SMALLPOX-ERADICATION AND MEASLES-CONTROL PROGRAMS IN WEST AND CENTRAL AFRICA — THEORETICAL AND PRACTICAL APPROACHES AND PROBLEMS

Dr. Donald A. Henderson
Chief, Smallpox Eradication Program
Communicable Disease Center, Public Health Service
U. S. Department of Health, Education, and Welfare

Reprinted from INDUSTRY AND TROPICAL HEALTH: VI
Published for the Industrial Council for Tropical Health
by the Harvard School of Public Health, 55 Shattuck Street, Boston, Massachusetts, 1967

Reprinted from INDUSTRY AND TROPICAL HEALTH: VI
Published for the Industrial Council for Tropical Health
by the Harvard School of Public Health, 55 Shattuck Street, Boston, Massachusetts, 1967

SMALLPOX-ERADICATION AND MEASLES-CONTROL PROGRAMS IN WEST AND CENTRAL AFRICA — THEORETICAL AND PRACTICAL APPROACHES AND PROBLEMS

Dr. Donald A. Henderson
Chief, Smallpox Eradication Program
Communicable Disease Center, Public Health Service
U. S. Department of Health, Education, and Welfare

THREE years ago in his keynote address to the Fifth Conference of the Industrial Council for Tropical Health, Dr. Karefa-Smart, then Minister of External Affairs of Sierra Leone, stated:[1]

> "I hope I am not being naive in suggesting that in hard dollars and cents, successful campaigns of eradication could be sounder investments than the most elaborate and well-run hospitals and clinics. . . . The tools for eradication have been provided for us by . . . research. It is the task of public health officials, industrial directors, and politicians to use these tools with courage, imagination and determination."

It seems appropriate that at this Conference three years later, a program for eradication, specifically smallpox eradication in West and Central Africa, can be discussed as an actuality.

On November 23, 1965, President Johnson offered United States assistance to a regional bloc of 19 West and Central African countries for the implementation of a coordinated five-year program of smallpox eradication and measles control (Figure 1). Assistance was offered in the form of technical staff, vaccines, jet injectors, vehicles, freezers, and field supplies. Operational responsibility for this African Project was assigned to the Communicable Disease Center (CDC) of the Public Health Service with financing provided through the Agency for International Development (AID).

To those of us particularly interested in the problems of public health and preventive medicine in the developing countries, the proposed project represents an unusual challenge. The project is the first in which the Public Health Service has had the opportunity to serve as the responsible principal for the development, planning, staffing, and operation of a long-term foreign assistance project of this magnitude. We believe the potential in this relationship, both to the Service and to the countries concerned, is considerable. Operating from a scientific base, the primary mission of the CDC has been the administration and application of disease-control measures in the United States. The West African project presents an

SMALLPOX ERADICATION
AND MEASLES CONTROL
in West and Central Africa

Figure 1

opportunity to focus current knowledge and skills on significant African health problems. Most important, this will be done in concert with national counterparts within the context of an African health structure and environment. The unique opportunity to learn as well as to teach is apparent.

From the time of the President's announcement last November, less than 12 months was available to us before field operations were to commence, if previous implied commitments on the part of the United States were to be met. In this brief time, a basic strategy and plan of operations were developed with and approved by the separate governments; a staff of 50 was recruited and trained; procurement was initiated; training manuals were prepared; and a wide range of logistical, housing, and administrative problems were resolved. Our staff is now arriving at their separate posts. Field operations will have begun by December 1966 in 15 of the 19 countries; programs in the remaining four will be initiated later in 1967.

This newborn project is just taking its first few hesitant breaths after a complicated, painful period of labor characteristic perhaps of a primiparous birth. As a parent, it is perhaps easier now to discuss the anticipations which we have for this infant than it will be perhaps six months or a year hence, when closer observation may perhaps disclose crippling congenital defects or injuries inflicted during the birth process.

Background of Project

The project had its genesis in three more-or-less parallel and simultaneous series of developments:

(1) Measles-vaccine testing and subsequent measles-vaccine programs in West Africa beginning in 1962.

(2) The development of portable jet-injection apparatus capable of intradermal application of smallpox vaccine.

(3) The increasing concern on the part of the nations of the world and the World Health Organization regarding smallpox and the potential for its global eradication.

Measles-Vaccine Programs in West Africa

During 1961, Meyer and his associates[2] conducted small-scale measles-vaccine trials in Upper Volta and demonstrated that the recently developed Enders B-level Edmonston strain of measles vaccine was safe and effective for use in African children suffering from malnutrition, malaria, and other illnesses. To the Minister of Health of Upper Volta, this was of considerable interest, for measles in Africa, quite unlike measles in the United States or the European countries, is a frequently lethal disease.[3, 4] Attacking, in the main, very young children (Figure 2), it is associated with a case-fatality rate of about five to 15 percent.[5] Fatality rates exceeding 50 percent have been noted in localized outbreaks.[6]

In response to a request from the Government of Upper Volta, assistance was provided by the United States for a nationwide measles-vaccination program beginning in the autumn of 1962. Over 700,000 children were vaccinated during a period of about five months.

Neighboring countries also requested assistance. Following small-scale training projects, vaccines and supplies were made available to six additional countries for vaccination programs beginning in the autumn of 1964 (Figure 3). Five more countries were provided assistance in the fall of 1965. In each country, measles vaccine sufficient to vaccinate 25 percent of the estimated susceptible population, i.e. children between six months and six years of age, was made available each year.

During the past two years, members of the Communicable Disease Center staff were provided on request by AID for short-term technical assistance. It was apparent, however, that with the difficulties of supply, the complexities of planning and execution of the vaccination programs, to say nothing of language barriers, a full-time technical staff would be of major assistance.

Portable Jet-Injection Apparatus for Intradermal Application of Vaccines

During the time the measles-vaccine programs were being carried out in West Africa, the CDC had been working with the Army Research and Development Command in field testing a hy-

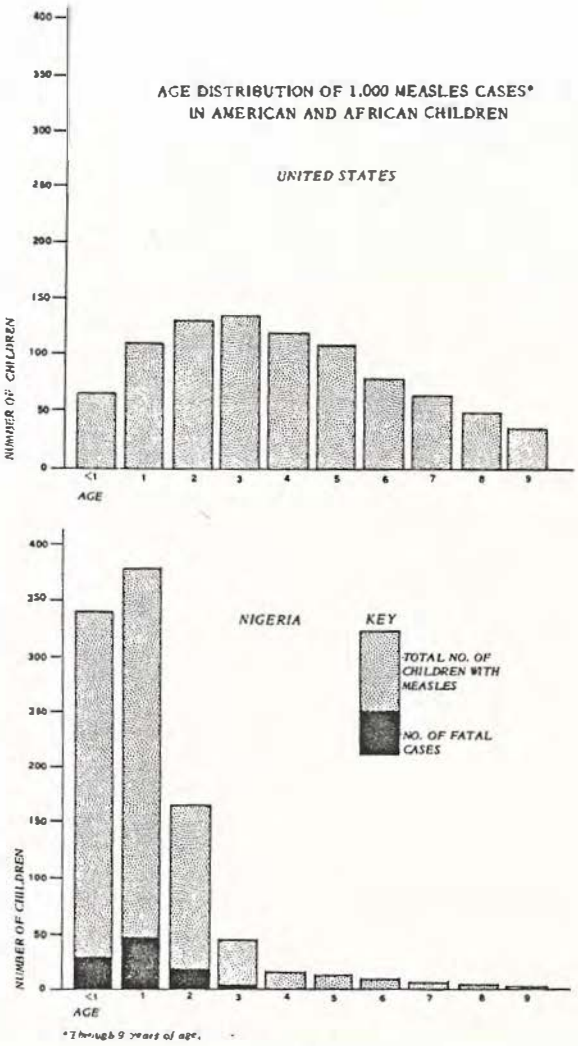

Figure 2

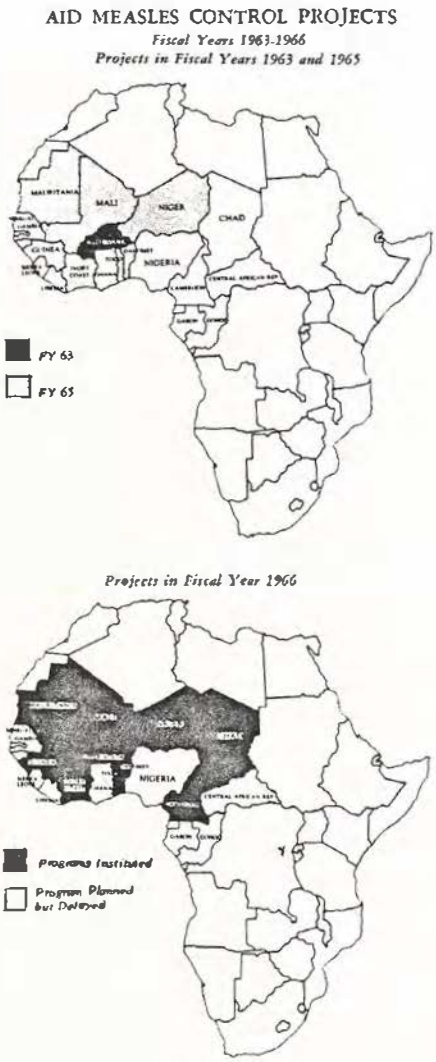

Figure 3

draulic-powered, foot-operated jet injector[7] (Figure 4). This injector weighs only 12 pounds. It is carried in a box about the size of an attaché case and is capable of administering between 600 and 1000 injections per hour. This portable injector represented a considerable advance over previously available jet injectors, since those with any potential for field use had required electrical power. In addition, the electrically powered injectors weighed nearly 40 pounds and required generators weighing 50 to 100 pounds. They were termed "portable" but were so only in a relative sense.

About four years ago, a special adapter for these jet injectors was developed.[7] This permitted the intradermal inoculation of vaccines. With this adapter, a bleb could be produced with remarkable consistency, and this bleb closely resembled that observed when an intradermal injection was given by needle and syringe. It was apparent that a new and potentially valuable tool for administration of the highly dermotropic smallpox vaccine was available.

Careful studies of primary vaccinees and revaccinees were carried out, beginning with small numbers of subjects[8] and expanding progressively until in Tonga over 40,000 primary vaccinations were performed and evaluated.[9] Initially, the vaccination lesions were examined and photographed daily and results were correlated with serologic

studies. In the course of these studies over 100,000 vaccinations were performed and evaluated. The results exceeded expectations. Consistently, primary responses were recorded in over 98 percent of primary vaccinees and "major reactions" were observed in about 90 percent of revaccinees. Similar responses were observed whether the injections were administered by the investigation teams or by local personnel.

In Northern Brazil, an operational study[10] was carried out to measure the comparative efficiency and the extent of coverage achieved by employing jet injectors at "collecting points" contrasted to a program employing multiple-pressure vaccination carried out in the more conventional house-by-house type of campaign. Results were evaluated by probability surveys conducted seven days following vaccination. The program of multiple-pressure vaccination on a house-by-house basis succeeded in reaching a somewhat higher proportion of the population. "Take rates" in this group were, however, distinctly lower than those observed following use of the jet injectors. Taking into account both factors, the proportion of persons *successfully* vaccinated was almost indentical in the communities studied. The overall cost, however, of the jet-injector program was only one-fifth that of the multiple-pressure campaign.

Mass programs employing the portable jet injectors to administer vaccines either subcutaneously or intradermally appear to have a real potential.

World Health Organization Program for Smallpox Eradication

The third of the components contributing to the genesis of the African Smallpox/Measles Program was the increasing impetus given to smallpox eradication by the World Health Assembly and its constituent members. In 1959, the Assembly had unanimously resolved to undertake a global program for smallpox eradication. That such a program might be feasible even in the developing countries had been amply demonstrated by the nations of the Americas. A smallpox-eradication program beginning in 1950 resulted in cessation of smallpox transmission throughout the Americas, with the sole exception of Brazil.[11] No program

Fig. 4—Hydraulic-powered, foot-operated jet injector.

was attempted in Brazil. The disease subsequently was reintroduced into Peru and Colombia, and once again assumed an endemic character. The futility of an eradication effort which was less than a total regional effort could not have been better documented.

Following the 1959 World Health Assembly resolution, a number of countries undertook intensified vaccination programs. Some progress was made (Figure 5). Many of the less affluent endemic countries, however, experienced difficulty in financing programs; voluntary assistance from the more prosperous, smallpox-free areas of the world was minimal.

At the May 1965 World Health Assembly, President Johnson pledged the support of the

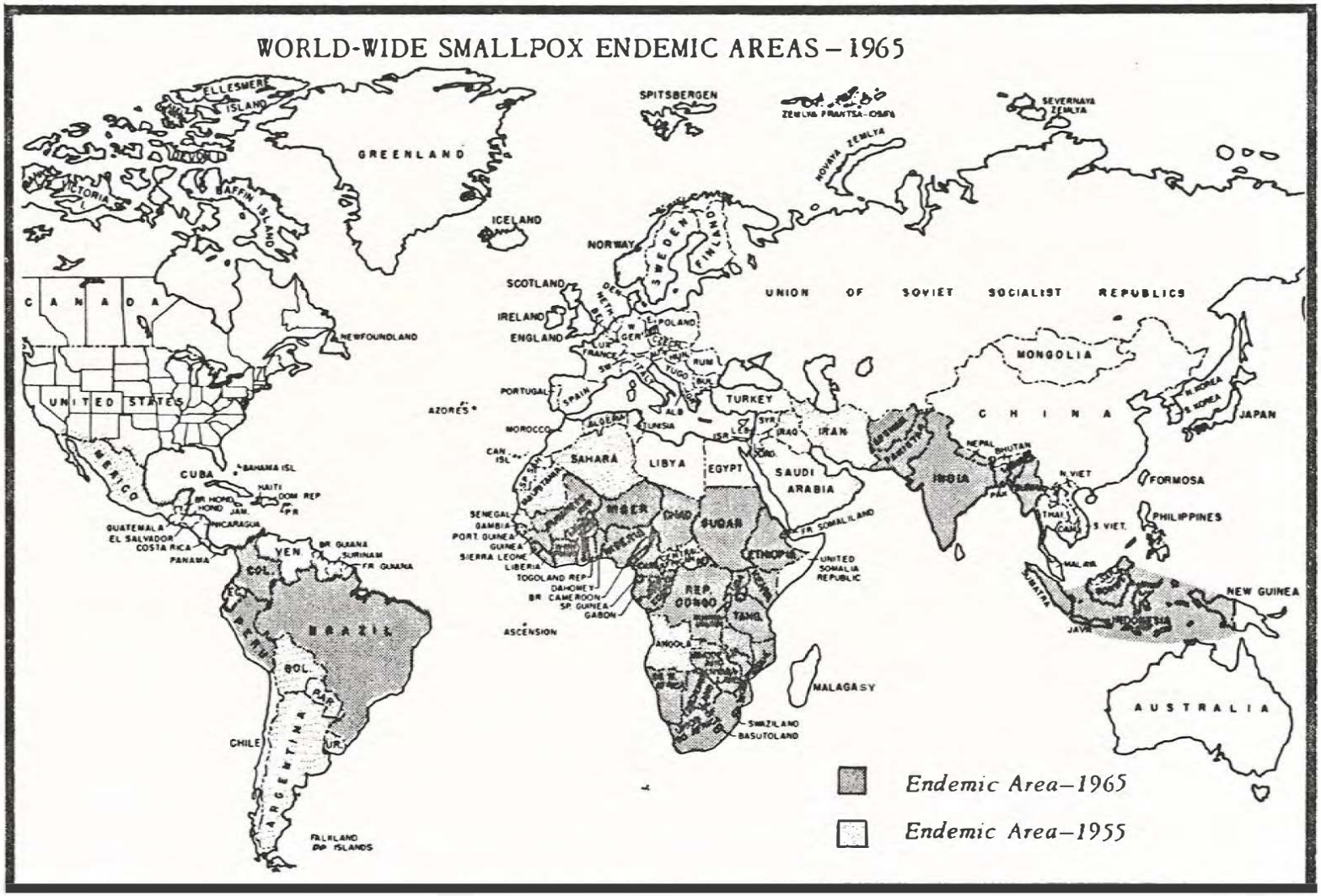
WORLD-WIDE SMALLPOX ENDEMIC AREAS – 1965
GREENLAND
ICELAND
NORWAY
SWEDEN
FINLAND
SPITSBERGEN
SEVERNAYA ZEMLYA
NOVAYA ZEMLYA
SCOTLAND
IRELAND
ENGLAND
UNION OF SOVIET SOCIALIST REPUBLICS
MONGOLIA
C A N A D A
NEWFOUNDLAND
UNITED STATES
PORTUGAL
SPAIN
AZORES
MOROCCO
TURKEY
IRAN
IRAQ
C H I N A
JAPAN
N. KOREA
S. KOREA
SAHARA
LIBYA
EGYPT
SAUDI ARABIA
INDIA
NEPAL
BHUTAN
N. VIET
FORMOSA
PHILIPPINES
MEXICO
CUBA
BAHAMA ISL
HAITI
DOM REP
GUATEMALA
EL SALVADOR
COSTA RICA
PANAMA
NICARAGUA
SENEGAL
GAMBIA
PORT. GUINEA
GUINEA
SIERRA LEONE
LIBERIA
TOGOLAND REP
DAHOMEY
BR CAMEROON
SP GUINEA
GABON
NIGER
CHAD
SUDAN
ETHIOPIA
FR SOMALILAND
UNITED SOMALIA REPUBLIC
REP. CONGO
TANG.
ANGOLA
ASCENSION
MALAGASY
SWAZILAND
BASUTOLAND
VEN
COL.
BRAZIL
PERU
BOL.
PAR.
CHILE
ARGENTINA
UR.
FALKLAND ISLANDS
BR GUIANA
SURINAM
FR GUIANA
NEW GUINEA
AUSTRALIA
Endemic Area–1965
Endemic Area–1955

Figure 5

United States "for an international program to eradicate smallpox completely from the earth within the next decade." The Assembly unanimously approved a resolution declaring the worldwide eradication of smallpox to be a major objective of the World Health Organization. The Director-General was requested to prepare a plan and cost estimate. At the 1966 Assembly, a budget of $2.4 million was approved by the Assembly to provide a portion of the material support required by the endemic countries; additional assistance from the member States was requested.[12]

The extension of the measles-vaccination programs to include a regionally coordinated smallpox-eradication effort was, therefore, a rather logical next step. The timely availability of the lightweight jet injectors appeared to solve a very real manpower problem so far as the African nations were concerned.

Theoretical and Tactical Considerations Regarding the Eradication of Smallpox

In recent years, the expression "disease eradication" has been rather freely employed, often evangelistically. As a goal, the concept of eradication is excellent; it is akin to being against sin. As to whether eradication is a realistic goal in the context of the epidemiology of the disease and with the tools at hand is quite another matter. In the case of smallpox, it is generally conceded that we do have an infectious disease with epidemiological characteristics that can be eradicated with the presently available preventive tools. It is, in fact, generally agreed that of all the human infectious diseases, smallpox is most susceptible to eradication.

Smallpox exhibits a number of unique characteristics that place it in this category. It is directly transmitted from man to man; there are no insect or animal reservoirs. Its existence may quickly be detected in a given area, for it has a reasonably distinctive clinical picture and rarely occurs in subclinical form. The victim of the disease is generally incapable of transmitting the virus for more than two to three weeks and is rendered essentially permanently immune against subsequent attack. A carrier state, such as occurs in malaria, is unknown. The two-week incubation period of the disease is sufficiently long and the disease sufficiently poorly transmitted to permit the timely initiation of containment measures adequate to avert a major outbreak.

The eradication of smallpox can be accomplished by rendering immune, through vaccination, a sufficiently large proportion of the population so that transmission is interrupted. A highly stable, lyophilized vaccine, which confers an excellent degree of protection for many years, is available.

The proportion of immunes required to effect eradication has been debated with considerable vigor. This is probably good evidence that reasonable data to clarify this question are simply not available. It is evident in this man-to-man transmitted disease that the proportion of susceptibles necessary to insure continued propagation of the disease is a function of the number of contacts which the infected individual may have with susceptible persons. In a densely crowded refugee camp or in a slum area, contacts between individuals are frequent; the probability of smallpox transmission is high; the proportion to be rendered immune similarly must be high to effect interruption of transmission. At the other end of the spectrum, among scattered, isolated individuals and families, the spread of smallpox should be limited even if few or none are vaccinated. It has been observed repeatedly, in fact, that smallpox spontaneously disappears from quite large population groups when the susceptibles necessary to maintain transmission are exhausted. In Iceland, for example, in 1707, a century before vaccine was available, a smallpox epidemic occurred but endemic transmission spontaneously ceased in a scattered population of 57,000.[13]

With this man-to-man transmitted disease, it is, I believe, a reasonable generalization to say that the less accessible the people, the less likely that smallpox will be transmitted to them. In the African Project, we place particular emphasis upon securing a high level of immunity among urban populations, among those in market towns and those who frequent market towns. With the rural-urban population-drift a worldwide phenomenon —and no less so in Africa—it is conceivable that urban centers, particularly the lower socioeconomic sectors, for example, may require annual immu-

nization campaigns to insure maintenance of adequate "herd immunity" levels. While higher immunity levels are required in the more urban areas, for the remote village, or the isolated small tribe, the immunity level is almost certainly of less importance.

I hasten to note, however, that these elementary guidelines will have to be subjected to test in the African environment. In Africa, nomads are numerous, particularly in sahara and savannah areas; traders who traverse enormous distances are many; migrant workers are frequent. Whether the dynamics of population intercourse permits smallpox to be maintained outside of urban African areas is unknown. Epidemiological studies will, of course, be required.

If we can reach at least 80 percent of the population throughout urban areas and market towns, plus some lesser proportion—perhaps 60 percent in peripheral areas—I feel that endemic transmission of the disease will cease in Africa.

Measles—Eradication or Control?

At the inception of planning for this project, a number of prominent eradicationists argued strongly that measles eradication rather than measles control should be the stated objective of the project. Although measles eradication in Africa may be feasible, several characteristics of the disease suggest that measles eradication may be more difficult than smallpox eradication. First, it appears that measles in Africa is a more highly communicable disease than smallpox. Such age-distribution data as are available indicate that smallpox, even in poorly vaccinated areas, occurs not infrequently among older children and adults. Measles, however, is rarely seen beyond the age of five;[2, 5] 85 to 90 percent of children are immune by their fifth birthday. Second, surveillance for measles cases is more difficult than for smallpox. The rash associated with measles is less distinctive and, in an African, may sometimes be difficult to detect or to diagnose. From studies in the United States, it appears that at least ten percent of measles cases occur in a subclinical or unrecognized form. Among Negro children this figure may be higher. In a study in the United States,[14] the proportion of unrecognized infections was found to be substantially higher among Negro children from middle-class families than among white children in a comparable socioeconomic group. Third, it seems a bit presumptuous to undertake measles eradication in Africa before such a goal has been demonstrated to be feasible in other countries with comparatively unlimited medical-care facilities.

With respect to measles, our goal quite simply is to reduce the frequency of the disease to the level where it is no longer a significant health problem. We feel this can be accomplished by the vaccination of children between six months and three or four years of age in the context of the smallpox-vaccination activities.

Practical Aspects of Implementation of the Program

As a first principle, it was recognized that the project had to evolve as a coordinated regional effort. Political boundaries in Africa are highly arbitrary, based more on factors concerned with colonialist expansion in the 19th century than on tribal or geophysical considerations. Tribes, divided arbitrarily, move readily across boundaries; nomads move freely in large groups; traders crisscross Africa, covering incredible distances. Without coordination of programs and a concerted common effort, smallpox eradication would not be feasible. For this reason, a Regional Project Office has been established at a central geographic point, Lagos, Nigeria, and staffed with a personnel of diverse, senior-technical competence. This staff will serve to advise and coordinate the overall program and will travel extensively throughout the region.

As a second principle, the paucity of trained medical and paramedical personnel and financial resources necessitates reliance upon an immunization campaign which is most economical of personnel and financial resources. We believe that mobile teams equipped with jet-injection devices represent the most satisfactory solution. In most French-speaking areas, mobile preventive medical teams are presently operative; similar teams have functioned successfully in the past in English-speaking areas.

Thirdly, experience with past vaccination programs has shown the need for independent assessment of the extent of vaccination as a "quality control" measure. Simplified statistical tech-

niques are being developed and tested for this purpose. The use of the silver-nitrate-dipped finger as a temporary "marker" for a vaccinee has been used successfully in Bolivia[15] and Iran[16] and will be evaluated for use in this program.

Fourth, a competent surveillance program, workable within the African context, will have to be developed. Since the goal of the project is a specific one, the reduction of smallpox to the level of "zero" cases, a mechanism must be put in operation to affirm that indeed at some point in time this level has been reached and maintained. A surveillance system rests upon a foundation of regular reporting from various "detection sites," e.g., hospitals, aid posts, etc. There is a surprisingly large number of such potential "detection sites" in each of the African countries; many, in fact, routinely report regarding the occurrence of illnesses seen at their posts. The basis for a surveillance program does thus exist.

With 19 countries involved, each with its own health structure and organization, it was recognized that a rigid "cookbook" type of operation was neither acceptable nor, in fact, optimal. Different strengths and weaknesses pertain in the health programs in each of the countries. Based on discussions with national health authorities, World Health Organization (WHO) consultants, regional health organizations, staff in West and Central Africa and other specially qualified persons in the United States and abroad, separate programs were broadly outlined for each country which incorporated the basic principles noted. Based on these program outlines and approximations, material needs have been determined which have permitted procurement to be initiated. However, the first year of the program clearly represents a period of testing and evaluation of techniques and methods.

Personnel

To provide technical assistance to the programs in each country, a team was proposed, consisting of a medical epidemiologist and an operations officer. The medical epidemiologist will be concerned principally with the overall plan of operation and the evolution of the surveillance and assessment phases of the program. The operations officer will be principally responsible for supply, logistics, team training, etc.; and also will serve as an active participant in all phases of the program. Since it was repeatedly stressed to us by African health officials that they had less need for "desk-bound" advisors than for individuals willing to take an active role in all phases of the program, it was felt that a young staff willing to experience the hardships of bush living for three to perhaps six months each year would be preferable.

Faced with the need to begin programs in the autumn of 1966, and considering the time required to recruit, process, and train personnel, and knowing of the difficulties that are experienced in recruiting for other foreign-assistance programs, we were particularly concerned with securing a requisite staff. Quite clearly, exceptional people were required, but could they be found in time? Surprisingly, limited recruiting elicited a flood of responses. We screened, in fact, between three and five persons for every position. Many of the staff are or were CDC employees; former Peace Corps staff are well represented along with university faculty, other personnel from the Public Health Service, from state and local health departments, etc. For next year, I would guess we already have at least 80 applicants for four possible positions as operations officers. The reasons for interest in this program are undoubtedly many. One quite clearly was the fact that the program is being operated from a "home" institution, the CDC, with technical back-up for the program and a range of possible positions available to individuals returning at the completion of two, three, or five years of service abroad.

Relationships with Other Institutions

The program has been developed in close conjunction with WHO staff; specific continuing liaison is being worked out with a WHO Intercountry Smallpox Advisor for West Africa. Working relationships with regional health organizations in the former French areas in West and Central Africa were established early and will be nurtured. Other organizations have expressed an interest in appropriate participation in this program—the Peace Corps, the League of Red Cross Societies, mission groups and others. Their participation is,

of course, contingent upon the wishes of national authorities, but I suspect that they will be welcomed.

Finally, perhaps as the most important feature of this total effort, there is an opportunity for Americans and Africans working in a common effort to both teach and learn in the context of African needs, problems, and resources. The extent to which the teaching and learning experience is an active and vital one will measure the ultimate success of the project as a whole. It would be my hope that this process might be extended to include both American and African medical students who, working with American technical staff and national health authorities, might gain an appreciation for preventive medicine and public health in the context of the community which could not be acquired within the four encrusted walls of the academic institution. It was an experience such as this which early in my own Public Health Service duty persuaded me that preventive medicine was an exciting and challenging experience totally different from that to which I had been exposed in medical school.

REFERENCES

[1] Karefa-Smart, J.: The challenge of unfinished tasks. In *Industry and Tropical Health V,* Harvard School of Public Health, Boston, Mass., 1964, pp. 13-16.

[2] Meyer, H. M., Hostetler, D. D., Bernheim, B. C., Rogers, N. G., Lamkin, P., Chassary, A., Smadel, J. E.: Response of Volta children to live attenuated measles virus vaccine. Bull. World Hlth. Org. *30:* 769-781, 1964.

[3] Senecal, J., Autry, L., Falade, S.: Infectious diseases in the child of pre-school age in Senegal. West African Med. J. *11:* 93-105, 1962.

[4] Morley, D. C. and MacWilliam, K. M.: Measles in a Nigerian community. West African Med. J. *10:* 246-253, 1961.

[5] Morley, D. C.: Measles in Nigeria. Amer. J. Dis. Child. *103:* 230-233, 1962.

[6] Budd, M.: Communicable Disease Center, Unpublished observations.

[7] Moseley, C. H.: Immunization by jet-injector technique. In *Industry and Tropical Health V,* Harvard School of Public Health, Boston, Mass., 1964, pp. 142-146.

[8] Millar, J. D. and Roberto, R. R.: Vacunación intradérmica contra la viruela por inyección a presión. Bol. Ofic. Sanit. Panamericana *57:* 537-547, 1964.

[9] Roberto, R. R., Millar, J. D., Tapa, S. Fanamanu, J. and Henderson, D. A.: Intradermal vaccination by jet injection: field test of a foot-operated jet injector in the Tonga Islands (in preparation).

[10] Millar, J. D., Morris, L., Dial W. W., Mack, T. M., Medeiros, A. A. and Macedo-Filho, A.: An assessment of spallpox vaccination by jet injection in a national eradication program (in preparation).

[11] Cockburn, W. C.: The WHO smallpox eradication program. Amer. J. Pub. Hlth. (in press).

[12] World Health Assembly Resolution, 13, May 1966. Document A19/P and B/2.

[13] Simon, J. quoted by Dixon, C. W.: in *Smallpox,* J. and A. Churchill, Ltd., London, 1962, p. 190.

[14] Guinee, V. F., et al.: Cooperative measles vaccine field trial. Pediatrics *37:* 649-665, 1966.

[15] Fredericksen, H., Torres Muñoz, N., Jauregui Molina, A. S.: Smallpox eradication. Pub. Hlth. Reports *74:* 771-778, 1959.

[16] Fredericksen, H. and Sheehy, J. P.: Smallpox control by mass vaccination with dried vaccine. Pub. Hlth. Reports *72:* 163-172, 1957.