Phys. **34**, 159 (1956); N. G. Einspruch and R. Truell, *Phys. Rev.* **109**, 652 (1958).
20. W. P. Mason, *J. Acoust. Soc. Am.* **27**, 643 (1955).
21. A. Seegar, *Phil. Mag.* **1**, 651 (1956); ———, H. Donth, F. Pfaff, *Discussions Faraday Soc. No. 23* (1957), p. 19.
22. H. E. Bömmel, *Phys. Rev.* **96**, 220 (1954).
23. L. MacKinnon, *ibid.* **98**, 1181 (1955).
24. W. P. Mason, *ibid.* **97**, 557 (1955).
25. R. W. Morse, *ibid.* **97**, 1716 (1955).
26. C. Kittel, *Acta Met.* **3**, 295 (1955).
27. R. W. Morse, H. V. Bohm, J. D. Gavenda, *Phys. Rev.* **109**, 1394 (1958) [theory of high-frequency case discussed by A. Pippard, *Phil. Mag.* **46**, 1104 (1955)].
28. See H. W. Lewis, *Science* **130**, 599 (1959).
29. W. P. Mason and H. E. Bömmel, *J. Acoust. Soc. Am.* **28**, 930 (1956); R. W. Morse, P. Tamarkin, H. V. Bohn, *Phys. Rev.* **101**, 1610 (1956); K. L. Chopra and T. S. Hutchison, *Can. J. Phys.* **36**, 805 (1958); K. MacKinnon and A. Myers, *Proc. Phys. Soc. (London)* **73**, 290 (1958); K. L. Chopra and T. S. Hutchison, *Can. J. Phys.* **37**, 1100 (1959).
30. J. Bardeen, L. N. Cooper, J. R. Schrieffer, *Phys. Rev.* **108**, 1175 (1957).
31. R. W. Morse, *J. Acoust. Soc. Am.* **30**, 380 (1958).

New Frontiers to Health in Africa

The creation of new, independent states in Africa poses new problems in the eradication of disease.

K. R. S. Morris

Those of us who are working in Africa are being confronted today by a disturbing reversal of the past half century's fine record of progress in the conquest of disease in that continent. The cause lies in the petty nationalisms now arising in new African states. That the effects may be serious, not only for the new countries but for territories far outside their boundaries, can be seen from the example of sleeping sickness.

Epidemics and Their Control

This disease, caused by the protozoan *Trypanosoma gambiense* and carried from man to man by the riverine tsetse flies, *Glossina palpalis* R.D. and *G. tachinoides* West, has been present in West Africa for 600 years (*1*) but only developed into widespread epidemics after 1920, although in East Africa catastrophic outbreaks had occurred in several places just after the turn of the century. These East African outbreaks were due to the introduction of infections from the Congo by travelers and slavers; I have traced (*2*) the spread of a series of epidemics from west to east across Uganda, each following a big population movement. The West African epidemics, greater both in extent and intensity than those of Uganda and Kenya, also followed big expansions in travel, commerce, and agriculture, which accompanied British and French colonization. By 1940, when the epidemics everywhere had reached their peak, there was severe depopulation of large areas, particularly in some of the most fertile and well-watered river valleys of the Volta and Niger systems (*3*). West Africa could ill afford nonproductivity in this territory, since in neighboring, unaffected areas the population was increasing by 10 to 15 percent in a decade and was starting to feel the effects of soil erosion and its associated evils.

This grave situation was tackled in slightly different ways by the governments of various colonial territories, with the French well in the lead, both regarding the scale of operation and the logic and thoroughness of application. The fact that the French had in French West Africa a uniformly administered territory, stretching from Dakar to Niamy on the Niger, made possible such a wide approach, but it took the vision and tenacity of Médecin Général Muraz to make this a reality by creating an autonomous "Service de la Maladie du Sommeil" in 1939, to deal with the whole of French West Africa according to a uniform plan, and the realism of Dr. Jamot to devise a method (mass survey and treatment with mobile bush teams of local natives) which would be effective against such a huge and dynamic problem (*4*). Moreover, Muraz recognized a pattern in the several epidemic areas, placed the headquarters of the Service at Bobo Dioulasso, in the heart of the largest of them, and divided the whole country into sectors of three grades—heavily, lightly, and very lightly infected—so that the degree of attack could be commensurate with the severity of the problem. The emphasis was heavily weighted on the side of chemotherapy, with tsetse fly control as a secondary measure.

In the Gold Coast, affected in the northern part by the huge Volta epidemic, emphasis was placed on vector control, since a method for the complete eradication of *Glossina palpalis* and *G. tachinoides* by selective clearing had been developed there (*5*). In 1940 and 1944, French entomologists visited the Gold Coast to learn this technique, which was then applied in the neighboring territories of the Ivory Coast and Upper Volta. Thus, in French West Africa, with the severely infected areas receiving three to four visits from the survey teams per year and with very thorough treatment and follow-up of patients, the French got their epidemics almost completely under control by 1945, the degree of control being greatest in the heavily infected savanna country of the hinterland, where "le selective clearing" had been most effectively applied, and least toward and in the more lightly infected rain-forest zone nearer the coast, where tsetse control was too difficult to be attempted. The French then introduced mass prophylaxis with lomadine, to deal with the

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residual endemic foci, with such effect that the number of new cases diagnosed per year in the whole of French West Africa was reduced from its 1941 peak of 29,798 cases to 4873 in 1955.

The extent of the reduction can be seen from a comparison of Figs. 1 and 2. Figure 1, based on Muraz's original survey of 1939, does not show the full extent of the epidemics in Guinea and Upper Volta, where even wider areas of severe infection had developed by 1941. Figure 2 gives the latest available data (1957) for the whole of the French territory; after the secession of Guinea in 1958, information from that colony dried up. However, the maps show well the spectacular success achieved by the French, with reductions of 90 to 99 percent throughout the vast area of the pandemic.

The difficulty of justifying the retention of a large and expensive organization to control a disease which was now of only minor importance was overcome by changing the original "Service Trypano" to "Service Général d'Hygiène Mobile et de Prophylaxie" and using the same very efficient teams and base establishments to diagnose and treat several other serious diseases in addition to sleeping sickness. In this way not only was there a greater degree of public-health improvement but a close watch could be maintained on the trypanosomiasis problem, which, though so greatly reduced, was fraught with explosive possibilities. The wisdom of this step was fully borne out by the results.

Although the approach to the problems of control differed in the Gold Coast, active cooperation with the French was maintained, and anti-trypanosomiasis measures were carried out simultaneously on both sides of the frontier. Political frontiers are rarely biological ones. In this instance the Black Volta River divided Ivory Coast from Gold Coast but formed the very backbone of the Volta epidemic. Cooperation was indeed essential for success. The British method of tsetse eradication was slower than the French one of repeated mass treatment and prophylaxis, but in the long run it was more effective and, above all, more permanent. Thus, by 1952, 3000 square miles of severely infected and partly depopulated country had been permanently reclaimed, with consolidation of the clearings and development of the region through farming, grazing, fishing, establishment of markets, and so on (Figs. 3–5).

By 1952, a 99.5 percent reduction in sleeping sickness—virtual elimination—had been effected in the first 1300 square miles reclaimed (the Lawra district), and a 95-percent drop had taken place in the remaining 1700 square miles of Wa district, where a rising

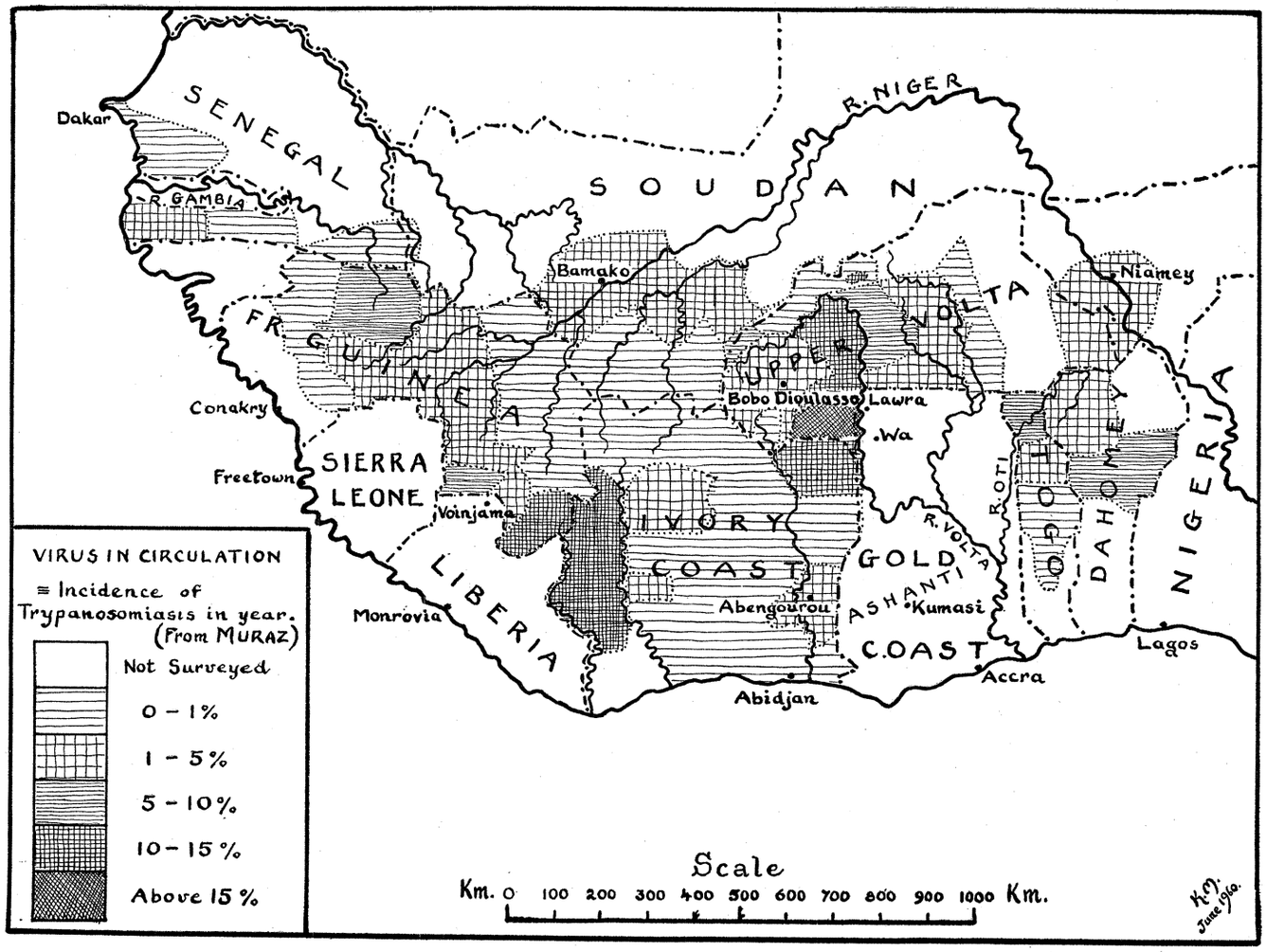

Fig. 1. Incidence of trypanosomiasis in French West Africa in 1939, before control measures had been undertaken.

epidemic had been still active in 1947. Moreover, in the Gold Coast a campaign of focal attack had now been put into operation (*1*), based on recognition of a pattern of true endemic foci, with high infection rates, from which movement of the local people and of traders and travelers caused an outward spread of infection and the setting up of peripheral, secondary areas of much lighter infection, particularly along trade routes. It was held that elimination of the vectors, and therefore of trypanosomiasis in these true foci, would result in the spontaneous reduction or even disappearance of the disease in the secondary areas also, making control there much easier and perhaps unnecessary. The success of this plan, with the Lawra-Wa foci showing high rates of reduction by 1951 and a simultaneous reduction occurring, without the application of any anti-tsetse measures, along the trade route from the Lawra and Wa districts to northwest Ashanti, 300 miles to the south (*6*), showed the validity of the concept. It also underlined the importance of population movements in the epidemiology of trypanosomiasis.

It is obvious that such an attack can only succeed if it is carried out logically over the whole of an endemo-epidemic area. Unfortunately, when I left the Gold Coast in 1952 this plan had been abandoned for one of small scattered clearings, a policy already shown to be ineffective against epidemic trypanosomiasis (*7*). The northwestern area of eradication has remained free, but elsewhere endemics have persisted, with occasional local outbreaks. A reversal of the original picture has, in fact, taken place: the main foci are now to the south, in Ashanti, from where the disease is being carried back into the savanna country of the north (*8*).

Changed Pattern in West Africa

The campaign of the French was designed to cover all their endemo-epidemic areas, as far as international boundaries permitted. While this spectacular control of the epidemics was being achieved, the pattern changed completely, as in the Gold Coast (now Ghana). The fierce outbreaks of 1930 to 1940 reached their full extent in the dry savanna country of the upper Niger and Volta rivers, with high rates of infection occurring right up to the northern limit of the range of the tsetse fly (*1*). The denser vegetation zones of the forest and coast showed much lighter infection or none at all. Today the active foci are located mainly in and around the forest and coast, the great inland savanna region being almost free, with the exception of a small residual endemic in northwest Dahomey and a larger one on the Niger

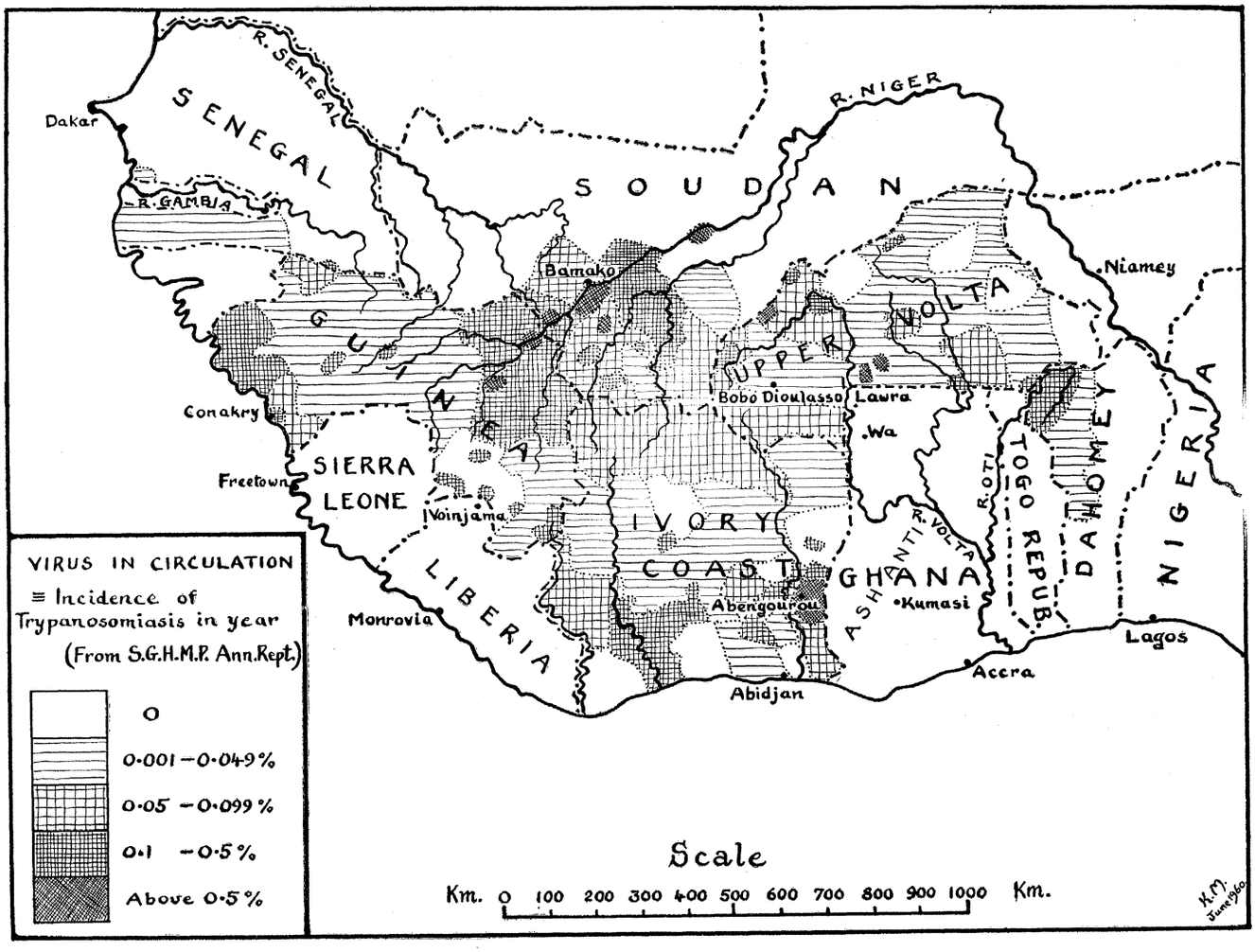

Fig. 2. Incidence of trypanosomiasis in French West Africa in 1957, showing the results of control measures.

Fig. 3 (top left). Selective clearing in the northern part of the Gold Coast in 1945. The large and valuable trees, such as mahogany, are preserved; the dense evergreen shrubs and smaller trees are removed. By this means the tsetse fly was almost completely eradicated from 3000 square miles of the Lawra and Wa districts, where there had been a serious epidemic of sleeping sickness in 1939.

Fig. 4 (top right). A river valley in the northwestern section of the Gold Coast after selective clearing.

Fig. 5 (bottom right). A river valley of the Gold Coast in an area which had been depopulated by a severe epidemic of sleeping sickness. After selective clearing the region was developed through grazing and farming.

around Bamako (compare Figs. 1 and 2).

Examination of the present-day endemics is illuminating.

The northwest Dahomey focus. This focus lies along the frontier with the new Togo Republic, in the upper Oti valley, where tsetse control cannot be complete, since the main river is in Togo. This focus has persisted since 1939, and though the present annual incidence of 100 to 200 cases marks a great reduction, it falls far short of eradication. Failure is due to the local tribes' refusal to attend inspections or even to have lomadine inoculations, the position being aggravated by proximity to the Togo Republic.

The Niger and tributaries around Bamako. This is another endemo-epidemic area of long standing, never completely controlled, with a sharp increase around Bamako itself, the incidence of 460 new cases in 1955 having risen to 718 in 1956, 800 in 1958, and 753 in 1959. Factors leading to the recent outbreak and its persistence are: (i) intimate contact between *Glossina palpalis* and man on the Niger and its many fly-infested tributaries, the sole water supplies in this dry savanna terrain; (ii) recent great expansions in population, trade, and traffic in Bamako and the surrounding villages, causing greatly increased contact between *Glossina* and man and accelerated dissemination of infection (Figs. 6 and 7); (iii) dislike on the part of the population of examination or lomadine prophylaxis and an alarmingly high rate of absenteeism (up to 60 or 70 percent) from surveys. In the absence of tsetse control, this rate of absenteeism is a serious threat to the success of the program. Of the 800 cases in 1956, only 272 were found by survey teams, the rest having been diagnosed at hospitals, dispensaries, and so on, often in an advanced stage —that is, after they had been accessible to the local tsetse for months, even years. That cases were missed in regularly conducted surveys was dramatically demonstrated by the diagnosis, in 45 days during 1957, of 117 trypanosomiasis cases among passengers on the Bamako ferry—nearly three a day!

On the coasts of Senegal, just south of Dakar, and of the Ivory Coast west

of Abidjan. Here small foci of 100-odd cases annually persist, largely because of the obstinate refusal of the population to cooperate in survey and prophylaxis programs.

In a 400-mile strip of Guinea, north of Sierra Leone and Liberia. This has been an endemic area since 1944, showing a disquieting increase and eastward extension into the Ivory Coast in 1957. Tsetse control in this semi-forest country was too difficult to be attempted. The recent outbreaks are due to increasing opposition of the Guinea populations, culminating in the complete immobilization of work through a strike of the hygiene service staff in 1957. Of the 782 cases diagnosed in that year, four-fifths were in advanced stages, the patients having refused to come in earlier, thereby constituting a menace to themselves and to their neighbors. The secession of Guinea in 1958 put an end there to the organized and well-coordinated services of the hygiene teams—services which have not been replaced. The Ivory Coast outbreak was almost completely under control by 1960, after repeated mass surveys and prophylaxis. No information is obtainable from Guinea, but in view of the fact that trypanosomiasis in this dangerously endemo-epidemic area was held in check only by unceasing and well-coordinated action by the French, without their services recrudescence is a certainty.

In the lower Ivory Coast. A serious endemic, with recent annual indices of 850 to 900 cases, has arisen around Abengourou, adjoining the Ghana border, in a forest area of great development, with extensive coffee and cocoa farms run by northern labor from Upper Volta and Soudan. When these latter territories were heavily infected (1934 to 1944), much infection was introduced into the forest by this migrant labor. The position is now reversed: the north is free; the southern endemic has shown a marked increase. The impossibility of tsetse fly control, the difficulties of reaching, diagnosing, and treating or protecting the mass of constantly shifting workers and petty traders, and the recent developments in farming, trading, and general traffic have combined to give rise to a serious problem today. The proximity to Ghana, with endemic trypanosomiasis in Ashanti and continual movement of natives across the frontier, aggravates the difficulties of control. French examination posts on the frontiers between Upper Volta and Ghana and Upper Volta and the Ivory Coast confirm the belief that infection is being transported by workers returning from Ashanti and the southern Ivory Coast.

In general, the territory in which eradication of sleeping sickness has been most nearly achieved is that in which some of the most severe and explosive epidemics took place but where tsetse fly control was understood and was courageously and effectively applied. Where there have been no attempts at entomological control, because it was considered impossible or too difficult and costly (in the forest zone), or where it was possible but not used (around Bamako), incidence of the disease has often been remarkably reduced but there has always remained a low, apparently irreducible minimum at which it was held only by vigilant application of mass treatment and mass prophylaxis, with the slightest interruption resulting in a recrudescence.

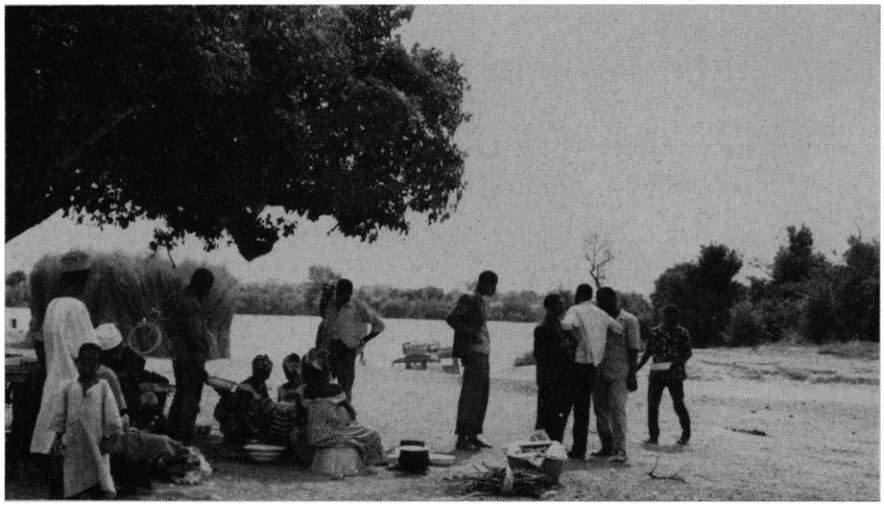

Fig. 6 (top). A ferry on the Niger above Bamako. Fig. 7 (bottom). Passengers and drivers waiting for the ferry near Bamako. A small market always develops at these ferries. Here the people are dangerously exposed to infection from the riverine tsetse flies, which breed in the evergreen vegetation along the river banks.

The New Frontiers

The value of these experiences is that they underline certain principles in the control of vector-borne disease from which future trends can be forecast.

Eradication of the disease can be achieved by vector control alone, if the control is complete; or by partial vector control plus chemotherapy, provided the attacks are well planned and simultaneous.

Chemotherapy alone brings great reduction but rarely eradication. When

chemotherapy is followed by chemoprophylaxis, eradication has been achieved but the situation is unstable, and with the vector still present there is danger of reintroduction and renewed outbreaks. Moreover, this procedure is absolutely dependent on coercion or cooperation of the population, and without this it breaks down. Even with full local cooperation the procedure involves constant attention to suspected areas by reliable and highly efficient teams. Relaxation of this vigilance results in rapid deterioration of the situation and renewed outbreaks.

One other factor, operating with increasing tempo today to hinder the eradication of trypanosomiasis and even to promote new outbreaks, is the amount of development taking place all over Africa. There are three important results: (i) Big increases in the amount and ease of transport (Fig. 8) make medical control of itinerant laborers, merchants, and others almost impossible and, as the whole history of sleeping sickness shows, greatly promote the spread of infection; (ii) new concentrations of people arise, which may lead to epidemic outbreaks if the people come in contact with *Glossina*; (iii) the clearing of forest and extension of farming can restrict the tsetse fly's range and force it into dangerously intimate contact with man.

The point that stands out in this analysis is the need for a greater degree of tsetse fly control to overcome the impasse of lack of popular support and the trends favoring transmission and spread. Control of the vectors in savanna country is well understood and needs only wider application. Forest and semiforest regions present greater difficulties, but these are not insuperable. Ten years ago the possibility of controlling *Glossina palpalis* in the high forest was demonstrated at Kumasi (*9*), and work that I am now doing in Liberia shows that rapid reduction of the same fly around forest villages can be effected by trapping (Fig. 9). There is also the striking success with sprays obtained by the Tsetse Control Department in Uganda (*10*). Control in forest will, however, always be costly, and the problem is likely to be more than local; this means that, to be effective, vector control must be combined with mass treatment and prophylaxis.

The French came very near to achieving their aim of eradicating sleeping sickness throughout French West Africa. Today, in addition to the difficulties intrinsic to the problem, they are faced with that most formidable obstacle —new political frontiers. Frontiers themselves, as Waddy has shown (*11*), are inconsistent with effective control of Africa's major diseases, a fact amply illustrated by the French experiences with trypanosomiasis. The French have also shown how dependent success is upon the meticulous planning and execution of a campaign down to its smallest detail. However ready the new na-

Fig. 8. A bridge under construction over the Lofa River in northern Liberia. The contracting firm, Raymond Concrete Pile Company, has recently built 300 miles of first-class road into the hitherto almost inaccessible hinterland. Developments such as these, which are going on all over West Africa, bring great benefits but also stimulate the spread of sleeping sickness. The riverine forest vegetation surrounding this bridge held dense populations of *Glossina palpalis*.

Fig. 9. A danger spot in the Guinea forest zone at Voinjama in northern Liberia, close to the Guinea frontier. The dense riparian forest is the habitat of *Glossina palpalis*, and sunny openings at water holes, bridges, and fords, where there is an abundant supply of human food, are the flies' feeding grounds. However, trapping by means of the Morris trap, shown here, has effected reductions of as much as 70 percent in the *Glossina* population.

tions may be to follow this precedent, it is unrealistic to expect them to achieve the necessarily high standards let alone have the resources in personnel and materials, for a long time. Meanwhile, the generations of a trypanosome are measured in hours, not years; epidemic diseases are no more respecters of time than of international frontiers. If the return of possibly disastrous epidemics is to be avoided, the solution must lie in the action of a body, such the World Health Organization, with the vision and status to put forward a realistic program of eradication on international lines. The aim is not too high; the benefits would be immeasurable.

References

1. K. R. S. Morris, *Bull. Entomol. Research* **42**, 427 (1951).
2. ———, *Trans. Roy. Soc. Trop. Med. Hyg.* **53**, 384 (1959).
3. ———, *Bull. Entomol. Research* **43**, 375 (1952).
4. Le Rouzic and Koch, *Bull. med. A.O.F., Special No.* (Dakar, 1949), p. 9.
5. K. R. S. Morris, *Bull. Entomol. Research* **37**, 201 (1946).
6. G. F. T. Sanders, annual report of Medical Field Units, 1951, unpublished.
7. K. R. S. Morris, *Nature* **164**, 1114 (1949).
8. D. Scott, *J. Trop. Med. Hyg.* **60**, 205 (1957).
9. B. J. A. Nowosielski-Slepowron, *Bull. Entomol. Research* **44**, 703 (1953).
10. *Ann. Rept., Uganda Dept. Tsetse Control* (Entebbe, 1958).
11. B. B. Waddy, *J. Trop. Med. Hyg.* **61**, 100 (1958).

Science in the News

The Atomic Airplane: "This Program Has Had a Very Irregular History"

The project to build an atomic airplane is now 14 years old, and in the unarguable words of a House appropriations subcommittee, it has had a very irregular history. To date over a billion dollars have been spent. The Defense Department estimates it will take at least another billion and another 5 years before a plane is actually in the air. The project has understandably become the most controversial in the Defense Department. It has been attacked from one side for not making an all-out effort to get some sort of atom-powered airplane aloft as soon as possible, from a second for trying to build a plane prematurely, and from a third for spending too much money on a project whose achievements, now that the first billion has been spent, are not very impressive and whose long-run value is difficult to define.

The first group of critics draw their strength mainly from the support of Congressman Melvin Price and several other members of the Joint Committee on Atomic Energy. These critics would like to see a plane in the air, any plane. They are willing to settle for what is called a "flying platform"—that is, a machine that may have no function beyond demonstrating that it can get off the ground.

At the moment the flying platform advocates are unhappy. Last summer, in the most recent of the program's many reorientations, the Defense Department decided to do its preliminary testing on the ground. The program is now concentrating on research, and letting the flying platform have only token support. The intent is to put a plane in the air only after an engine has been developed that will keep the plane aloft for a very long time, although probably not at supersonic speeds.

This approach seems to command broad support, not only in the Defense Department, but in the AEC and among the scientific advisory committees that have studied the project. But it is the source of strong feelings among the flying platform advocates. Here are excerpts from an impromptu lecture Congressman Daniel Flood delivered at a House appropriations committee hearing. The witness was Admiral Burke, the chief of naval operations, who has very little to do with the atomic airplanes. But Congressman Flood was sufficiently irritated about the way things were going to make a speech on the subject nevertheless.

"When Secretary Wilson [Eisenhower's first Secretary of Defense] was here a few years ago," said Flood, "I tried to ask him to explore the moon with me or hit it with tin cans, or a slingshot, or something, but hit it quick. He laughed at me and said he was not interested in finding out whether the moon was made out of green cheese. This was about a year before the Russians shot Sputnik. . . . I am having the same attitude with the Department of Defense and everybody down there about a nuclear-powered aircraft. I do not care how big it is, and I do not care how much it costs. I want the Department of Defense to propel an airframe with nuclear power 50 feet off the ground, 20 miles an hour, if need be. But move it. . . . Wilson, wherever he is, may laugh at this and say it does not mean a thing. That is a matter of opinion. This is a horse race. I would like to see the United States propel aircraft by nuclear power first. . . . If you think it has the tremendous psychological advantage or potential impact that I think it has—on a lot of people all over the world—why do you not try harder for it? Why do you not twist somebody's arm?"

Admiral Burke: "Because it costs too much."

Mr. Flood: ". . . That is the end of the argument, not with me but with you people who have the other problems. . . . This statement of mine . . . is treason according to the new line in Washington . . . because the budget is placed before what I think should come first, among other things, including a nuclear powered aircraft."

But Flood's feelings were not shared by many of his fellow members of the appropriations committee, and particularly not by Chairman Clarence Cannon. Most accepted the Defense Department's assurance that the best scientific estimates strongly suggest that a crash program merely to get a plane in the air would be a misuse of money and scientific talent that might be spent better on other research and development projects, including the advanced reactor and engine research at which the program is currently aimed. But a