

Infectious Disease in Africa. A Personal Viewpoint of Research and Control Measures

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Research in the field of infectious disease in Africa today is a function of many groups, some national, some foreign, and some multinational. There is little interaction among these, and progress is hampered by language barriers, by political events associated with the acquisition of independence, and by the inadequate training of Africans during the colonial period. Research at the most basic level is conducted outside Africa itself, while the emphasis in African institutions is on field studies, on improved method of surveillance and treatment, and on the development of vaccines. Modest numbers of younger Africans are receiving training, within Africa and abroad, and it is likely that the quality of teaching, research, and epidemiologic work will improve substantially over the next two decades.

It was my good fortune, as a Rockefeller Foundation consultant, to spend 6 wk in 1974-75 touring laboratories in East and West Africa where schistosomiasis (bilharzia) and trypanosomiasis are studied. I wish to report here some of the most insistent impressions growing out of scientific visits to Kenya, Tanzania, Uganda, Senegal, Upper Volta, the Gambia, Zaïre, and Nigeria (Fig. 1).

COMMUNICATION

Africa appears to function as a group of relatively independent blocs, determined largely by colonial history and, above all, language. Kenya, Tanzania, and Uganda form the East African community, speaking English as a scientific and academic language, while Nigeria, Ghana, and the Gambia form an English-speaking bloc in West Africa. In contrast, the vast French West African bloc includes Mauretania, Senegal, Upper Volta, Mali, Niger, the Ivory Coast, Togo, and Dahomey (Guinea is set apart for political reasons at present), and there is the additional group of states of former French Equatorial Africa: Chad, Gabon, Congo Brazzaville, and the Central African Republic. Zaïre, the former Belgian Congo, remains somewhat separate because of its connection with Belgium rather than France; and Madagascar, also French-speaking, is set apart geographically. Additional blocs which I did not visit were Portugal overseas (Angola and Mozambique) and the anglophone groupings of Egypt, the Sudan, and Ethiopia; Liberia and Sierra Leone; Zambia, Rhodesia, and Malawi; and the Union of South Africa.

Thus science and medicine are conducted in English, French, or Portuguese, and there is poor communication between blocs. Communication is hindered as well by invisible political barriers—for example, Americans are not welcome in communist Brazzaville, although significant work is going on there. Fortunately for the American visitor, English is the language used by Swedes, Dutch, and Germans, wherever they work in Africa.

More is demanded of every African than of any visitor. To function at all, he must be master of at least three languages: one or more tribal languages, including his



FIG. 1

own, the local lingua franca, and the European language current in his bloc. For example, some Kenyans must function in Kikuyu, Swahili, and English; some Senegalese in Toucouleur, Wolof, and French; Malians in Bambara, Dioula, and French; and so on. This is no mean feat. A wide-spread nationalistic trend, exemplified by the recent adoption of Swahili as the national language of Kenya, will inevitably intensify the problem of scientific communication within Africa and between Africa and the rest of the world.

AGENCIES

A major hurdle for the medical observer is to understand the welter of agencies active in Africa and their relation to each other. Only after this is accomplished does it become possible to look at individuals and the work they do and to evaluate these as to quality and pertinence.

Agencies of Individual Governments

Each country is divided into sectors, in which medical care and prophylaxis are supervised by designated health officers acting under the *Ministry of Health*. In the bush, most of these health officers are still expatriates (foreigners), though in the larger towns 50% may be African. Each Ministry also has *équipes mobiles* (mobile teams), which carry out surveillance, treatment, and some degree of vector control, e.g., for trypanosomiasis.

The national universities operate under the *Ministry of Education* and have no connection with the foregoing. They incline heavily to various field studies and applied research.

Governmental Cooperation

Foreign governments support research and control measures related to infectious disease through major administrative departments, notably *USAID* and *IDCR* (International Development and Research Center), U.S. and Canadian counterpart agencies; *ODA* (Overseas Development Administration), the comparable British Agency; *Service de Cooperation*, the French agency, which works through several outlets, notably *OCCGE* (Organisation Centrale pour Collaboration en les Grandes Endemies) and *OCEAC* (Organisation de Coordination pour la Lutte contre l'Endemie en Afrique Centrale) in French West and Equatorial Africa, respectively, and *ORSTOM* (Organisation de la Recherche Scientifique et Technique de l'outre Mer) (primarily entomological) in both; also the *Netherlands Technical Assistance*; and similar Belgian, Swedish, and German Agencies.

In addition, our Peace Corps has a British counterpart, the *VSO* (Volunteers for Service Overseas), a French one the *VSN* (Volontaires de Service Nationale), and so on. The young people sent by these agencies may turn up in any of the positions discussed here, for example, as bush doctors responsible for a sector.

International Agencies

These include *WHO* (the World Health Organization), *FAO* (the Food and Agriculture Organization), *UNDP* (United Nations Development Program), the *World Bank* and several more. *WHO*, in particular, supports general research programs such as the "Lutte contre le paludisme" (struggle against malaria), which provides research funds for investigators in many different types of laboratories. There are similar "luttés" against onchocerciasis, leprosy, etc. *WHO* also developed a *WHO Immunology Research and Training Centre* in Ibadan, which turned out a series of Ph.D.'s who have entered academic life throughout Nigeria. The center now has been relocated in Nairobi, Kenya, while the original laboratory continues in Nigerian hands.

A new development is the creation of large centers, which enjoy multiple support and are largely outside the legal framework of the countries in which they reside (by prior written agreement with the corresponding governments). Examples are *IITA* (the International Institute for Tropical Agriculture) in Ibadan, *ICIPE* (International Centre for Insect Physiology and Ecology) in Nairobi, *ILRAD* (International Laboratory for Research on Animal Disease) in Kabete near Nairobi, and a new superinstitute to be set up in N'dola, Zambia. In almost every case, these are funded by the group of international agencies listed, plus private foundations (below) and governments of as many as 25–30 countries!

The international agencies continue to develop new programs for studying infectious disease. Two recent examples concerned with African trypanosomiasis are:

1. *UNDP: Trypanosome Surveillance and Glossina Control in the Moist Savanna Zones*: two years at \$1,000,000 each. *WHO* and *FAO* are the executing agencies, but support is derived from *OCCGE*, *NITR* (Nigerian Institute for Trypanosome Research), the medical faculty at Abidjan, Ivory Coast, the veterinary research center at Bamako-Sotuba, Mali, and 19 Ministries of Health.

2. *FAO Program for the Control of African Trypanosomiasis*: several successive 5-yr phases at \$2,250,000. These have not as yet gotten off the ground.

Foreign Governmental Research Support

Laboratories made up largely of expatriates and supported by *CDC* (our Center for Disease Control), the *MRC* (British Medical Research Council), the *U.S. Army*

(Walter Reed), or *Navy*, e.g., NAMRU-3 (The Naval Medical Research Unit in Egypt and Addis Ababa) abound.

Private Foundations

One thinks immediately of the *Rockefeller*, *Clark*, and *Ford Foundations* in the United States, the *Wellcome Trust* in Britain, and similar foundations in other countries. These not only set up their own laboratories but also provide fellowships and research support to existing persons and institutions.

Foreign Universities and Institutes

Certain institutions of the previous colonial powers maintain a close relationship with research in Africa. One may list the *London School of Hygiene and Tropical Medicine*, the *Glasgow University Veterinary Faculty*, the chain of *Instituts Pasteur* (Dakar, Abidjan, Brazzaville, Tananarive) linked to IP in Paris, rather similar *Instituts de Médecine Tropicale* in Basel and Antwerp, and the *Instituto de Higiene e Medicina Tropical* in Lisbon. These play a highly significant role in offering training to young Africans, usually with fellowship support, and conversely to Europeans interested in going to Africa.

Religious Institutions

Mission hospitals and schools antedate most of the other institutions listed above, and they still play a very significant role in the treatment and prophylaxis of infectious disease. The tide of Africanization (below) is causing many to terminate their activities.

MEDICAL AND SCIENTIFIC INSTITUTIONS

All the financial effort implied by the above list is funneled through a limited number of outlets. Some *new schools or departments* are supported, as in the case of Ahmadu Bello University in Northern Nigeria. Its Veterinary Faculty in Zaria is largely supported by Americans (USAID, funded through Kansas State University) and by the Dutch (Netherlands Technical Assistance), but the Nigerian government also contributes substantially. Alternatively support may go to *small research units*, such as the Wellcome Trust Research Laboratory in Nairobi (schistosomiasis) or the MRC Immunology Unit in the Department of Medicine, Ahmadu Bello U. (infectious diseases), or to *research institutes* such as the Swedish Armauer Hansen Institute in Addis Ababa (leprosy). Distinct from these are the *foreign individuals or small groups who visit Africa annually*, usually for several months in the summer or the dry season, to do field studies and to gather material for the winter's effort back home. Examples are members of the Division of Geographic Medicine at Case Western Reserve and the Department of Medicine at Harvard, who join the WHO and Wellcome groups in Nairobi each year to study schistosomiasis, or the Lister group from London who visit northern Nigeria annually to study trypanosomiasis.

Some institutions are now entirely in African hands, such as ICIPE and the medical and veterinary faculties at Ibadan, while others remain entirely expatriate, notably many of the institutes and smaller laboratories and the *Instituts Pasteur*. Still others are in transition, e.g., Ahmadu Bello University. The large multiple support institutes are expected to be half and half, but it is likely that initially their professional staff will be largely expatriate. "Community" laboratories in British East Africa, such as EATRO and EAVRO (the East African Trypanosomiasis and Veterinary Research Organizations), and West Africa, such as NITR, have been al-

most entirely Africanized. A comparable process however, has not occurred in OCCGE, OCEAC, and ORSTOM in French West Africa.

The communist nations provide aid in a form distinct from any of the above, none directed specifically to health problems. The USSR carries out building projects, which are often poorly tailored to the needs of the recipient nation, as for example an Olympic stadium and swimming pool in Upper Volta. The People's Republic of China, following the lead of the Taiwanese, has introduced the culture of rice in Mauretania and Upper Volta (and presumably in other African countries), enforcing strict sanitary procedures which have virtually eliminated schistosomiasis within the project areas. A pleasant example of true international cooperation is found here, since it is the French of OCCGE who monitor disease levels in the participating Voltaic communities.

NONSCIENTIFIC CONSIDERATIONS

Political Events

The achievement of *independence* has in many instances led to the temporary collapse of well-established surveillance mechanisms for controlling infectious disease. This has been conspicuously demonstrated in the immense country of Zaïre, where sleeping sickness was nearly eradicated in 1960 but is again epidemic in many areas. What remains of the Belgian surveillance system is no longer adequate to cover the entire country. However Africans are being trained as rapidly as possible to replace the departing Belgians as heads of the équipes mobiles, and there is some evidence that the disease is again being brought under control. President Mobutu recently announced that religious teaching will no longer be permitted in Zaïre, and this sounds the death knell to many missionary activities, quite possibly including their schools, dispensaries, and hospitals. *Africanization*, in progress throughout the countries I visited, is directed not only at whites who are recognizably connected with the former colonial powers but also at Indians, especially in East Africa, and even at Africans from other countries. Its effect has frequently been to replace competent medical men and scientists with less adequately trained personnel and thus to destroy the efficacy of a given laboratory or school. An extension of this process is a conspicuous *lack of support* by individual Ministries of Health for "community" agencies. Expressed as it is in financial terms, this attitude contributes to a progressive loss of effectiveness of EATRO, EAVRO, OCCGE, etc.

Watergate offers a recent reminder of the pervasiveness of *corruption* in political institutions. Where it is seen in developing nations, as when tribal connections outweigh considerations of merit or need in the evaluation of individuals, it may seriously hamper both research and medical care. Examples encountered in my travels varied from occasional directors of laboratories or deans of faculties, who feather their own nest instead of doing their job, to a small number of mediocre or corrupt expatriates who prefer to hang on in Africa rather than return to their countries of origin. It is interesting that, among the foreign groups active in Africa, the Swedish agencies have an explicit and rigid policy of leaving at the first breath of corruption in any form and taking everything (down to the last scalpel) with them. They are highly respected, and their approach has been quite successful.

Lack of Coordination Among Government Agencies Concerned with Health

This is a striking problem in many countries. However it is recognized as a problem and is being met, as for example by the creation of a new Health Council in

Zaire, which brings together the Ministries of Health, Education and Religion, FOMECO, FOMETRO, FONAMES,² and the University and which cannot help but improve a now chaotic situation. Where budgets and activities of cooperation arms, such as AID or OCCGE, are in part controlled by individual Ministries, the purpose of research, even at the applied level, is frequently not grasped or deemed significant by Ministry officials. Members of the OCCGE team in Upper Volta, as their official budget shrinks, must obtain grants from WHO in order to do any research, and they are swamped by requests for surveys which tend to displace research activity.

Unwillingness of Educated Africans to Leave Urban Centers

Where laboratories or institutes are located in smaller towns or in the bush, they have great difficulties maintaining an adequately trained staff.

Breakdown of Equipment

This becomes the major problem in many laboratories, because no one competent to repair the equipment is available any more and because Africans have not been trained for repair work. It applies to everything from trucks to refrigeration units to electronically controlled apparatus. A similar breakdown is seen in the loss of tsetse colonies or of inbred mouse colonies used for research. One can make a strong case for regarding the provision of good electronics and machine repair shops and the training of personnel for these as having a higher priority than virtually any other form of research support at the present time.

These nonscientific considerations should not lead to undue pessimism about the future of the new African nations. Nigeria, which is the size of France, has 55 million inhabitants and already appears to have adequately trained cadres of Africans to carry on the functions of government, education, etc. In the other countries visited, excellent Africans are present at all levels of government as are hard working expatriates getting on with the job of training. The difficulties are real, but I think they will be surmounted.

TRAINING FOR AFRICANS

Educators in the developed nations frequently hold the view that citizens of the third world trained abroad become spoiled by their experience and unwilling to return home. One might be led to conclude that useful training must take place within each new nation if it is to be effective. However, one meets excellent people trained in both ways, for example among the outstanding faculties of the medical and veterinary schools in Ibadan. Most of those trained locally ultimately seek post-doctoral experience in Europe or the United States before launching medical or research careers in their own country.

There are several institutions abroad which concentrate on training Africans for work on infectious disease, notably the London School of Hygiene and Tropical Medicine, the Veterinary Faculty of Glasgow University, and the Incorporated Liverpool School of Tropical Medicine; the laboratories of Capron, Gentilini, and Thomas in Lille, Paris, and Lyons; the Institute of Tropical Medicine in Antwerp, and so on. The United States has no institution with a comparable emphasis, and it is likely that the total number of Africans trained at Walter Reed, Yale, etc., does not exceed the number trained in any one of the European countries.

²Fonds Médical de Coordination, Fonds de Médecine Tropicale, Fonds National pour l'Assistance Médicale et Sociale.

By and large, the expatriate centers in Africa itself (NAMRU-3, the Institute of Tropical Medicine in Kinshasa, OCCGE in Bobo Dioulasso) make little attempt to train Africans to a professional level, since their focus is on epidemiologic field studies and clinical and basic research. The WHO immunology research and training centers, however, have served as very valuable training sites, first in Ibadan and now in Nairobi. The Ibadan center, over 10 yr, produced seven African Ph.D.'s, all of whom have initiated active academic careers in different parts of Nigeria and one of whom now directs the center itself following the departure of the expatriate staff. Among the most impressive centers of training are places where teaching oriented expatriates have accepted the task of creating or revitalizing academic departments of African schools. The Pathology Department at U. Ibadan is to a considerable extent the handiwork of an English pathologist. Similarly the Parasitology Department of the Veterinary Faculty in Ahmadu Bello University, Zaria (northern Nigeria) is being built slowly but surely by a Dutch group with funding by the Netherlands Technical Assistance and the Nigerian government. The latter has a highly effective Ph.D. training program, emphasizing combined course and thesis work in the U.S. and in Nigeria and designed to train as many as 35 young faculty members by 1978, at which time the Dutch project will be phased out. The new Ph.D.'s are competent and devoted young scholars.

Therefore, there appear to be good training opportunities for young Africans. It is interesting that overall, veterinarians appear more interested in availing themselves of these opportunities than physicians. The future of existing professional training programs is clouded by a noticeable decrease in the quality of teaching at all levels of education, resulting from the exodus of expatriates and the inadequate supply of well-trained local people to replace them. This is particularly harmful at the level of primary and secondary education, since young people of college age in, e.g., the Gambia or Senegal, are no longer well enough trained to enter a European or British university and by their presence contribute to a lowering of quality in the U. of Dakar, which had been first rate for many years. The best solution would be to send more youngsters to school in Europe, Britain, or the U.S., but this has not occurred to a significant extent.

UNITED STATES INVOLVEMENT

The degree to which each African population retains its bonds with the previous colonial power is striking. This is seen both in the language used throughout the given area, in the culture to which local Africans appear to aspire, and in the choice of places to which young Africans go for advanced training. The interest of the colonial power in sustaining this relationship is doubtless humanitarian on the part of many of the participants but, at the level of government funding, must be assumed to reflect economic self-interest for the most part. Of the places I visited, Zaïre seemed to be least concerned with these ties to the past.

The United States, while not having colonial ties with Africa (except in an indirect sense, with Liberia), is not unconcerned with Africa and its problems. The size of the USAID commitment, directed especially to helping the people of the Sahel, is ample testimony of concern in the most genuine sense. In the specific context of infectious disease, United States interest is expressed principally through Army or Naval medical research units, such as NAMRU-3, scattered representatives of CDC, the Hope mission (heavily involved at the moment in training faculty at the new U. of Ife campus in Nigeria), and training and research programs funded by AID through American universities (Colorado State and Kansas State Universities in the Veteri-

nary Faculties of Nairobi and Ahmadu Bello U., respectively). Note that the ICMR (International Centers for Medical Research) of NIH, through which funding is available, is actually unused in Africa.

In addition to the absence of past involvement, the U.S. effort suffers in two other respects. We do not have a tradition comparable to that in Britain or France, of long individual service abroad. Also most all our efforts overseas are hampered by rules which require individuals to return to the U.S. after a single year of service or at most 2 yr. Our European counterparts are frequently assigned for periods of 4 yr or more (even 10). Few Americans remain in an African post long enough to become really familiar with the complex machinery required to get things done or long enough to accomplish anything, and few Americans appear to want to. Thus we lack outlets and people with the needed personal involvement, and our rules hamstring useful service. Zaïre, with weak ties to its colonial past, may well be the best target of U.S. involvement and it is significant that USAID has only one desk for all of West Africa and another desk for Zaïre alone.

INFECTIOUS DISEASES (Les Grandes Endémies)

Prevalence

Of the great viral diseases, *smallpox* has been effectively eradicated in all parts of Africa except Ethiopia. *Measles* remains a principal cause of death in children under 5, especially when combined with malnutrition, and it is seen in unfamiliar forms associated with defective immune responses, such as enteritis and giant cell pneumonia. Immunization against measles has been rather unsuccessful (effective protection in about 30% of those vaccinated). It is unclear if this is due to breakdown of the refrigeration chain, a common African problem, or to the local prevalence of strains of virus unrelated to those used in preparing the vaccine. The latter possibility is under investigation in several laboratories. *Yellow fever* remains endemic in much of Africa, along with *dengue* and other arboviruses, and with rarer viruses such as *Lassa fever*, *Marburg*, etc.

The usual bacterial infections such as *typhoid fever*, *dysentery*, and *streptococcal disease*, remain common. *Cholera* has not been a recent problem in most of Africa but remains a threat, as for example among pilgrims returning to Kano in Northern Nigeria from Mecca, where a substantial epidemic is currently underway, or among refugees from Angola to Zaïre. There is little assurance that the disease was completely eliminated from W. Africa following the major outbreak in 1970. *Meningococcal meningitis* occurs in epidemic form in a belt in northern Nigeria and the adjacent countries, and is followed by unusual complications such as arthritis, cutaneous vasculitis, episcleritis, and pericarditis. *Leprosy* is widespread and is the subject of elaborate surveillance and treatment programs in several of the countries visited as well as of intensive research (see below).

Of the parasitic diseases, *malaria* remains holoendemic throughout the area visited and is the prime suspect in all cases of unexplained fever, many of which nevertheless are really due to viral disease or to spirochetosis. Human *trypanosomiasis* (sleeping sickness) peaked at the turn of the century and then was brought under more and more effective control until, by 1960, there were less than 1000 new cases per year in most countries of East and West Africa. Surveillance programs were in several instances, destroyed by the chaos surrounding independence and the disease is now epidemic in the Sudan and parts of Zaïre, and is spreading in Uganda and Guinea. The moist savanna zone of central Nigeria is al-

most uninhabitable because of tsetse fly infestation and associated trypanosomiasis. In the other countries it is considered a minor problem. *Schistosomiasis* is widely prevalent, usually in the form of *S. hematobium* infection, which tends to be seasonal since the intermediate host is a snail which survives the dry season. Its clinical importance is under debate, and the disease is regarded as a harmless nuisance by many medical men!! *Schistosomiasis mansoni*, whose intermediate host requires water all year round, is present in small pockets throughout Africa but becomes a major hazard wherever there is a dam, irrigation project, or even an industrial project which brings large numbers of people together. Thus it is spreading rapidly in newly irrigated lands near Lake Victoria and in the wet lands above the Volta dam in Ghana. New drugs (niridazole, hycanthone) are proving efficacious here, as are certain control techniques (see below). *Filariasis* is very widespread, and *onchocerciasis* is a major problem in several areas of West Africa. Knowledge of this disease remains in a descriptive phase—current studies are directed to distinguishing varieties of the organism which produce “river blindness” from those which do not. There is a big push to control the vector by spraying in Upper Volta, Dahomey, and the Ivory Coast. Finally *leishmaniasis* is important throughout the countries visited.

Two points should be emphasized here. First infectious diseases of cattle are regarded as of the highest priority in many parts of Africa. Among those diseases which deny large areas to the raising of food animals, East Coast fever, caused by a protozoon *Theileria parva*, and trypanosomiasis are the most important, but others such as babesiosis and cysticercosis are also significant. Second, *malnutrition* is as important as infection in killing children and in eliminating their defenses against such infections as measles. The connection between *overpopulation* and malnutrition is understood in Kenya, which includes population control as a line item in the national budget, but is ignored in populous Nigeria and indeed in all of West Africa, where Islam grafted on a polygamous culture strongly inhibits discussion of this fundamental aspect of health.

Methods of Study and Control

Since this essay is not intended as a systematic review of our present knowledge about infectious disease, I shall not comment on those bacterial infections for which there exist well-recognized techniques of prophylaxis and chemotherapy. For virus diseases such as smallpox and measles, *vaccination* is the principal weapon available at present and, as noted earlier, it has been effective in eradicating the former but relatively ineffective in the latter. For other categories of viral disease such as those caused by one of the arboviruses or by Lassa, diagnosis is sketchy at best and treatment nonexistent.

Perhaps the most interesting current progress involves leprosy and the great endemic parasitic diseases, malaria, trypanosomiasis, schistosomiasis, filariasis (including onchocerciasis), and leishmaniasis. Each country has well elaborated programs of *surveillance and treatment* for one or more of these, usually carried out by équipes mobiles assigned to one of the medical sectors and by fixed dispensaries and mission hospitals in the area. The personnel of the équipes mobiles (for example, those which are concerned with leprosy in Upper Volta or with trypanosomiasis in Zaïre) are all paramedics, i.e., with no more than 1 or 2 yr of formal training, but are expert in the disease for which they are responsible. They reach every village in their assigned area once annually, identify new cases by clinical and/or laboratory

tests, treat these, and check on cases treated earlier (follow up may continue for 3 yr). Their work may be backed by centers for clinical study and research on the particular disease. Examples in the case of leprosy, are the Pavillon de Malte (Dakar), the Institut de La Lèpre Marchoux (Bamako, Mali), and the Armauer Hansen Institute (Addis Ababa); these vary in level of sophistication from the first of these, in which no study has yet been carried out of lymphocyte responses in different types of leprosy, to the last, in which all the techniques of contemporary cellular immunology are brought to bear on the leprosy problem and the separation and purification of leprosy antigens are far advanced. Surveillance and treatment have had little apparent effect on the prevalence of malaria or of leprosy, but have been highly effective in controlling sleeping sickness. In filariasis, leishmaniasis, and schistosomiasis, case finding and treatment as means of systematic control are virtually nonexistent, though extensive surveys are made both by existing agencies such as OCCGE and OCEAC and by traveling visitors.

Drug testing is another common activity. New drugs such as niridazole and hycanthone are revolutionizing the approach to the schistosomiasis problem, and several drugs are being tested in each of the other diseases listed. Such testing is usually an accompaniment of *field studies*, carried out by all the groups listed earlier in the present report. An attempt is made, through such studies, to answer crucial questions such as the progressive "domestication" of some species of tsetse flies (in West Africa) or the actual life span of individual schistosome pairs in man.

Vector control appears to offer promise of disease control in every instance. Projects may be nothing more than the application of conventional rules of hygiene, as in the case of the Chinese rice cultivation projects in Upper Volta. More elaborate attempts to control schistosomiasis by the use of molluscicides to eliminate snails, are being compared with the results of careful case finding and treatment and with the adoption of proper sanitation measures, which eliminate discharge of fecal matter (and hence of eggs) into water used for laundry and for bathing and/or provide piped water for the latter. Such a project is under way in Madagascar (under the Swiss Tropical Institute), but has given less clear-cut answers than a similar program of the Rockefeller Foundation laboratory on the island of St. Lucia in the Caribbean. Parenthetically, the findings in the latter study, which deals with static populations in isolated valleys, where banana cultivation is the principal economic activity, are clearly inapplicable to populations of fishermen, as in Lake Victoria or nomadic cattle herders such as the Masai of Kenya and Tanzania or the Peulh of West Africa.

Vector control, in the case of trypanosomiasis originally took the form of brush cutting and trapping the tsetse flies. Current activities include selective killing of game species which serve as common alternative hosts (in Zambia) and spraying of the bush along watercourses during the dry season with suitable insecticides (in Nigeria). This is highly effective in the dry savanna areas where in fact the tsetse flies show seasonal migration into the watercourse areas, but is useless in the moist savanna, where no such migration occurs. Disturbing questions which have assumed prominence in northern countries, such as the long-term effects of massive insecticide applications on general ecological situations—invertebrates, birds, mammals, man—have not passed the discussion stage here. New approaches still under investigation, are the dissemination of sterile males and the use of chemoattractants to enhance trapping of tsetse. These have required the development of mass tsetse breeding techniques, as at the Tsetse Research Laboratory in the Veterinary Field Station, Langford, near Bristol in the U.K., and at Maisons Alfort in Paris, the

working out of techniques and dosages for sterilization of males by X-irradiation or chemosterilizants without loss of other biologic functions, the running of pilot tests (near Lake Chad) to ascertain the effectiveness of the method, and finally large-scale testing which is just getting started. A massive attempt is under way in French West Africa to eliminate the *Simulium* fly, which serves on the vector for onchocerciasis, by spraying rivers with larvicides. While all these attempts are based in the United Kingdom and in Continental Europe, perhaps the most far-reaching studies of the vectors are now underway at ICIPE (the International Center for Insect Physiology and Ecology) in Nairobi.

Vaccine development is being vigorously pursued with several of the major human and cattle infestations, notably with trypanosomiasis and East Coast fever. The approach, however, must be described in many cases as a blunt axe. Thus several laboratories simply are gathering antigenic variants of one or another species of trypanosome in the hope of preparing a vaccine which will contain every variant-specific antigen the vaccinated individual is ever likely to encounter in, e.g., Kenya or Nigeria. Immunization may be attempted with a live vaccine, followed at the proper interval by effective chemotherapy, or by the use of irradiated organisms. Some attempts are underway to obtain "attenuated" strains for use in a vaccine. However the laboratories in Africa are not, by and large, looking for common antigens which could be used in a vaccine nor attempting the use of isolated, purified antigens delivered with appropriate carriers or adjuvants. These approaches, while not remarkably sophisticated, remain nevertheless the province of the better laboratories in Europe or America.

Basic research, so essential to success, particularly in connection with vaccines or drugs, tends quite properly to be minimized in Africa. The pressure in many African institutions to carry out adequate surveys, to achieve proper case-finding and treatment, to develop vaccines, and to test drugs, not to mention the more fundamental need for proper hospital diagnostic laboratories and procedures, virtually preclude any possibility of research requiring sophisticated equipment and reagents. The best basic work is largely the province of small expatriate laboratories such as the WHO and Wellcome units in Nairobi, the MRC unit in the Department of Medicine of Ahmadu Bello U. in Zaria, and NAMRU-3 in Egypt; of temporary visitors from abroad such as the Lister Institute group, which visits Nigeria for 2 mo annually; or of European or American laboratories, e.g., the Molteno Institute in Cambridge, which have no direct outlet in Africa. These remarks should not be construed as implying that no good basic research exists in African institutions. On the contrary, there is indeed some excellent research, as at ICIPE or the former WHO unit in Ibadan, but it is limited in amount.

This is hardly the place for an extensive discussion of current *research problems*. I can simply say that these vary from extremely basic (example: the immunological and biochemical events which trigger and drive the process of antigenic variation in trypanosomes) to highly practical (example: to develop a simple sensitive technique, usable in the field, to measure circulatory schistosome antigen as a method of diagnosing schistosomiasis and estimating its severity). The *quality* and *sophistication* of current projects of course varies widely. Aside from the widespread lack of equipment requisite even for simple modern diagnostic procedures, such as lymphocyte transformation, it is clear that some scientists have yet to acquire a working knowledge of contemporary cellular immunology. This is not surprising, and one is encouraged to find very rapid changes taking place in the research carried out in Africa.