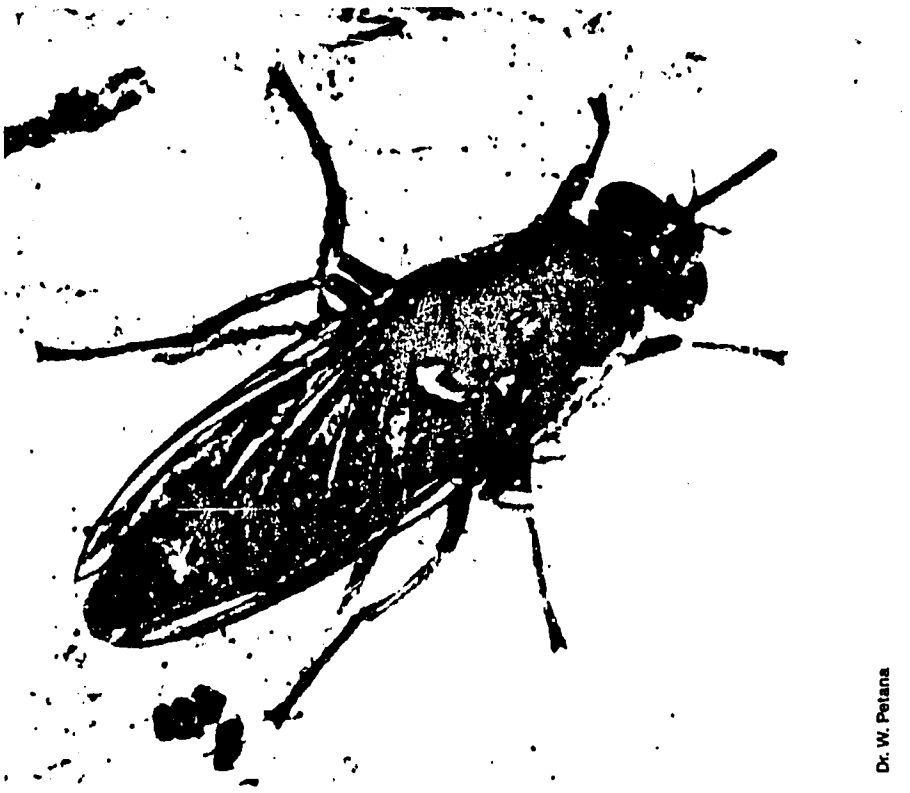
2. What operational and research needs should be met to improve the impact of such programs?

3. What, if any, gaps occur in international programs? Particular emphasis should be placed on ascertaining deficiencies in preplanning and land-use capability studies; site management and environmental impact, especially with regard to control activities expanding into new areas, and interrelationships with other prevalent diseases.

4. What studies are needed of tsetse fly ecology and distribution and what research on developing technologies for control that will minimize reliance on the use of pesticides?

5. What would a model tsetse and trypanosomiasis control program look like?

The task force holds the view that a model program can only be an integrated one in the most comprehensive sense of the term. It should start with a thorough knowledge of the problem and its magnitude; take into consideration the socioeconomic goals that individual nations wish to achieve in resolving the problem; deal with national and regional capabilities for tsetse and trypanosomiasis control; and depend on a sound technical strategy for combating tsetse and controlling the disease. Plainly, such a program must be based on a comprehensive understanding of existing programs and how they may be coordinated, as well as a clear identification of those gaps in research and operations that need to be filled. This report takes up these points in succession.



Tsetse fly: trypanosome carrier causing sleeping sickness in man and trypanosomiasis in livestock

Combating tsetse, Glossina spp., and controlling trypanosomiasis[1] in livestock or sleeping sickness in man in the widest sense means dealing with 22 species of flies and at least six species of trypanosomes; understanding the intricate relationships linking vector, host, and disease organisms; and realizing the ineluctable fact that both

1. Trypanosomiasis more accurately designates the disease in livestock today than does nagana, so the task force uses trypanosomiasis throughout the report.

vector and parasite are shifty in character in their attack on the people, domestic livestock, and wildlife of Africa. Simplified, vastly simplified, however, the problem narrows to a technical one of coping with five or six species of fly occupants of savanna, riverine, and forested areas, and with three subgenera of trypanosomes, each having fairly circumscribed host preferences but capable of adapting to other hosts.

But coping with tsetse flies and trypanosomes per se would merely have academic significance were it not for the suffering, the deaths, indeed, the epidemics these organisms have caused in human beings and what they portend in the future and were it not also for the economic loss they bring about by barring millions of hectares of choice land from the production of livestock. Furthermore, once tsetse and trypanosomiasis are removed from areas they occupy, any land development will require keen sensitivity to the socioeconomic as well as to the ecological problems inherent in opening new areas.

Tsetse and Their Habits

Tsetse belong to the wilds (bush and forest) of Africa, but like certain species of mosquitoes, they can and do invade domestic sites. They prey on man and beast, mainly at the interfaces of cropland, pasture, and bush. When the pressures of populations, with their attendant demands for food and fibers, stimulate man's encroachment of bush and forested land, they become embroiled in the controversy of clearing the land and exposing it to the vicissitudes of development or leaving it undisturbed, with tsetse and trypanosomiasis guarding it in its pristine condition.

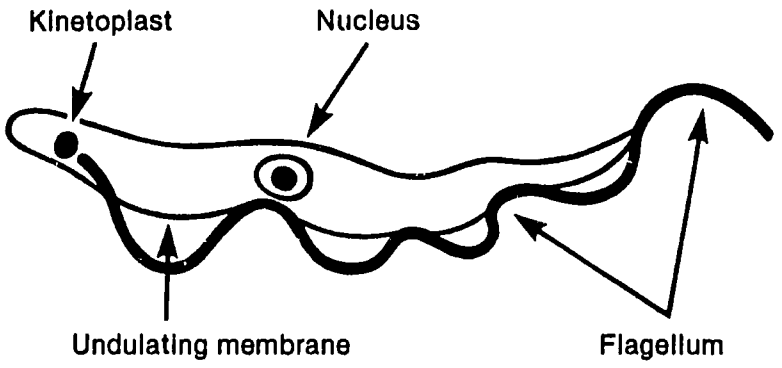
Glossina morsitans (its subspecies), *G. pallidipes*, and *G. longipalpis* are the main vectors carrying trypanosomes to animals over the savanna belt of Africa, whereas *G. tachinoides*, *G. palpalis*, and *G. fuscipes* transmitters of *gambiense* sleeping sickness to man and livestock dominate the riverine and forested areas. *G. morsitans morsitans* is the main vector of rhodesiense sleeping sickness in man. The

life cycles of these tsetse are similar, but the species and the subspecies are particular about the ecological niches they occupy.

After the male and female have paired, which may take up to five hours, the female is fertilized for the rest of her life. A fertilized tsetse may fly into a region which no others inhabit. Still she will continue to produce fertile eggs for the remainder of her life--which can be as long as 200 days. A tsetse female produces eggs, but she does not lay them as do ordinary flies. She will hatch out a single egg inside her own body and feed the larva through special glands. Within the female the young larva will then shed its skin three times. One larva is born at a time and it appears as a whitish maggot 5 to 7 mm long.

The female fly often chooses shady, loose soil in which to place her young, and there the larva burrows from sight within 20 minutes. Once inside the ground, the skin of the larva hardens into a brown pupa. Within 35 days the maggot inside the pupal case changes into an adult fly. A fertilized female bears only two or three larvae a month.

To feed, an adult female will puncture the skin of man or animal, guzzle blood and trypanosomes (if the animal is infected), which will then travel down her digestive tract and distend the abdomen. From



Structure of the trypanosome

there the trypanosomes, long and slender, make their way through the various parts of the gut to the salivary glands or proboscis. In the process they are transformed to metacyclic forms, short and stumpy, which are inoculated subsequently with the saliva into animal or man as the fly sucks up another blood meal. Important intricacies in the passage of the trypanosomes through the tissues of the insect have as yet to be revealed. This stage in the cycle of the trypanosomes may influence their virulence, for in their transformation in the insect to metacyclic forms they seem to revert to the parental or basic type.

Variations occur, of course, in any stylized version of tsetse processing trypanosomes. Some evidence has accrued that flies other than tsetse can transmit certain species of trypanosomes between mammalian hosts, but their effective role in transmission of the disease needs to be studied further.

According to Bruce,[2] who first observed them, trypanosomes reside, multiply in the blood, "seize upon and worry the red blood corpuscles," sap them of nutrients, and ultimately (Trypanosoma brucei) invade the cerebrospinal fluid of the host. Once established within the host, the trypanosome exhibits remarkable powers of adaptation to escape host reactivity, a phenomenon known as antigenic variation. In this process, the trypanosome is able to undergo an apparently inexhaustible series of variation of its surface antigens and so evade the host's immune response. Accordingly, the numbers of parasites in the blood fluctuate due to the destruction of trypanosomes by the host's antibodies and the emergence of parasites of different antigenic constitution. As a result, the parasite is able to survive within the host and produce an ongoing disease and an immunological situation that has thus far thwarted the creation of an effective vaccine.

2. David Bruce. Preliminary Report on the Tsetse Fly Disease, or NAGANA, in Zululand (Durban: Bennett and Davis, 1895).

Trypanosomiasis

In Animals

T. congolense, *T. vivax*, *T. simiae*, and *T. brucei* constitute the main species of trypanosomes that individually or associated one with another cause disease in livestock.

Zebu infected with trypanosomiasis

Within a few days of being bitten by an infected tsetse fly, livestock develop a raised cutaneous swelling several centimeters in diameter. This is the chancre, and it persists for several days. Its onset precedes parasitemia (the appearance of parasites in the blood) by

a few days and is accompanied by the development of fever and marked enlargement of the draining lymph nodes. The parasites become established in the bloodstream, where they undergo antigenic variation until the death of the host or until the host recovers spontaneously.

The cardinal clinical sign of African trypanosomiasis is anemia. Infected cattle cease grazing in the heat of the day. Typically they become dull and lethargic, trekking well behind the rest of the herd. In extreme cases, they become recumbent and characteristically place their mandible on the ground, apparently lacking the strength to hold their heads up. Reflecting the anemia, the pallor of oral and conjunctival mucous membranes can be marked. While fever occurs, it can be difficult to assess because of the extremes in rectal temperatures that normal animals register in tropical and subtropical areas.

The disease occurs in forms ranging from acute to chronic. Many animals die within weeks of becoming infected, although they may appear to be in good condition at the time of death. Occasionally an animal has recovered spontaneously, and many will linger for months--even years. Animals with a persistent low-grade anemia, signifying that the trypanosomes are few in number and hard to find in the blood, express the chronic phase of the disease. They show marked wasting, they are usually stunted and in poor condition, and the ever-present anemia reduces their capacity to forage. This weakness in turn limits their ability to produce beef for consumption or calves for a new generation. These chronically nonproductive animals populate grazing areas without producing an economic return, and many females that conceive may abort, adding further to the loss. Abortions sometimes to the extent of "storms" can occur. What calves are born tend to be premature or very small. Although infected animals do show a willingness to eat and drink, their food intake falls as the disease progresses, possibly a result of lethargy plus inability to forage.

The immediate cause of death in infected livestock is acute congestive heart failure, which develops as a result of anemia and damage to the heart muscle.

Economic Impact

Throughout the 36 countries[3] in tropical Africa in which it prevails, trypanosomiasis causes more losses of livestock than does any other disease. It kills or disables camels, horses, pigs, sheep, dogs, and goats. The incidence of the disease ranges within wide limits according to the tsetse species prevalent, the density of infestation, the species of trypanosomes carried, the rate of infection, and the feeding preferences of the flies, to mention but a few of the factors. Much of the forest and savanna zones constitute high-risk areas, and in such areas trypanosomiasis prohibits exploitation of abundant fodder resources.

Tsetse flies of the savannas are capable of large-scale territorial expansion that endangers pastoral use of fodder sources in invaded areas. The impact on the rural economy is severe, with loss of available resources and overutilization of remaining safe pasturages.

Human Sleeping Sickness

Two subspecies of *Trypanosoma brucei* cause sleeping sickness in human beings. *T. b. rhodesiense*, which is spread roughly from Ethiopia to Botswana, produces an acute or subacute form of the disease. *T. b. gambiense* typically causes a chronic form from the eastern shores of the Rift Valley lakes westward to the Atlantic coast, from Angola in the south to Senegal in the north.

As in livestock, the first sign of infection is the chancre, a tender swelling at the site of the infective bite that develops two or three days afterward. In areas endemic to *T. b. rhodesiense*, people do

3. Angola, Benin, Botswana, Burundi, Cameroun, Central African Republic, Chad, Congo, Equatorial Guinea, Ethiopia, Gabon, the Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Liberia, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Uganda, Upper Volta, Zaire, and Zambia of the Organization of African Unity plus Namibia and Rhodesia.

recognize the chancre as the early sign of sleeping sickness and may present themselves at a medical center before the infection has become generalized, that is, when the parasites have invaded the blood and tissue fluids, usually around the fifth day after infection. The early phase of the disease is characterized by periodic parasitemia. The phenomenon is irregular in terms of its duration (one to four days) as well as the time between intervals (one to eight days). During episodes of parasitemia, patients suffer from severe general malaise accompanied by fever, headache, and joint pains. In the early stage, patients feel reasonably well between the parasitemic waves. They become active as usual and thus are often under the false impression that they are cured.

Again, as in animals, general enlargement of the lymph nodes is an early symptom. It is followed by anemia, loss of weight, and swellings of the limbs. Lesions of the nervous system gradually manifest themselves, first by insomnia and such peripheral signs as an exaggerated sense of pain and abnormal reflexes and later by somnolence, epileptic-like fits, and psychotic symptoms, until eventually the patient reaches a comatose end phase. A puffy face and an empty stare are other common symptoms characteristic of the advanced stage of the disease. In most cases, secondary infections, usually pneumonia, cause death. The rare patient who survives until the extreme state is totally emaciated and in deep coma.

The above describes the T. b. rhodesiense disease; T. b. gambiense infection differs in its clinical course. In the early phase, parasitemias and the associated malaise and fever are much less virulent and may remain unnoticed. The development of the lesions is considerably slower than in T. b. rhodesiense: in T. b. rhodesiense the average survival of the untreated patient is three to six months; in T. b. gambiense it varies from three months to several years. The characteristic pathological picture is one of disseminated inflammation of the

Dr. T.A.M. Nash

By Permission granted by President and Fellows of Harvard College

Sleeping sickness in man

brain and other organs, with perivascular infiltrations of white cells and accumulation of extravascular fluid (edema).

Socioeconomic Impact

Whether acute or chronic, trypanosomiasis is nearly always fatal when left untreated; it has been associated with vast, continent-wide epidemics. Depopulation through death and/or migration of infected peoples to safer areas renders useless many of the really productive and fertile lands of the continent.

Figures recording the incidence of the disease when it has broken out in epidemic proportions must be viewed with reservation, but several examples can convey its seriousness. An epidemic of trypanosomiasis killed 200,000 people in Uganda in the early part of the century.

The true incidence of the disease is impossible to estimate, because of the limited reliability of current methods for case detections. Furthermore, out of the 35 million people estimated to be at risk, only 10 million are under regular medical surveillance. Even so, an average of 10,000 new cases are reported yearly from all over Africa. The importance of continued medical surveillance was demonstrated in Zaire, where after several decades of comprehensive coverage of the population the prevalence had been stabilized at 0.01 percent. Following the total disruption of services for eight years, in the early 1960s the prevalence of the disease had increased to 18 percent in some villages, and in 1970 the overall prevalence was still 0.84 percent.

The invasion of human trypanosomiasis into rural areas goes on today through the intricate association of the disease and of tsetse with men, with domesticated stock, and with provision of infestable habitats in hedgerows and among fruit trees. Ivory Coast plantations have fostered sleeping sickness situations difficult to contain except with expenditures of scarce technical expertise and financial resources. Such foci of sleeping sickness could rise to epidemic proportions and disrupt rural communities before authorities can act appropriately if the supplies, equipment, and trained personnel for regular medical surveillance are lacking.

GOALS AND STRATEGIES FOR TRYPANOSOMIASIS CONTROL

Coping with the tsetse and trypanosomiasis year after year has been, and still is, a multimillion-dollar responsibility that African and foreign governments, academic institutions, and international agencies bear. Notwithstanding the dedication and expertise of thousands of persons from all walks of life so employed, additional monies and staff are essential for closing gaps in research and achieving effective vector and parasite control. Monies disbursed annually and manpower employed could be husbanded far more effectively than they are now if the goals of all African governments were clearly defined and if rational, coordinated strategies for assaults on the fly and the disease were thoroughly understood and respected.

Goals

One aspiration is to strive for socioeconomic advancement, which would lead to improved health and welfare among peoples of Africa. Another goal is specifically connected to creating effective national and regional programs for tsetse and trypanosomiasis control.

Economic and Social Development

In those areas where sleeping sickness prevails and human health is endangered, reducing the incidence of sleeping sickness and curing those who have contracted it will, of course, take priority over other socioeconomic considerations. Where trypanosomiasis is widespread among livestock, combating the disease then centers on land use, on balancing long-term versus short-term needs, on controlling the disease or eradicating it, on opening up new pasturage to livestock production or on maintaining these in reserve, and on halting and reversing advances of savanna tsetse. If an overall land-use policy were thoughtfully prepared nation by nation and such policy clearly stated and adhered to, such questions as do crop up about tsetse and trypanosomiasis control

despoiling the continent would rarely arise. Or, if they did, they could be satisfactorily answered.

In regard to eradication[4] or control of tsetse, under ideal conditions the benefits of land use following eradication will far outweigh the costs incurred. To establish this point, however, land-use studies must precede tsetse eradication schemes. Where technically and economically feasible, an eradication program is an excellent step to take. It can be costly, but it is a "once only" effort. Where the fly has been eradicated, optimum land development can be secured over a long-term period through vigilant political and administrative actions. Where eradication is not possible, the benefits of control are not clear-cut; the cost of repeated action against disease and vector and benefit from improved land use need to be worked out.

The African governments should consider whether or not their socioeconomic goals have been carefully defined, clarified, and articulated. If not, they should be delineated with precision.

Furthermore, all future campaigns aimed at modifying the trypanosomiasis threat to livestock by tsetse eradication or control should include studies on resulting socioeconomic and related changes.

Effective National and Regional Tsetse/Trypanosomiasis Control

The priority given to the control of tsetse flies and trypanosomiasis will vary from country to country in accordance with their incidence in human beings and animals, their effects on the national economy, and the human and financial resources provided for dealing with the problems of tsetse and trypanosomiasis control. Clearly, the urgency will be greater to combat animal trypanosomiasis in countries where the demand is great to develop tsetse-infested land than in countries where, except for a few special localities, no such demand exists. The technical feasibility of tackling the problems of trypanosomiasis also will vary.

4. Throughout this report, "eradication" is employed in a locale-specific sense. It should not be taken to mean the elimination of a species of insect from its entire range.

The eradication of Glossina is often possible near the fringes of a species distribution or in discrete fly belts, whereas it is impracticable in countries near the center of a species distribution and where human population density is low.

Strategy

A sound strategy for tsetse/trypanosomiasis research and control would encompass improving national field and research capabilities for coping with tsetse and trypanosomiasis. It would involve instituting effective control measures against the fly and against trypanosomes. Such a strategy would draw on current activities and lead to the design of future ones for combating the fly and controlling the disease. It should represent the best possible use of all information and techniques for combating the insect and the trypanosomes it carries.

Improving National Capabilities

The development of national capabilities for effective disease control will depend on cooperation and coordination of activities among those ministries responsible for agriculture, human health, animal health, land use, and wildlife resources. It will also require cooperation between neighboring countries in combating the fly and the disease in contiguous infested areas.

The five important components in national capabilities are (1) diagnosing on an adequate scale the disease in human beings and in animals and surveying the activities of the fly and the spread and intensity of the disease; (2) establishing effective tsetse and trypanosomiasis surveillance, research, and control units; (3) strengthening institutional competence in research; (4) training African specialists in trypanosomiasis control; and (5) designing appropriate technology for control. Each of these components is discussed below.

Diagnosis and Surveys

A well-trained field worker will experience little difficulty in establishing the presence of trypanosomes in the blood of a percentage

of livestock in a herd suffering severely from trypanosomiasis. However, before assigning production or death losses in a herd mainly to trypanosomiasis, one has to ascertain the presence or absence of other blood infections such as anaplasmosis and babesiosis. In young animals, the bloodsucking stomach worms also contribute to the anemia.

Confirming a clinical diagnosis in a herd requires only the use of a good microscope and a well-prepared fresh or stained blood film. Several parasitological diagnostic techniques are currently in use, each with its own advantages and disadvantages. At present, the buffy coat dark-ground phase contrast technique would appear to be the best.[5] It is the most sensitive, allows trypanosome species identification and at the same time the measurement of the packed red-cell volume; this makes it possible to estimate the seriousness of the anemia.

If, however, only one cow is available, the diagnosis may be quite difficult. The great variations in the levels of parasitemia that occur throughout the day frustrate accurate readings, as does the fact that trypanosomes may no longer be detectable in animals with a chronic form of the disease.

Surveillance must become an essential part of future programs of tsetse or trypanosomiasis control in order that the full benefits of control be realized and maintained.

If production losses from trypanosomiasis are to be measured in a herd of livestock or chemoprophylaxis to be practiced rationally or a vaccine to be tested, surveillance must be continual over at least two years.

As in diagnosis, the techniques of surveillance are relatively simple but must be applied at least four times a year, and preferably more often. In addition to examining the blood for parasites and measuring the degree of anemia, animals must be identified permanently by ear tagging or branding; they must be weighed at each examination and

5. See J. Paris et al. "An evaluation of the sensitivity of current trypanosome parasitological and diagnostic techniques," World Animal Review (in press).

their body condition assessed; deaths and disposals must be recorded accurately and necropsies carried out wherever possible; calf births have to be dated, as must abortions; and all diseases, other than trypanosomiasis, must be recorded.

One veterinarian can do this for 1,000 livestock with the help of an additional microscopist and animal holder, provided they are given a reliable motor vehicle, a good microscope, a hematocrit centrifuge, a portable weighing machine, a generator, and an office or small laboratory as their headquarters. Consumable supplies include petrol, bleeding tubes, hematocrit tubes, and microscopic slides.

In addition to surveillance of the disease following trypanosomiasis control measures, a monitoring program must be established to detect changes in density of the infesting tsetse populations. This is particularly important after an attempt at tsetse eradication within a prescribed area, because then presence or absence must be confirmed with certainty. To increase the effectiveness of such monitoring, sampling techniques for detecting tsetse populations of very low density are in urgent need of improvement. People trained to capture and recognize the different species of tsetse will be needed for this program.

Establishing Effective Tsetse and Trypanosomiasis (T and T) Surveillance, Research, and Control Units

The national tsetse and trypanosomiasis capability should consist of vector, human and animal health, training, and research components. The vector component usually consists of teams of about five tsetse control assistants or surveyors who are primary school leavers and who have been trained to locate and capture tsetse; identify species, sex, and hunger stage; and indicate on simple sketch maps the location and habitat relationships of the capture.

They may also collect material for specialized studies (blood meals, dissections). These people are usually recruited locally and specially trained. They also execute antivector measures (ground-spray, clearing, ground support for air-spray, sterile male release), and they

undertake surveillance of the results. These workers require special allowances because of the arduous nature of their field duties and their high degree of skill and reliability.

A capable, reliable, and enthusiastic body of tsetse control assistants or surveyors is absolutely essential for the collection of information on which any effective counteraction must be based.

Special laborers are needed who can be paired with the trained and literate assistants to expand survey capability, assist in transporting essential items on survey assignments in roadless areas, or assist in the execution of antivector activities. Depending on circumstances, groups of surveyors and special laborers come under the control of field assistants who are promoted either from experienced surveyors or from secondary school leavers aspiring to become control officers. The latter are usually recruited from subprofessional diploma holders in medical or veterinary subjects who have passed an additional training course in tsetse ecology, survey, and control and who take control and coordinate area operations.

Entomological, veterinary, and medical personnel, with specialist training, work with the vector units to define geographic distribution and habitat relationships of tsetse in different localities, carry out field research (e.g., on resting habits and persistence of insecticide deposits), provide epidemiological information relating to the containment of trypanosomiasis episodes, and provide overall design and direction of antitsetse activities.

The vector component requires adequate transport (trucks, pickups, motorcycles, pedal cycles), equipment (tents, beds, etc.), materials (traps, hand nets, compasses, etc.), finance for running costs, and allowances to service extensive deployment in the field. Offices, stores, vehicle workshop, and map-making capabilities are usually essential. Laboratory space for entomological and trypanosome studies and workroom for junior staff may also be essential. The map-making facility will consist of a trained draftsman supported by equipment such as drawing instruments, sets of standard topographic maps, and aerial

photographs from which working maps showing required detail can be prepared. A diazo printing facility is usually essential.

For the human and animal health components, professional/scientific personnel who have undergone specialist training in entomological, protozoological, and disease aspects and in control/eradication activities are required. Usually, routine treatment of animal trypanosomiasis is carried out by district veterinary services, but specialist contributions are required to report on the actual incidence of infection and drug resistance, to advise on prophylactic and curative treatment regimes, and for the elucidation of trypanosomiasis episodes. Similar spread of interest is required in human sleeping sickness. However, more specialized and direct control of treatment is necessary (hospitalization may be required) and the elucidation of the epidemiology of outbreak situations assumes greater importance than it does in livestock situations. This component usually works closely with or within the vector component, which itself is part of either the medical or veterinary service, according to which is most appropriate.

Some countries have a tsetse control program (T and T units) operating with or without the support of donor countries or international organizations. Many nations have no such program. Of those in the former category, the control strategies adopted may need examination. In some of those in the latter category, tsetse control programs may need to be instituted.

Certain areas of tropical Africa in which the eradication of the tsetse may have been achieved must not be neglected; apparent tsetse-free regions must not become reinvaded. Both donor and recipient countries should insist on good organization and management in the conduct of control projects. Adequate funds and their wise allocation, adequate supply of properly trained manpower, and above all, knowledge of the problems in the field are essential to the success of any program under consideration.

Although the eradication of tsetse flies from certain areas of

tropical Africa constitutes a much desired goal, the consequences of projects directed toward this end and the impact of land resource development on the quality of the environment should be adequately assessed for their long-term effects. Tsetse retreats in the face of sound land-use management.

In a control program, a considerable volume of ongoing field investigation is required to define the geographic limits and habitat associations (particularly resting and feeding behavior) of the different tsetse infestations and the relationships these have to particular trypanosomiasis problems. This is essential for the containment of the existing situation, the effective utilization of advanced institutional research findings, and the exploitation of newly developed antitsetse technologies as these become available. Continuing collection of facts is also necessary on the incidence of infections, responses to therapy, and follow-up of vector control/eradication operations. Institutional research of an advanced nature is required, and this may be shared by a number of countries having a similar ecological background. It may also be conducted at local universities, as is increasingly the case.

Strengthening Research Institutions

The largest allocation of funds for research must go to strengthening existing African institutions, notably the faculties of veterinary medicine, certain programs of the government veterinary services, the specialized institutions devoted exclusively to research on tsetse/trypanosomiasis, and to such international institutions as ILRAD, the International Livestock Centre for Africa (ILCA), and ICIPE. In several of these institutions, young African scientists who are beginning careers in research on these problems need operating funds, equipment, and supplies. A modest way in which to strengthen research institutions is to search for young scientists already motivated and committed to tsetse or trypanosomiasis research, furnish them with limited equipment and supplies enabling them to proceed with investigations, and at the

same time, insist that their institution does the same. Funds for letting young scientists visit other laboratories, meet colleagues, and broaden horizons are also essential.

WHO and the UNDP/World Bank/WHO special programs on research and training on tropical diseases, among others, are important sources for research on trypanosomiasis in human beings. Many existing institutions now engaged in tsetse and trypanosomiasis research (outlined in a succeeding section on current activities) and equipped with adequate budgets could sponsor the applied and basic research that need to be undertaken. The task force sees little justification for creating new research institutions in African countries for such purposes except for establishing the national T and T units just described.

Bilateral funding agencies have generously supported research on tsetse flies and trypanosomiasis in years past, and they continue to do so. FAO provides limited research contracts to African research institutions, and bilateral assistance agencies generously support research on tsetse flies and animal trypanosomiasis. But African governments must bear the primary onus for strengthening research institutions in Africa.

Training

The future of efforts to control tsetse and trypanosomiasis will depend on herculean efforts to train and retrain people at all levels. Training programs should be built around such projects as the eradication of tsetse from an area, the use of insecticides to effect control, land development, chemotherapy or chemoprophylaxis as applied to animals and to human beings, and improved efficiency in producing breeds of livestock possessing some resistance to trypanosomiasis.

The urgency for training applies at all levels--to professional leadership, middle-grade staff, and junior staff. The professional staff includes the physicians, the veterinarians, and the entomologists with a university background; middle-grade staff represents the cadre of people who will have completed secondary school and a course in an appropriate training institution; the junior field staff consists of the

large number of primary school people essential for carrying on routine tasks such as spraying insecticides and trapping flies.

Professional Staff. Experienced scientists and other professional staff members will need to acquire skills to direct and undertake research, organize surveillance and control programs, participate in decision making concerning disease control, vector control, and land-use studies, and organize periodic leadership training seminars and related learning opportunities.

For recent graduates, it would be desirable that they have a year or so of practical field and laboratory experience on the tsetse and trypanosomiasis problem after taking a degree in the life sciences. Then they would proceed to the M.Sc. or Ph.D. by project work in a pertinent topic. Cooperation between universities and research centers would be important, as would a long training stint in the local country. Periodic regional, not national, training courses need to be organized on general aspects of trypanosomiasis for newly qualified M.Sc.'s and Ph.D.'s, whose research background will necessarily be of a very specialized nature. Short courses would also be appropriate to teach techniques unique to tsetse and trypanosomiasis control.

Middle-level Staff. Medical and veterinary assistants should take short courses on specialized trypanosomiasis techniques at regional or national established institutions. Tsetse control assistants would need two-year courses at a specialized center. At present, two local centers--at Kaduna, Nigeria and Bobo Dioulasso, Upper Volta--train personnel. These centers could be established either on a national or subregional basis. There is an urgent need for similar centers in East Africa, central Africa, and southern Africa.

Responsibility of such staff will include the training of junior staff at the national level.

Junior Field Staff. The junior staff makes up the field teams associated with field research and control operations. Their training essentially occurs on the job.

The importance of following up the original training cannot be

overemphasized. All three levels of trained personnel must be properly channeled for best use during tsetse/trypanosomiasis activities. All personnel should have a sense of career structure and goals, which might be overseen by a training officer in STRC/IBAR and/or by a specially recruited consultant. The training needs of various countries at various levels could be assessed by STRC/IBAR, with assistance from multidisciplinary missions.

Training courses of international scope will be more realistic and economical than courses organized on a national basis. They can address the problem of the tsetse fly and trypanosomes as international travelers that do not respect national boundaries. An ideal international course might start with three or four people who could give 100 days a year of service to the program, expand to a group of nine or ten in the course of two or three years, with the subsequent development of specific training centers. A starting budget of $500,000 per year would be minimal; the cost would probably increase to $2 million annually in four years' time.

In consultation with OAU, WHO, and FAO, each nation should organize and implement training courses geared to prepare staff for tackling the problems of tsetse and trypanosomiasis control within its boundaries. Subsequently each country should participate in comprehensive regional training programs sponsored by multilateral donor agencies.

Designing Effective Control Technology

Controlling sleeping sickness in man and trypanosomiasis in animals depends on two obvious tactics: management or extermination of the fly and/or the systematic treatment of man and animals to eliminate the trypanosomes. For animal trypanosomiasis a third tactic would be to capitalize on and improve trypanotolerance of livestock to these disease agents.

Measures Against the Fly. No special feature characterizes the fly as a pest, or indeed the continent of Africa as a proving ground, that sets either of them apart from the rest of the world for the measures one takes to combat insects. With tsetse, as with other pests, habitat

manipulation, on occasion recklessly performed, preceded the use of effective insecticides. Then came the chlorinated hydrocarbons as powerful insecticides, followed by carbamates, organophosphates, cyclodiene insecticides, and lastly, synthetic pyrethroids. A second look at manipulation of the environment is now taking place, accompanied by intensive research into the biology and the physiology of the insect itself. Orchestrating the use of insecticides with other methods of control--such as the use of parasites or predators, or manipulating the environment to depress the tsetse populations--contributes to an integrated control system likely to be far more effective than reliance on one measure, insecticides, alone.

The use of insecticides. DDT, BHC, and other insecticides were first used in the 1940s and early 1950s; in recent years, dieldrin and endosulfan have formed the backbone of chemical control in campaigns to eradicate tsetse. Both ground- and aerial-spraying techniques have been employed. They have largely replaced the drastic and environmentally damaging methods of the past--shooting game to deplete the food reserves of tsetse and slash burning of brush to destroy the habitat of the fly--now practiced in limited areas only.

When feasible, insecticides are aimed at exterminating the fly from a particular location, rather than at reducing fly populations to an acceptable level from the standpoint of disease transmission. Attempts at control usually lead to perpetual requirements for repetitive applications.

Before any major insecticide campaign can be initiated, the surveillance team must have a spraying technique known to be effective against the species of tsetse to be attacked under the particular environmental conditions (taking into account topographical, climatic, vegetational, and faunal factors) of the proposed operational area. Testing may involve small-scale trials of various techniques before proceeding to actual sprayings. Insecticidal operations should proceed, wherever possible, in discrete belts of infestation; the desirability of taking advantage of natural barriers to reinvasion cannot be overempha-

sized. The creation of artificial barriers (e.g., by clearing land or applying insecticide) should be avoided wherever possible, because their effectiveness is often limited. Such barriers are expensive to establish and maintain and can only be justified when a relatively small barrier can be used to protect a large cleared area.

Once a survey of the distribution and resting sites of the species has been completed, it is necessary to determine the time and duration of insecticide treatments, the extent of the area to be treated, and the requirements for personnel and materials (e.g., vehicles, spraying equipment, insecticides) for the implementation of the spraying campaign.

Ground-spraying techniques for tsetse control consist of applying persistent insecticides--such as dieldrin and DDT--to vegetation by using hand-operated sprayers that deliver sprays selectively to sites within an extensive area where the resting flies alight and make contact with the insecticide. Ideally, the persistence of the insecticide should be sufficient to make only one application necessary, and the selectivity of the application technique should ensure that a minimal amount of insecticide is used, so as to reduce the cost and environmental pollution. Well-trained and -supervised spraying teams are essential, and they must have suitable equipment as well as proper facilities for workshop and field maintenance of equipment.

Ground spraying of insecticide is efficient, provided the area of selective spraying is not too large and funding is available for the implementation of large-scale control and eradication operations. However, spraying operations can be improved as follows:

1. The spraying equipment should be refined to improve the accuracy of delivery in directing the spray to the target, ease of handling, robustness, and constancy of emission rate. Availability of suitable equipment is a problem in some African countries.

2. Large-scale, ground-spraying operations require specific insecticides with low mammalian toxicity, thus reducing the hazard of noxious side effects to the environment and to the operator. In the

absence of such an insecticide, the use of a very selective application should bring about the same results. Using this kind of agent requires a precise knowledge of resting sites of the various target species.

In some parts of West Africa, tsetse vectors of both animal and human trypanosomiasis have been eradicated with residual spray applications of dieldrin and endosulfan applied by helicopter at dosages of approximately 1 kg/ha for both dieldrin and endosulfan to 10 to 20 percent of the infested area. These treatments have affected mortality rates in many nontargeted species, although they recovered after single exposures to applications achieving tsetse elimination. Dieldrin was more toxic to warm-blooded species than endosulfan, and cold-blooded vertebrates were more sensitive to endosulfan.

Fixed-wing aircraft are in regular use in southern Africa for the control of savanna tsetse (e.g., G. morsitans). The technique consists of applying endosulfan as an aerosol to disperse droplets that land directly on tsetse, whether on the wing or at rest. Aerosol applications are made during the early morning, the late afternoon, or throughout the night, when weather conditions are most stable. Four to five sequential treatments (at a dosage of 6 to 15 g/ha per treatment) are required at 10- to 20-day intervals in order to keep areas fly free for livestock grazing.

Control of flies in riverine and savanna woodland areas requires the treatment of many fly ambits. Most can be treated by helicopter, but applied research is required to evaluate the use of insecticides so applied as aerosols and fine sprays on tsetse and their potential in dealing with emergency sleeping sickness situations and in killing vectors of livestock trypanosomiasis. Some progress has already been made in evaluating promising antitsetse agents applied by helicopter.

The use of fixed-wing aircraft for aerosol and spray application to riverine woodland and more densely forested areas (e.g., the southern Guinea savanna zone) has yet to be evaluated, although some experiments have been initiated in forested lands. Advantage of natural fly barriers must be taken into account in large-scale operations, although the

long-term effectiveness of tree clearings, barriers, and buffer zones treated by ground or air is questionable. Studies are necessary to prevent invasion by various species of tsetse.

Habitat manipulation. Altering the vegetation of tsetse habitats so as to render trypanosomiasis of minor significance or make it disappear can be an efficient control method on a local scale. With regard to human sleeping sickness, the discriminative clearing of riparian tsetse habitats has, in combination with diagnosis and treatment, achieved notable success in the past, but the method has become unduly costly. It requires continuous supervisory and financial commitments to prevent regeneration and provide surveillance for sleeping sickness infection.

Similar problems arise in dealing with savanna tsetse infestations in tree savanna and woodland. Adequate vector suppression is achievable when the method of land utilization--e.g., the creation of improved pasturage--bars regeneration of woody plants. This measure, however, can only be applied on a limited scale. Where savanna tsetse are involved and when susceptible livestock are not part of the social structure or land utilization practice, it is possible, through planning the location of habitations in relation to cultivation and woodland, to reduce man-fly contact to an acceptable level and even to eliminate it. Later it may be possible to introduce livestock. Livestock trypanosomiasis continues to be a problem at tsetse densities that are no longer significant in producing the human disease. Tsetse infestations can persist in the rangeland used by livestock, in conserved components of the land resource, and in those areas not suited to cultivation. Historical studies may reveal if the circumstances of apparent freedom from a human trypanosomiasis problem in tsetse-infested areas can be adapted to current use. Sociological studies may reveal other factors that influence man-fly contact and which can be used to control human sleeping sickness.

The effectiveness of habitat manipulation must be improved through

examination of historical and sociological studies; intensification of studies on tsetse ecology, particularly habitat relationships; the insect's flying, feeding, and breeding behaviors; population dynamics; predators; and methods of impeding regeneration of woody plants.

Genetic manipulation. The application of gamma radiation to sterilize adult males of screwworm flies in the 1940s and the subsequent liberation of those males en masse in order to outnumber normal males, reduce the progeny of females, and send screwworm numbers on a downward trend to extinction brought to light new technology for controlling insects. This concept, now called the sterile insect release method (SIRM), depends for its success on efficient and inexpensive methods of rearing large numbers of insects, sterilizing them, and releasing them into the wild population. The effectiveness of the approach also depends on a low density of wild pest populations in nature and a thorough knowledge of the biology of the target pest. Tsetse flies meet these conditions for the most part, and for more than 10 years, experiments have been underway in Africa to test SIRM for eradicating the flies from certain habitats.

Two field trials of the method have recently been completed in Bobo Dioulasso, Upper Volta and Tanga, Tanzania. A third trial has recently been initiated in Vom, Nigeria. The technique may not replace insecticides or other methods in future control or eradication projects, but it could play a part in establishing barrier zones in cleared areas, be used where insecticides cannot be applied, or be administered as the coup de grâce to a tsetse population already reduced by insecticides or other means.

Evaluations must be completed of the two recently concluded programs of research and pilot studies on SIRM. Further studies should be undertaken to determine what role SIRM might play in a tsetse control program.

Hybrids bred from certain subspecies of *G. morsitans* and *G. palpalis* exhibit degrees of sterility. Laboratory data suggest that

sufficient numbers of males of certain subspecies could introduce enough sterility into the natural population to effect population reduction. The recent development of economical methods for rearing tsetse indicates that a field trial would be suitable for testing the potential usefulness of the method.

Biological control. Since tsetse flies are indigenous to Africa, by rights they should have a number of parasites and predators that keep their population in check. Such parasites and predators operate in a cyclical way and establish a balance between the host and the parasites or predators. The prevalence of tsetse and the extent of the diseases they transmit attest to the failure at natural population levels of these parasites and predators to maintain tsetse well enough in check. In order to make the parasites and predators of tsetse in Africa more effective than they are, they would have to be released often enough and in sufficient numbers so that they could disable or kill off the tsetse population far more effectively than they do now.

Exotic parasites could be imported and evaluated for their control of tsetse flies, and several pupal parasites are currently available for importation. Methods for mass producing and releasing them have been developed. The merit for their use in Africa, however, needs to be assessed. The potential undesirable side effects of their introduction into nonindigenous areas also need to be known.

Physiological controls. Utilizing insect growth regulators (IGRs) for controlling tsetse might have many advantages over other available techniques because such substances are specific, they have few undesirable side effects on humans and their environment, and they act only by interfering with normal physiological processes in the insect. Not only the IGRs but hormones, antihormones, and pheromones as well offer promise as substances to be exploited for control, or at least for monitoring the population of the flies. Research on the olfactory and visual stimulants that govern the behavior of tsetse has been underway in Rhodesia for years; it is yielding information useful for trapping flies. Similar investigations took place in Upper Volta and Ivory Coast

under the aegis of the Organisation de cooperation et de coordination pour la lutte contre les grandes endémies (OCCGE).

Research should be intensified on the physiology and the behavior of tsetse along three lines: studies of hormonal and other physiologically active substances that might interfere with the normal reproductive processes; identification and isolation of attractants and repellents; and determination of the roles played by visual and olfactory stimulants.

Measures Against Trypanosomes. Assaults on the fly and onslaughts against trypanosomes do not constitute "either-or" propositions; they complement one another. Any measure directed against trypanosomes, whether chemoprophylactic, chemotherapeutic, or building up the host's tolerance or immunity to the organism, shares in a fascinating problem. How does one tamper with the bloodstream of man or animal--the most delicate of environments--to kill the parasite but leave the host unharmed?

Chemoprophylaxis and chemotherapy for animal trypanosomiasis. Chemoprophylaxis and chemotherapy are widely used against animal trypanosomiasis. More than 25 million treatments are carried out in Africa every year. This control method relies on the use of five compounds: homidium, quinapyramine, diminazene, pyrithidium, and isometamidium salts. Except for swine trypanosomiasis caused by *T. simiae* and against which one is virtually unarmed, these compounds afford effective treatment of the different animal trypanosomiases. However, the respective indications for each drug must be followed, because the activity of the agents varies with the trypanosomiasis to be treated and their toxicity with the animal under treatment.

Pyrithidium and isometamidium salts exert a valuable preventive action that can last from two to four months depending on how intense the risk of infection is. However, all the trypanocides, and particularly those that exert preventive action, can easily induce drug resistance in trypanosomes. They should be used only under strict control and then with circumspection.

In practice, chemoprophylaxis does not seem desirable for livestock permanently residing in tsetse-infected areas unless the animals are thoroughly controlled and a strict treatment and dosage regimen can be ensured. However, chemoprophylaxis is quite justified in protecting livestock that must travel to market through tsetse-infested areas, provided that they are slaughtered soon after. It is also justifiable for cattle on seasonal movements across tsetse-infested belts if curative treatment with an effective trypanocide resistant to the prophylactic compound used is carried out as soon as the livestock are back in tsetse-free areas. In practice, isometamidium can be used as the preventive and diminazene as the curative drug, since neither appears to induce cross-resistance. Similarly, chemoprophylaxis is justified for livestock living on farms and ranches and under veterinary control.

The increasingly frequent appearance of drug-resistant trypanosome strains is disquieting. However, cross-resistance has not yet been reported between diminazene and isometamidium; consequently, the risk of drug resistance might be mitigated by using the two drugs in alternation. This situation may be only temporary, because partial relationships do exist between the chemical structures of the two compounds. The development of new drugs, belonging if possible to other chemical groups and acting in different ways, remains highly desirable.

The development of chemoresistance is the main deterrent to heavy use of trypanocidal drugs with prophylactic activities. These compounds belong to a small number of chemical groups and cross-resistance has been observed (at least in laboratory conditions) among them. Since 1960, no new trypanocidal drug has gone beyond the experimental stage. The need is urgent for new chemotherapeutic agents. New approaches to drug development should be sought through biological research on the mode of action of trypanocidal compounds. Screening programs for new compounds should be reinforced.

Research on the development of drugs and field testing facilities in Africa must be strengthened; the search pursued for an active drug for field use against T. simiae; the persistence in meat of trypanocidal

drugs studied, particularly on those drugs exerting preventative action; strict veterinary control exercised on the supply of trypanocidal drugs to obviate overuse of drugs and consequent build-up of chemoresistance; and support given to the chemical industry and African governments to find new drugs.

Chemotherapy for sleeping sickness. For human beings under threat of infection by *T. b. rhodesiense*, chemoprophylaxis is not recommended. The period of complete protection with known drugs is short and variable, and the use of drugs presents a serious risk of masking the disease in its early stages when it is most easily curable. In *T. b. gambiense* areas, both suramin and pentamidine have been given to individuals exposed for a limited period. However, no objective evaluation has yet been made of this measure's protectiveness.

For mass use, pentamidine has been preferred to suramin because of its apparently longer period of protection and greater ease of administration. Although the period of protection varies among individuals and areas, it should never be assumed to exceed six months. The usual single prophylactic dose is 4 mg/kg body weight, given by intramuscular injection. Mass prophylaxis should be considered only if the two following conditions are fulfilled: an efficient preliminary survey has shown that no existing cases have been treated with but a single dose inadequate for cure and that the whole population has been protected at intervals not exceeding six months.

In human trypanosomiasis, the finding of new chemotherapeutic drugs commands priority. Tryparsamide is no longer produced, and of the five drugs currently used to treat sleeping sickness--nitrofurazone, suramin, pentamidine, berenil, and melarsoprol--only melarsoprol controls the late stage of the disease. Suramin, pentamidine, and berenil are given as the sole therapy to the few patients in whom trypanosomiasis is detected in the early stage when the cerebrospinal fluid is normal. Or they are administered as preliminary treatment before melarsoprol to patients with abnormal cerebrospinal fluid. Any course of treatment for sleeping sickness requires 30 to 40 days of hospitalization. Although

preferable, hospitalization is rare in early cases of T. b. gambiense.

Melarsoprol is extremely toxic, and dangerous reactions occur frequently, even when experienced people supervise its administration. Mortality rates of 2 to 5 percent have been associated with its use in some areas and as much as 15 to 20 percent in others. Because of the long duration of treatment, the danger of fatalities from reactions and intercurrent infections, and the special nursing care and practical skills involved (lumbar puncture, meticulous intravenous administration), the availability of devoted and well-trained personnel is of great importance to the success of the treatment.

The growing frequency with which cases of drug resistance occur is a cause for serious concern (although nitrofurazone can be employed in melarsoprol-resistant cases, its toxicity makes it unsuitable for regular use). In a few years' time, sleeping sickness may no longer respond to any drug currently in use. Unless a major and successful effort is made in chemotherapy and new effective drugs are developed, sleeping sickness may again become an incurable disease.

Industry, academic institutions, and governments should intensify studies to find more effective and less toxic drugs as eventual substitutions for those now in use for controlling human and animal trypanosomiasis.

Immunization. At best, available methods for controlling trypanosomiasis (systematic case detection with treatment and tsetse fly control) only limit the disease. The introduction of an effective vaccine could make a major contribution to trypanosomiasis control. It would also do far more than satisfy that immediate practical objective. Trypanosomes and related protozoa have to date thwarted the efforts of researchers to immunize human beings or animals against them in the way that human and animal hosts have been immunized against viruses and bacteria. Success in producing a vaccine for trypanosomiasis could open the way for similar achievements on related diseases.

The major obstacle to finding a trypanosome vaccine is the ability of the parasite to undergo antigenic variation, a process whereby

trypanosomes change the antigenic character of their surface coat and so evade the host's immune response. The immune response against each variant, although effective in killing any trypanosomes which possess that particular antigen, is invariably too late to act against that proportion of the population which has altered its antigenic identity. Thus, the number of parasites rises and falls in waves, with each new parasite population carrying different surface antigens. Since these surface membrane antigens induce protective immunity, resistance to trypanosome infection can only be produced when trypanosomes with the same surface antigen are used for vaccination and challenge. Challenge with parasites bearing a different surface coat results in infection.

An effective vaccine would evidently have to contain all variable antigen types (VATs). Such a vaccine would be difficult if not impossible to concoct, because the number of VATs, although as yet undetermined, is likely to be large. However, advances in scientific knowledge and technology have opened up several different avenues of potentially profitable research. In the case of T. brucei, at least, a tendency exists for certain VATs to occur preferentially in the early parasitemic peaks; these have been called predominant VATs. In addition, the passage of trypanosomes through the tsetse fly may result in a return to a common parent antigenic type or to a small number of types; these have been termed "basic strain antigens." The number of basic strain antigens within a given geographic area may be limited, and it is possible to envision the production of a "cocktail" vaccine consisting of predominant VATs, a number of metacyclic basic strain antigens, or both.

Modern biochemical technology now allows the purification and characterization of many subcellular fractions, including the variable antigen which induces protective immunity. For example, researchers have shown that the surface variable antigen is a glycoprotein. The path to understanding antigenic variation must come from an investigation into the molecular biology of the trypanosome. Recent advances in in vitro cultivation of African trypanosomiasis and genetic engineering have expanded our horizons in this area. With such tools it might be

possible to investigate the genetic basis of antigenic variation with a view to defining the number of variants coded in the parasite's genetic composition. Eventually, the genes responsible might be cloned into a suitable microbial system, which in turn could provide bulk production of variable antigens for vaccination.

Two features of African trypanosomiasis are immunosuppression (a depressed immune response) and high levels of gamma globulin, only a proportion of which is apparently directed against the trypanosome. An understanding of the basis of immunosuppression and the immunological mechanisms that kill the trypanosome might allow the administration of stimulants for improving the host's immune response to the trypanosome. This would be an effective way to control the parasite.

According to preliminary field studies conducted several years ago, livestock subjected to infection and treatment regimens developed a degree of resistance to subsequent challenge. No one has pursued these studies. Further consideration should be given to the basis and economic benefits of this approach.

Trypanotolerance. Along the west coast of Africa, several breeds of cattle exhibit partial resistance to trypanosomiasis, in that they can survive and reproduce in tsetse-infested areas without chemotherapy. Certain breeds of sheep and goats and some species of wild game also express this partial resistance. This characteristic is known as trypanotolerance. The nature of trypanotolerance is inadequately understood. It may be genetic in part because all of the humpless (taurine breeds) cattle in Africa possess resistance of variable degree. Proper selections of resistant types for breeding will increase the general level of resistance of the herd. Moreover, exposing these livestock repeatedly to the same population of trypanosomes in a given area seems to enhance their innate resistance. Supplementing the caloric intake of animals with crop byproducts during the dry season, administering judicious chemotherapy, and undertaking limited brush clearing all seem to increase the productivity of such herds. Whatever the nature of this resistance, the trypanotolerant breeds can live and

produce in areas infected with tsetse flies where no zebu cattle can survive.

In some parts of West Africa, the trypanotolerant breeds are virtually the only source of milk and beef in the absence of tsetse eradication. They also make excellent draft oxen. Hence, trypanotolerance should be fully understood and used to thwart trypanosomiasis in cattle, sheep, and goats. The potential for trypanotolerance, indeed for resistance, in other animals among the wildlife of Africa ought to be thoroughly researched. If the partial resistance these breeds possess can be reinforced by subjecting them to repeated infections of trypanosomes from which they recover, a vaccine to protect these livestock might be developed much more easily than a vaccine to protect fully susceptible livestock.

Trypanosomiasis-plagued countries should update their information on the status of the disease in their national herds and acquire baseline data on the productivity of trypanotolerant livestock under differing environments and levels of tsetse threat. In addition, the genetics of trypanotolerance needs to be elucidated.

Basing Future Initiatives on Current Activities

Among 36 African countries beset with tsetse and consequently having problems with animal trypanosomiasis and/or sleeping sickness, most have established control operations comprised of various techniques. Some have specialized institutes dealing with research and training.

Kenya and Nigeria have comprehensive programs involving their faculties of veterinary science, specialized institutes, and tsetse/trypanosomiasis units within their governmental departments of veterinary science. With donor-agency support, Tanzania and Upper Volta are engaged in feasibility studies of the sterile insect release technique for controlling tsetse. Most francophone countries (Organisation de coordination pour la lutte contre les endémies en l'Afrique centrale, OCEAC, with headquarters at Yaoundé, Cameroun; and OCCGE at Bobo-

Dioulasso, Upper Volta) have programs of action to control sleeping sickness. The eight member states of OCCGE recorded less than three cases of human trypanosomiasis per 100,000 people in 1977. Through its university and field work, Rhodesia supports research on trapping flies and on the response of tsetse to olfactory and visual stimuli. In Botswana, a far-flung program for the control of trypanosomiasis in cattle is underway in the Okavango Swamp. Zambia has a program in tsetse ecology and control. In Upper Volta and Ivory Coast, researchers have made detailed investigations of tsetse ecology. In the Gambia, Mali, Upper Volta, and Togo, programs on trypanotolerance are underway. Sudan, the site of many of the early studies on tsetse and trypanosomiasis, continues to support programs on tsetse ecology and control.

Traditionally, the United Kingdom, France, and Belgium have been deeply involved in tsetse/trypanosomiasis research, training, and control activities in home-based institutes and programs located in Africa. The United Kingdom has a long history of support for research on and control of African trypanosomiasis. During the colonial era, control services were set up in many countries and two major institutions were established to undertake research in the former British territories in East and West Africa (now the East African Trypanosomiasis Research Organization, Uganda, and the Nigerian Institute for Trypanosomiasis Research, Nigeria). Today, the Ministry of Overseas Development (ODM) supports major research programs in both Britain and Africa; in Britain, research is undertaken at the Center for Overseas Pest Research (COPR) and in numerous universities. Since their inception, the London School of Hygiene and Tropical Medicine and the Liverpool School of Tropical Medicine have conducted research on trypanosomiasis. The Tsetse Research Laboratory, funded by ODM and administered in association with the University of Bristol, was established in 1961; it is concerned primarily with research into the biology of tsetse flies. ODM also funds services for the identification of tsetse blood meals (at Silwood Park, Imperial College, London) and the maintenance of

tsetse colonies (at the Tsetse Research Laboratory) for supplying tsetse to workers in the United Kingdom and elsewhere.

For a long time, France has engaged in tsetse/trypanosomiasis research, training, and control through national institutions such as the Institut d'élevage et de médecine vétérinaire des pays tropicaux (IEMVT) and the Office de la recherche scientifique et technique d'outre-mer (ORSTOM) and cooperative programs with health and veterinary services of African countries and subregional organizations such as OCCGE and OCEAC. Recently France, in cooperation with the Federal Republic of Germany, has undertaken (in Upper Volta) major programs of research on the sterile male technique, on trypanotolerance, and on training of field control officers.

Belgium has also been deeply involved in trypanosomiasis activities either in home-based institutes, such as the Antwerp Institute of Tropical Medicine, or in programs located in Africa, principally in Zaire, Rwanda, and more recently, Ivory Coast.

The Federal Republic of Germany, in addition to its joint research and training activities with France, is now carrying out research programs on chemotherapy of animal trypanosomiasis (in Kenya) and on trypanotolerance (in Togo); tsetse surveys in Upper Volta, Ivory Coast (in cooperation with FAO), and Ghana; control operations in Nigeria and Cameroun.

The European Economic Community supports numerous projects such as tsetse control in Chad and the rearing of trypanotolerant cattle in Mali, Upper Volta, Ivory Coast, and other countries.

Numerous private organizations, including universities, research institutes or foundations, and chemical industries are, to various degrees, involved in trypanosomiasis research and training. The Rockefeller Foundation, instrumental in creating ILRAD, has sponsored research on immunology and on parasite-vector relationships.

In the United States, Yale University, Rockefeller University, the University of Pennsylvania, Walter Reed Army Institute of Research, the

University of California at Davis, and Texas A & M conduct basic studies on trypanosomiasis. USAID, among other donor agencies, finances one-fourth of the operating budget of ILRAD; it supports as well the SIRM programs in Tanzania, a team of specialists in Mali, and cooperative research with the International Atomic Energy Agency (IAEA).

The aforementioned governments, institutions, agencies, and organizations plus many others--each contributing in its own way to the strategy for tsetse and trypanosomiasis control--together form a matrix in which one element complements or supplements another, and in which all are interdependent. Within this system, cooperation and coordination at various levels of action and of research occur spontaneously. The complexity of this system should inspire rather than deter newcomers anxious to do their part in resolving the tsetse and trypanosomiasis problem. As provision of manpower, materials, and finance inevitably shift and change, so opportunities arise to fill important gaps. Indeed, major advances have come about recently from recruits to institutions new and old, and from their freshness of approach to research programs established only during the last 5 or 10 years, not just in Africa but in other parts of the world as well.

Monitoring tsetse and trypanosomiasis on a continent-wide basis transcends individual and country initiatives; international organizations are well equipped for this responsibility.

The International Scientific Committee for Trypanosomiasis Research and Control (ISCTRC), placed under the aegis of OAU following dissolution of the Commission for Technical Cooperation in Africa, has for more than 30 years provided a forum for all those concerned with human and animal trypanosomiasis control, dissemination of information, and research and training. The ISCTRC biennial scientific meeting brings together laboratory research and field workers from all over the world to discuss different aspects of ongoing and future activities in human and animal trypanosomiasis. The ISCTRC Executive Committee, composed of experts from various disciplines and representatives of concerned international organizations, with IBAR as permanent Secretariat,

has assisted in the promotion and coordination of joint activities undertaken by various institutions involved in human and animal trypanosomiasis. The committee aided FAO, WHO, and OAU in several major activities carried out in cooperation with bilateral assistance agencies and international research institutes. IBAR is also responsible for updating the tsetse distribution map of Africa.

In cooperation with interested countries and institutions, FAO has initiated a large-scale program for the control of African animal trypanosomiasis and the development of affected areas.

During the preparatory phase 1975-79, FAO placed overriding emphasis on training at all levels in order to strengthen national structures and allow the establishment of specialized units involved in control and the development of reclaimed areas. Training has generally been carried out in cooperation with other institutions, particularly WHO and OAU, and with the support of several assistance agencies, and has involved about 120 specialists from various disciplines.

For the coordination and effective participation of all parties concerned, FAO is forming:

1. A committee on African animal trypanosomiasis composed of representatives of member nations and observers of interested institutions (including WHO and OAU).

2. An intersecretariat coordinating group consisting of representatives of institutions participating in or associated with the program, such as WHO, OAU, and the various assistance agencies.

3. An ecological/technical advisory panel and a development advisory panel to provide technical advice on the program.

The program will enter its operational phase in 1980. It will provide or channel support for national or subregional tsetse control and development programs.

In identifying priorities within its program, FAO would rank first the multidisciplinary missions designed to merge the governments' planning into an overall approach to control and development efforts. Ranked second would be the expansion of training, in cooperation with

WHO and OAU, in order to have adequate personnel available at all levels and in all disciplines to execute the program. The sponsorship of applied research would follow, particularly research on improvement of tsetse control techniques and on various aspects of trypanotolerance.

Other activities include the surveys and feasibility studies carried out in 16 countries, the FAO/ILCA/United Nations Environment Program (UNEP) Study on Trypanotolerant Livestock, the compilation of trypanosomiasis and development activities carried out or planned in the tsetse areas, and several expert consultations concerning technical aspects or the implementation and management of the program.

UNDP/World Bank and WHO also sponsor programs of research and training in tropical diseases; ILRAD and ICIPE have received substantial and sustained support from UNDP through its Division for Global and Inter-regional Projects. This support has been specifically designed to amplify the resources available for complementary and coordinated action to promote research on tsetse and trypanosomiasis. Through its Regional Bureau for Africa, UNDP also supports several national projects concerning tsetse surveys, pilot trials, and the rearing of trypanotolerant livestock as well as regional projects on applied research and training in trypanosomiasis/tsetse control.

The World Bank also participates in various development programs concerning tsetse-infested areas.

WHO, following a resolution of the 28th World Health Assembly (1975), has implemented a special program on six tropical diseases, including sleeping sickness, which encompasses training and research on both vector and disease as major components.

The Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture has undertaken a research program on the sterile male technique.

UNEP participates in a study on trypanotolerant livestock, carried out in cooperation with FAO and ILCA.

In the network of international institutions sponsored by CGIAR, two centers are concerned with trypanosomiasis. ILRAD deals with immunological approaches to trypanosomiasis control, whereas ILCA has

undertaken studies on the conservation and the improvement of trypanotolerant livestock and on economic assessment of animal production in the tsetse area.

Apart from CGIAR and in a class by itself, ICIPE carries out research on the physiology of tsetse flies; it has recently developed its research program on tsetse ecology as well.

Cooperation among various countries and organizations has permitted the carrying out of several important activities that would have been difficult for one institution to accomplish alone. For example, the FAO/OAU/WHO/ILRAD Leadership Training Seminar on Tsetse/Trypanosomiasis Control was held in Nairobi in 1977, through the support of France and the United Kingdom. The Tsetse and Trypanosomiasis Information and News Service is sponsored by FAO, OAU, WHO, COPR of ODM, and now IEMVT. Postgraduate training courses on tsetse/trypanosomiasis have been underwritten by FAO, France, the Federal Republic of Germany, and the United Kingdom; a second FAO/OAU/WHO seminar specially devoted to tsetse control was held at Bobo Dioulasso in 1979. Cooperation takes place with bilateral agencies, such as the École de lutte anti-tsetse and the Research Center on Tsetse Genetic Control in Bobo Dioulasso, which are both cosponsored by France, the Federal Republic of Germany, and the IEMVT in Chad.

To be effective, future initiatives must fit well amidst the plethora of the current ones just described. They must address outstanding gaps as referred to in this report, notably: training and supporting specialized manpower; stimulating the formation of permanent national multidisciplinary units in which medical, veterinary, and entomological disciplines are represented; establishing pilot control projects; and affording financial assistance to research in such subjects as trypanotolerance, immunization, new drugs, tsetse ecology, and tsetse control.

OAU, FAO, WHO, and UNDP, among other international organizations, can and do perform vital coordinating functions in research and action programs on tsetse and trypanosomiasis. Here the challenge--a sensitive

one--is to foster, rather than to dominate or stultify, future initiatives from all sources and to ply the art of coordination in a comprehensive and tactful sense so as to encourage the participation of legions of new individuals, institutes, and governments who will focus on the gaps yet to be closed.

CONCLUSIONS AND RECOMMENDATIONS

Tsetse and trypanosomiasis control is a prerequisite to optimal socioeconomic development of the many African countries afflicted with the insect and the diseases it carries.

The ecology and the biology of tsetse have been thoroughly researched for decades in a quest for vulnerability that may be exploited for eradicating or controlling these insects. Nevertheless, in a number of affected countries, the fly and the disease as impediments to development are still insufficiently understood. This important area of research must continue.

1. The task force recommends intensifying studies on the biology, ecology, behavior, and vectoral capacity of tsetse. New discoveries on these subjects may contribute to better uses of insecticides and other methods of tsetse control more effective than those presently in vogue.

National and regional goals, as the bases for designing policy to cope with the problem, may often be inadequately defined; as a consequence, trypanosomiasis is far more prevalent and destructive than it need be.

2. The task force recommends that:
   a. On the request of concerned countries, financial and technical assistance be provided for an assessment of epidemiological and socioeconomic data whose results would help administrators arrive at or improve national policy with respect to trypanosomiasis.
   b. Concerned countries be supported in the preparation of programs designed to implement national policy on tsetse and trypanosomiasis control.

Before trypanosomiasis and tsetse control programs can be instituted in any nation, that nation must have a well-defined policy on land use and socioeconomic development. This, of course, is a national responsibility.

3. The task force recommends that any active operations concerned with animal trypanosomiasis control or eradication involving the development of new areas be closely integrated with planned land development and take cognizance of traditional livestock and agricultural practices.

Cost and benefit of tsetse and trypanosomiasis eradication or control, although obvious and considerable, are not easily quantified. Nevertheless,

4. The task force recommends that costs of control and/or eradication be related as much as possible to the benefits that may accrue from the implementation of such programs.

In some countries, the urgent need for controlling or eradicating trypanosomiasis may exceed national capabilities in terms of manpower, funds, and equipment. Requests for external assistance in such instances, especially in planning efficient operations, must originate from the governments of countries where the disease is endemic.

5. The task force recommends that governments call on OAU/ISCTRC and other international organizations and agencies to assist in developing national and/or subregional plans for tsetse and trypanosomiasis control.

National field capabilities, if lacking, constitute a major obstacle to the deployment of financial and technical assistance from outside a country to help eliminate or reduce the impact of trypanosomiasis on rural development or to conduct research on it. Hence:

6. The task force strongly recommends, as did the 1975 FAO Consultation on Trypanosomiasis in Accra, the establishment of national multidisciplinary tsetse/trypanosomiasis units in each country where trypanosomiasis is endemic.

Diagnosis and surveillance must become an essential part of future programs of tsetse or trypanosomiasis control in order that the full benefit of such control be realized and maintained. Diagnosis and surveillance are critical especially in preventing or managing human sleeping sickness.

7. The task force recommends that bilateral agencies support training and assist in providing basic diagnostic tools to improve present medical surveillance for the 35 million people permanently exposed to trypanosomiasis.

The task force believes that training people is the single most important requirement for trypanosomiasis control. Training must be closely geared to strengthening research institutions and developing programs for action.

8. The task force recommends that each country concerned be supported in establishing national plans for training tsetse/trypanosomiasis control and research specialists, middle-level field control officers, and junior staff for control campaigns.

Insecticides will continue to serve as frontline weapons for the control of tsetse for the foreseeable future. Recent campaigns for tsetse control have usually included some environmental monitoring to assess the impact of widely applied insecticides on organisms not targeted for extinction. These studies have revealed some short-term consequences negative to the environment. Application techniques must be modified continually to reduce the chance of harm to the environment.

9. The task force recommends that:

   a. Investigations continue on the search for selective uses of existing insecticides to reduce the hazard of any long-term adverse effects of these chemicals on the environment.
   b. Research and development be conducted with a view toward adopting new insecticides more effective and less persistent than those now in use.
   c. Applied research be encouraged to assess the suitability of aerial applications used for treating various types of habitats.
   d. Equipment for ground-spraying operations be evaluated for its suitability under varying conditions of use.

Research on biological, physiological, and genetic dynamics of

tsetse offers good prospects at low cost for devising new control measures which may be effective per se or which may complement other methods in use.

10. The task force recommends that:
    a. The two recently completed major programs of research and pilot studies on SIRM, one in Upper Volta and the other in Tanzania, be thoroughly evaluated as soon as possible for guidance on the potential contributions SIRM may make to integrated control programs for flies.
    b. Research be accelerated on other methods of controlling the fly, by biological or physiological means, by hybridization techniques, and by actually manipulating the genes of the fly. Should a satisfactory method be developed, *Glossina* would be particularly vulnerable to this type of control in view of its low reproductive potential.

Trypanosome's increasing resistance to current drugs for animal trypanosomiasis and sleeping sickness threatens drug effectiveness. Research and screening programs for trypanocidal compounds in pharmaceutical industries have undergone a considerable reduction--out of the 10 industrial programs existing some 10 years ago, only 3 still function.

11. The task force recommends that:
    a. Industry, academic institutions, and governments intensify studies to find more effective and less toxic drugs against sleeping sickness in man and trypanosomiasis in livestock.
    b. Donor agencies subsidize pharmaceutical organizations, particularly those within their own countries, to enable them to carry out research and development of new trypanocidal drugs.

A practical method of protecting animals from trypanosomiasis (conceivably human beings as well) could come about through advances in immunology which derive from the search for a vaccine.

12. The task force recommends that African governments and donor agencies increase their support for research on immunological processes that may lead to the development of antitrypanosomiasis field vaccines.

Reliance on trypanotolerance--a phenomenon only partially understood--has intrinsic worth as a practical measure for controlling trypanosomiasis in livestock. A precise understanding of this phenomenon could enhance its usefulness for trypanosomiasis control; it could illuminate the function of drugs and the nature of the immune response as well.

13. The task force recommends that:
    a. The productivity of trypanotolerant livestock be studied under different management systems, in different ecological zones, and under varying degrees of trypanosomiasis risk.
    b. The methodology required for measuring the level of trypanosomiasis risk to which the host is exposed be ascertained.
    c. The mechanism, genetics, and environmental determinations of trypanotolerance be researched.

Notwithstanding the myriad projects of action against trypanosomiasis and of research, serious gaps remain to be closed. Coordination of existing projects already takes place at different levels of complexity, but such coordination needs to be strengthened to provide a strong base for future initiatives.

14. The task force recommends that:
    a. Coordination of activities in human and animal trypanosomiases control, in training, and in research continue to be undertaken through WHO for human disease and through FAO for animal trypanosomiasis and related development.
    b. ISCTRC should continue to serve as the regional structure for the promotion, integration, and coordination of activities for combating the human and animal forms of the disease in Africa via training, research, control, and surveillance programs.

Certain key organizations charged with coordinating functions could meet their responsibilities far more effectively than is presently possible if they possessed adequate financial and staff resources.

15. The task force recommends that:
    a. The capacity of ISCTRC Executive Committee, as a first priority, be expanded with the objective of developing within Africa the leadership for tsetse and African trypanosomiases, with the view to designing and implementing research, training, and control programs integrated with land development.
    b. STRC/IBAR, which is the permanent Secretariat of the Executive Committee of ISCTRC, be strengthened by additional highly qualified professional staff of such status as to enable it to formulate strongly needed policy and recruit and administer the necessary financial and manpower resources outside of Africa.
    c. Substantial, sustained, and ever-increasing support be provided to the Secretariat to enable it to assume this perpetually expanding responsibility. A budget of approximately $250,000 should be given to the Secretariat for these purposes in the coming year, increasing the amount to approximately $600,000 per annum in over five years. Such funds will initially have to be sought from external sources, but it is essential that continuity of financial support to the Secretariat be assured through increasing contributions by OAU on a phased basis of the associated financial costs.
    d. Based on the technical knowledge that exists to conduct operational programs of development and animal trypanosomiasis control, a special fund should be made available to FAO to enable such programs to be undertaken. This money would be provided with the understanding that such programs would probably take at least 10 years to complete.
    e. Bilateral assistance agencies should cooperate with FAO,

OAU, or WHO in establishing and funding multidisciplinary missions to assist in the development of national or subregional programs, including all aspects of training, research, control, and related development, but such missions should originate with the Executive Committee of ISCTRC.

ADDITIONAL READING

For those who seek additional information on the tsetse and on the trypanosomiasis problem, Man Against Tsetse: Struggle for Africa, by John J. McKelvey, Jr. (Ithaca: Cornell University Press, 1973), will give general background and historical information. J. Ford and K. M. Katondo have designed maps of tsetse fly (Glossina) distribution in Africa, 1973, according to subgeneric groups ("Maps . . . 1:5000000" Bulletin of Animal Health and Production 25 [1977]:187-93).

H. W. Mulligan's text The African Trypanosomiases (New York: John Wiley, 1970) is a prime source of reference, particularly on the trypanosomes. Drs. P. deRaadt and J. R. Seed have written "Trypanosomes causing disease of man in Africa," in Parasitic Protozoa (volume 1, pp. 175-237, Academic Press, New York, 1977). In Tropical Doctor (3 [1973]: 110-12), Dr. H. Buyst treats in detail the symptoms and the diagnosis of sleeping sickness gained from his own experiences in Zambia.

FAO/UNDP sponsored an Expert Consultation on the Economics of Trypanosomiasis in a report issued in 1977 (Rome: FAO, 1977, W/L 5740). The report includes 10 appendices, each a country study. M. Négrin and K. J. R. MacLennan report for Botswana; J. Gruvel and J. G. Gauch for Ivory Coast and Upper Volta; J. Gruvel for Benin, Chad, and Mali; J. Ford for Ethiopia and Somalia; A. M. Jordan, W. I. McIntyre, J. G. Le Roux, and M. Négrin for Nigeria; and K. J. R. MacLennan for Zambia. Dr. G. L. Kazyumba has just published an article on sleeping sickness in the Republic of Zaire over the past 25 years (1952-1976), "L'endémie sommeilleuse en République du Zaire au cours des 25 dernières années (1952-1976)" (Médecine d'Afrique Noire 26 [1979]:47-52).

Whether to eradicate or simply to control tsetse and trypanosomiasis may strongly influence the socioeconomic development and the maintenance of satisfactory environmental conditions. Dr. A. M. Jordan restated clearly the pros and cons for eradication vs. the control of tsetse flies (Nature 273 [1978]:607-9).

On the subject of diagnosis, J. Paris, Max Murray, and R. Agure have written "An evaluation of the sensitivity of current trypanosome parasitological and diagnostic techniques" in the World Animal Review (in press).

The Report of the Second Consultation on the Programme for the Control of African Trypanosomiasis (Rome: FAO, 1979; AGA-803 [1978]) suggests inter alia ways in which nations may improve, if necessary, capabilities for effective tsetse and trypanosomiasis surveillance, research, and control. In a similar vein, Dr. K. J. R. MacLennan has recently finished a paper entitled "A general perspective of tsetse-transmitted

trypanosomiasis in relation to the rural economy in Africa," which he expects to be in press soon.

The Tsetse and Trypanosomiasis Information Quarterly (1 [1-4] [1978]:11) announces a forthcoming 300-page, three-volume Manual for Training of Tsetse Control Personnel, to be published under FAO auspices.

Publications evaluating the use of insecticides to control tsetse are legion. Among the recent ones, C. W. Lee tells of "New development in tsetse fly control using aircraft" in Agricultural Aviation (18 [1977]:6-17). In the Proceedings of a Tsetse Control Seminar in Blantyre, Malawi (n.p.:n.d.), B. K. Na'isa has written on the effects of dieldrin formulations on fauna in a swamp habitat in Nigeria sprayed to exterminate Glossina.

Articles by Challier, notably "Amélioration du rendement de piège biconique pour glossines (Diptera, Glossinidae) par l'emploi d'un cône inférieur bleu," by A. Challier, M. Eyrand, A. Lafoye, and C. Laveissière (Cahiers ORSTOM--Serie Entomologie Médicale et Parasitologie--15 [1977]:283-6), contributes to our knowledge of pest-management practices, whether for monitoring, controlling, or eradicating tsetse. S. K. Maloo has published "Relationships between hosts and trypanosome infection rates of Glossina swynnertoni Aust. in Serengeti National Park, Tanzania" in the Annals of Tropical Medicine and Parasitology (67 [1973]:205-11).

Two workshops that were held at the International Centre of Insect Physiology and Ecology, Nairobi, under the direction of T. R. Odhiambo, led to the publication of Summary of Proceedings and Discussion of the Strategy Workshop on Parasite-Vector Relationships with Particular Reference to the Tsetse Fly (Nairobi: ICIPE, 1974) in the first instance, and Proceedings of the Workshop and Tsetse Ecology and Behaviour (Nairobi: ICIPE, 1977) in the second.

Two anonymous publications from the joint FAO/IAEA Division of Atomic Energy in Food and Agriculture deal with the male sterility method for insect control. They are (1) Sterility Principle for Insect Control or Eradication (Vienna: IAEA, 1971), proceedings of the FAO/IAEA symposium, Athens, Greece, 14-18 September 1970, and (2) Computer Models and Application of the Sterile-Male Technique (Vienna: IAEA, 1973), proceedings of an FAO/IAEA panel, Innsbruck, Austria, 13-17 December 1971. Drs. D. A. Dame and D. L. Williamson reported on "Progress with the sterile technique for Glossina morsitans control in Tanzania" in the Transactions of the Royal Society of Tropical Medicine and Hygiene (73 [1979]: 133).

In regard to immunization, Dr. Keith Vickerman has described antigenic variation in trypanosomes in Nature (272 [1978]:613-17).

FAO has published a comprehensive description of the present situation, current activities, and proposed research on trypanotolerance entitled First FAO Expert Consultation on Research on Trypanotolerance and Breeding of Trypanotolerance Animals (Rome: FAO, 1976; W/K 1614, AGA-820 [1976]).

Many organizations deal with the entire spectrum of current activities and future initiatives. People interested in keeping abreast of tsetse and trypanosomiasis action and research activities should consult the current papers that FAO, WHO, and ISCTRC of OAU and their companion organizations issue. Likewise, they should peruse the abstracts of the Tsetse and Trypanosomiasis Information Quarterly, begun in 1978 and sponsored jointly by the Center for Overseas Pest Research, FAO, OAU/STRC, and WHO. One could cite many other publications; the aforementioned ones represent but a few examples from the body of literature as a whole; they may, however, serve to introduce one to the fascinating literature on trypanosomes and the tsetse fly.

ACRONYMS

CGIAR	Consultative Group on International Agricultural Research
COPR	Center for Overseas Pest Research
FAO	Food and Agriculture Organization of the United Nations
IAEA	International Atomic Energy Agency
IBAR	Interafrican Bureau of Animal Resources
ICIPE	International Centre of Insect Physiology and Ecology
IEMVT	Institut d'élevage et de médecine vétérinaire des pays tropicaux
IGR	Insect Growth Regulator
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
ISCTRC	International Scientific Committee for Trypanosomiasis Research and Control
OAU	Organization of African Unity
OCCGE	Organisation de coopération et de coordination pour la lutte contre les grandes endémies
OCEAC	Organisation de coordination pour la lutte contre les endémies en l'Afrique centrale
ODM	Ministry of Overseas Development
ORSTOM	Office de la recherche scientifique et technique d'outre-mer
SIRM	Sterile Insect Release Method
STRC	Scientific, Technical and Research Commission
UNDP	United Nations Development Programme
UNEP	United Nations Environment Program
USAID	United States Agency for International Development
VAT	Variable Antigen Type
WHO	World Health Organization of the United Nations