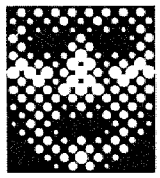
CDC and the Smallpox Crusade



CDC and the Smallpox Crusade



For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CDC and The Smallpox Crusade

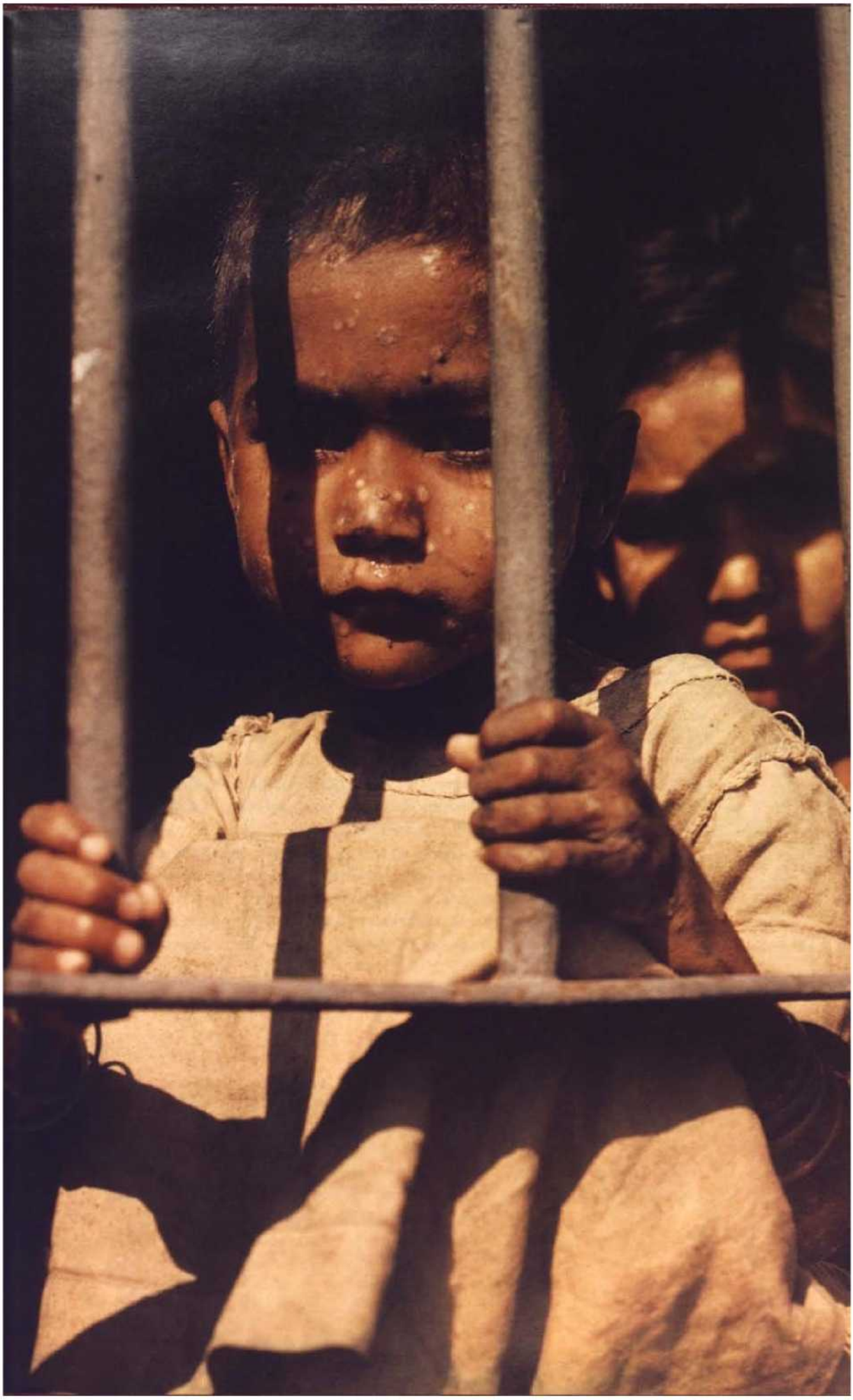
Horace G. Ogden

U.S Department of Health and Human Services
Public Health Service
Centers for Disease Control
HHS Publication No. (CDC) 87-8400

Free at last.

Recovering from smallpox,
Bogra, Bangladesh. 1975.

Photo by: Carol F. Music



Free at last

Rounding the corner of a health clinic bungalow, I gazed deeply into the pain and trust of a beautiful girlchild. She sat on a windowsill, behind bars, recovering from smallpox. A boy patient joined her.

My heart winced. I felt the nightmare of a youngster's fever and rash . . . a person's struggle with pain and fear . . . a family's struggle with separation and loss . . . a survivor's struggle with life, indelibly marked and dishonored by the community. I experienced anew being a prisoner of one's own skin in any community.

Our eyes embraced. It was January 1975 in Bogra, Bangladesh. She yearned to breathe free. When would that be?

For hundreds of years, smallpox had run unleashed among millions of people, keeping nations suppressed and a world held hostage. Yet, persistent advancements after 1950 showed clear promise of global eradication of the disease; and to this end the World Health Assembly declared, in 1966, a worldwide Smallpox Eradication Program.

Remarkable leadership and personnel around the world provided crucial, ongoing skills to augment each endemic nation's campaign. Families of overseas consultants from the Centers for Disease Control, such as I, had a rare opportunity to see a portion of the last vestiges of smallpox amidst the rigors of surveillance and containment in the field. Freedom came very hard-won, mile by mile, year by year.

For those who have suffered, recovered, or died from smallpox, for those who have been isolated behind bars during a storm of ill contagion, for those who untiringly led or participated in this movement to uproot smallpox infection: we are all as one, and we are all now free of this fight and this fear of death and discrimination.

Our children can now breathe free.

Carol F. Music
Atlanta, 1987

Acknowledgments

Narrating the story of the successful quest for global eradication of smallpox, which highlights the vital contributions made by the Centers for Disease Control (CDC), is surely among the most delightful chores a writer could undertake. For this writer it was doubly so, for he had the good fortune to work closely during the post-smallpox years with many of the leading actors in the drama and to partake of their abiding enthusiasm.

Special appreciation is due, first of all, to Dr. Donald R. Hopkins, who, as CDC's Deputy Director during the time the book was produced, gently but firmly kept the writer on target and deadline and was able to make all the necessary things happen to bring the project to fruition. In these latter endeavors he was greatly aided by Ms. Kathy H. Rufo. In addition, Dr. Hopkins, himself the author of an outstanding book on the history of smallpox, served the invaluable purpose of sharpening the author's occasionally wavering precision of fact and word.

For many hours of delightful conversation that transmitted both the substance and the spirit of this remarkable saga, the author is profoundly grateful to Drs. David J. Sencer, William H. Foege, J. Donald Millar, J. Michael Lane, Stanley O. Foster, Leo Morris, and James H. Nakano and Messrs. Billy G. Griggs, James W. Hicks, and Andrew N. Agle, plus several others who in brief sessions helped to nail down a point or fill in an anecdote. They breathed what life the narrative possesses.

Nearly all of these colleagues also contributed to the review of all or parts of the manuscript. Foege, Millar, Lane, Griggs, and, of course, Hopkins were especially generous in reviewing two or more iterations of every chapter, despite the enormous pressures of their respective positions. To this list must also be added Mr. Donald A. Berreth, who served throughout as the author's official taskmaster and whose final review was especially valuable.

The writer's special thanks go to Ms. Marcela Barr of the Pan American Health Organization, whose word-processing services were of the highest quality and who never failed to meet even the most absurd deadline. Ms. Linda Kay McGowan of CDC performed the essential duties of editing with great skill and sensitivity. Also, I owe enormous thanks to Ms. Peggy Phillips of CDC for her talented and creative contributions to the design and production of this book.

Dr. D. A. Henderson, now Dean of the School of Hygiene and Public Health at Johns Hopkins University, merits special thanks for his generosity in making available the drafts of several chapters of the definitive work on the global smallpox eradication program now in preparation at the World Health Organization. Much of the information related to the global program outside the immediate involvement of CDC was gratefully borrowed from the materials supplied by Dr. Henderson.

Finally, **very special acknowledgment is due to Mr. Mark Lapointe**, without whose work this volume literally could not have been produced in this form at this time. Mr. Lapointe, who has just returned from an extended assignment in Senegal, performed exhaustive archival labors and also produced an indispensable collection of taped interviews with most of the CDC participants in the campaign in West and Central Africa. His research and his preliminary draft of part of the narrative furnished the foundation on which this book is built.

For all of these, and for the privilege of becoming a belated and vicarious participant in the CDC adventure, my deepest thanks.

Horace G. Ogden

Foreword

It is fitting that this book, which describes the contribution made by the Centers for Disease Control (CDC) and its staff to the global eradication of smallpox, appears as the world prepares to celebrate the tenth anniversary of that unprecedented achievement. Under the leadership of the World Health Organization (WHO), humankind united to defeat an ancient foe.

The official account of this worldwide effort is contained in *Smallpox and Its Eradication*, written by Drs. F. Fenner, D. A. Henderson, I. Arita, Z. Jezek, and I. Ladnyi, of WHO. The events described in this narrative were a part of that overall campaign and are summarized in the official WHO account.

This volume, written by Mr. Horace G. Odgen, is intended to serve a complementary purpose. It records in some detail the events that led to CDC's involvement in smallpox eradication, the excitement and formidable challenges of the Smallpox Eradication/Measles Control Program in West and Central Africa, which was funded by the U.S. Agency for International Development (AID) and largely executed by CDC, and the considerable scope of CDC's participation in other aspects of the worldwide campaign. The perspective provided on these events and the details of their formulation and implementation may provide valuable lessons for those who carry out future public health programs.

It should be emphasized that the programs described in this account were not "one-man shows," or even "two-man shows." In every country in which they worked, CDC personnel served as advisors—albeit very active ones—to their national counterparts and to the many national staff members who actually performed most of the task that made the programs successful.

Despite the difficulties, setbacks, and doubts mentioned herein, smallpox was eradicated. The world of public health may draw inspiration from this accomplishment. It is significant that twenty years after a resolution of the World Health Assembly that marked the beginning of the final smallpox eradication effort,

another assembly resolution in 1986 has declared the challenge of eliminating dracunculiasis (guinea worm disease).

Three aspects of the United States' role in smallpox eradication deserve special emphasis. The first is that a global program may be built on different and even conflicting priorities. The West and Central African campaign, for example, combined distinctly different interests of U.S. health authorities and the African governments concerned: the former being primarily interested in smallpox eradication; the latter primarily in controlling measles.

The second is that U.S. participation turned out to be a remarkably good economic investment. A total of $32 million was spent by the United States over a ten-year period for the global campaign. This entire sum has been recouped by the United States, in 1968 dollars, every 2½ months since 1971. This is the amount saved because we have been able to halt routine smallpox vaccination, eliminating the complications of vaccinations, reducing foreign quarantine needs, and eliminating requirements for vaccination on entry to the country.

Third, the program firmly established the principle that protecting the United States from some diseases may be best accomplished by helping others to control the problem abroad. This lesson may be especially relevant to control of measles and poliomyelitis today, and perhaps eventually of acquired immunodeficiency syndrome (AIDS).

For CDC, and indeed for the world at large, the legacy of this global triumph is not only that smallpox has been eradicated, though that alone would surely have been more than enough. In addition, we have benefitted immeasurably from the cadre of people who participated in the campaign and from their enthusiasm and knowledge. Their numbers are legion, and many of them continue to apply and build upon the skill with which problems were solved and the spirit in which it was done. To all of them, leaders and workers alike, this book is respectfully and affectionately dedicated.

David J. Sencer, M.D., M.P.H.
Director, CDC
1965-1977

William H. Foege, M.D., M.P.H.
Director, CDC
1977-1983

James O. Mason, M.D., Dr.P.H.
Director, CDC
1983–

Table of Contents

Acknowledgments		vii
Foreword		ix
Introduction		xiii
CHAPTER		
1	The Lines Are Drawn	1
2	Preparations	13
3	Victory in Africa	37
4	Domestic Policies for Smallpox Control	71
5	Smallpox Conquered	85
Epilogue		111
Bibliography		115
Index		129

Illustrations start after page 70

Introduction

In October 1977, in the country of Somalia on the horn of East Africa, a young man named Ali Maow Maalin contracted the world's last case of naturally occurring smallpox. In the succeeding ten years, the disease has made only one appearance—the result of a tragic laboratory accident in Great Britain. Smallpox as a natural enemy of humanity has been expunged from the earth.

Global eradication of smallpox, by any measure, ranks among the great achievements of humankind. Gone, through concerted human effort, is a disease which has brought death to countless millions, repeatedly altered the course of history, and traveled as a dreaded companion through the centuries to every inhabited corner of the world.

The story of this accomplishment has been told and will be recounted many times. Its magnitude has yet to be fully appreciated, just as the toll of the disease itself has tended to be obscured by history's preoccupation with wars and the deeds of kings. This recognition will come.

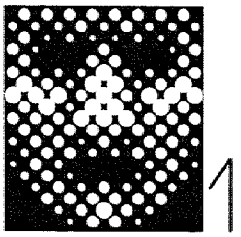
But the intent of this narrative is far more modest. It seeks to chronicle the contributions of one organization, the Centers for Disease Control (CDC) of the U.S. Public Health Service, to this worldwide triumph. It is written while living memories are still fresh, while the stories swapped by veterans of the smallpox campaigns can animate the memoranda already gathering dust in the files.

Its plan is simple. The first chapter is intended to furnish a framework. It describes the disease and extracts a few highlights from the rich history of its presumed origins and successive impacts on the world's cultures; it touches briefly on human efforts over time to understand and combat this deadly enemy. Then, it introduces the three agencies principally involved in the smallpox eradication effort: the World Health Organization (WHO), CDC, and the U.S. Agency for International Development (AID). The concluding section of chapter 1 is

designed to set the stage by summarizing the smallpox situation as it existed when the eradication program was launched in the mid-1960s.

Chapters 2 and 3 describe in greater detail the smallpox eradication and measles control program in twenty West and Central African countries as it was planned and carried out, largely by CDC personnel in collaboration with the national governments, on behalf of WHO, with funding support from AID. The West African campaign receives the most detailed attention, in part because this was the area in which CDC made its greatest initial contribution but also, as will be seen, because in many ways West Africa was the proving ground and turning point of the struggle.

Chapter 4 discusses changes in U.S. domestic policies and public health practices resulting from the changing smallpox situation around the world. Chapter 5 summarizes briefly CDC's participation in the late stages of eradication in Latin America and describes the major campaigns in India and Bangladesh in the early and mid-1970s, leading to the final victory in the war-torn East African countries of Ethiopia and Somalia. It is interesting to note in passing that the northeastern quadrant of Africa, where the last cases were tracked down, was also the broad region from which, many centuries earlier, smallpox probably launched its devastating marches across Asia, Europe, the remainder of Africa, and ultimately the New World.



THE LINES ARE DRAWN

THE NATURE OF THE ENEMY

The Organism

The cause of smallpox as it was known throughout most of human history was a virus that produced the disease known to science as variola major. Late in the nineteenth century, a second type of smallpox was identified, known as variola minor because its effects were much less severe. A third strain, unofficially labeled variola intermedius, was found in East Africa in the 1960s. Vaccinia virus, which was essential to the eradication of smallpox, is also a member of the orthopox virus family.

Persons afflicted with variola major showed no signs of illness until about the ninth day. Then, for three or four days, they were likely to suffer fever, nausea, and headaches, which often seemed to subside. Next, red spots began to appear on the face and spread rapidly. The spots, flat at first, swelled into vesicles and then pustules. Many died soon after the rash appeared; others several days later. The pain and discomfort were terrible to endure. Over all, death claimed about one-fourth of those infected. Those who survived were often left with permanent scars. Most who recovered were immune to the disease for life.

Most victims acquired the disease by inhaling the virus through close contact with an infected person. Those not in face-to-face contact could acquire the disease from clothing or blankets, and corpses of victims were a dangerous source of infection. The infectious stage generally began just before the rash appeared and lasted as long as three weeks.

Exposure, even direct exposure, did not necessarily result in infection. Even susceptible members of a victim's immediate household might escape the infection. Nevertheless, when smallpox struck a population not previously exposed, as happened many times throughout history, a devastating epidemic almost always occurred. Later, when a large proportion had either become immune or died, the disease would decline, recurring after enough years had passed to build up a susceptible population. In fact, since smallpox could only be transmitted from one person to another and did not naturally infect animals—as many other diseases do—it required a substantial susceptible human population to stay alive. In larger communities the virus never completely disappeared but smoldered along for several years between major outbreaks.

These characteristics of variola major generally applied to variola minor as well. Recovery from either resulted in immunity to both forms of the disease. But there was one critical difference. Variola major killed at least one-fourth of its victims; variola minor brought death to fewer than one in 100, and its survivors were less likely to be severely scarred.

Smallpox Through History

Whatever its origins may have been—very possibly as a disease of animals—smallpox had probably made its successful and fateful adaptation to humankind by some 10,000 years ago. This date would correspond with the early formation of farming communities, which would have provided a population stable enough for sustained transmission from person to person.

Ancient historical accounts, medical writings, and religious and mythological evidence all indicate that smallpox was known in at least three parts of the world— Egypt, India, and China—well before the beginning of the Christian Era. The evidence is most solid, and the probable antiquity greatest, in Egypt. Three mummies dating from the sixteenth to the eleventh centuries B.C. have been examined by modern observers and show unmistakable signs of smallpox-like infection. The most famous of these, that of the Pharaoh Ramses V, who died in 1157 B.C., has characteristic pustules strikingly similar to those observed in victims in the twentieth century A.D., more than 3000 years later.

In India, Sanskrit medical texts and sacred books suggest smallpox epidemics dating at least as far back as 1500 B.C. More recently, in the fourth century B.C., there are indications that the invading army of Alexander the Great may have been met by smallpox in India, just as Hittite invaders may have encountered smallpox in Egypt at an earlier date. In the case of China, it appears that the

disease was imported in the pre-Christian Era, perhaps by the Huns. The Chinese called the sickness "Hunpox," an early manifestation of a human tendency to blame misfortune on alien influences illustrated in our own century by the "Spanish flu" of 1918 and the "Asian flu" of 1957.

In classical Greece Thucydides described a plague, possibly smallpox, that greatly weakened Athens in its struggles against Sparta in the fifth century B.C. It was said to have come from Ethiopia via Libya and Egypt. Northeast Africa and the Middle East could well have been the original source of many smallpox outbreaks, which followed armies and trading caravans throughout antiquity and into our own era. Troops under the banners of Carthage, Rome, and many lesser powers brought it with their baggage trains. The spreaders of Islam, the pilgrims who later trudged back to Mecca, and the Crusaders who sought to regain the Holy Land from the "Infidel" all were among the unwitting carriers throughout vast areas of Europe and Africa that had previously been too sparsely settled to sustain the disease. By the sixteenth Christian century, it was established throughout Europe. And in that century the ports of Europe served as its springboard to the New World. A little later the slave trade vaulted it from sub-Saharan Africa to Brazil and the Caribbean islands.

Throughout history smallpox has been a most democratic scourge. Its toll among royalty has been widely chronicled. Elizabeth I of England was a celebrated victim and a lucky one, recovering almost unmarked. Less fortunate were her successors in the post-Restoration House of Stuart. Princess Mary of England, her husband William II of Orange, and her brother the Duke of Gloucester died of smallpox in their twenties, all within a decade of each other. In the next generation Queen Mary II died of the disease, as did a younger brother who would have succeeded to the throne; another Duke of Gloucester, son of Mary's sister Queen Anne, died at age eleven—all of this happening between 1650 and 1700. In Austria eleven members of the reigning House of Hapsburg died of smallpox between 1654 and 1767, resulting directly in four shifts of the line of succession. In France Louis XIV's heir, the grand dauphin, died of smallpox in 1711, and his great-grandson and successor, Louis XV, died of the disease more than half a century later after a fifty-nine-year reign, almost on the eve of the French Revolution.

As with captains and kings, of course, so with commoners. Tevye in *Fiddler on the Roof* observed that "being poor is no disgrace, but it's no great honor either." Certainly, it was no protector against smallpox. Through the centuries the disease established itself as endemic across virtually all the known world—Africa, Asia, the Indian subcontinent, the islands of the Western Pacific, Europe, and eventually the Americas. Periodically, it broke out in devastating epidemics.

In a single century, the eighteenth, the roll call included the following, among many others: five major epidemics in London between 1719 and 1746, each killing thousands, most of whom were children; similar outbreaks in Rome,

Berlin, Geneva, and other European cities; awesome pandemics in India, including one that may have caused 3 million deaths in the state of Bengal; epidemics in Sennar and in Sumatra; 40,000 deaths in Belém, Brazil, in 1750; a pandemic throughout South America in 1764-1765; and devastation of the Hottentot tribe in South Africa in the 1750s. Smallpox prolonged the siege of Boston at the outset of the American Revolution, probably prevented the U.S. capture of Quebec, and saved Great Britain from the invasion of the "Second Armada" from France and Spain.

Entire settlements were wiped out. Sunbury, a town near Savannah, Georgia, was established in 1780 and occupied by the British during the war. A smallpox epidemic in 1813 made it a ghost town; all that remains of it is a Georgia State Historical Site.

Combatting the Disease

It was at the end of the fateful eighteenth century that an English physician named Edward Jenner discovered vaccination, placing in man's hands at long last the instrument that would turn the tide.

Through the millennia before Jenner's discovery in 1796, the ancient enemy had held the upper hand in an unequal struggle. Nearly two more centuries would pass before achievement of the ultimate triumph confidently predicted by that farsighted Virginia gentleman, Thomas Jefferson, who wrote to Jenner: "You have erased from the calendar of human afflictions one of its greatest. . . . Future nations will know by history only that the loathsome smallpox has existed."

As with many other phenomena feared and little understood, smallpox has been associated with many deities in many cultures. Not the earliest but among the most widely worshipped was the Chinese smallpox goddess T'ou-Shen Niang-Niang, who was revered by Buddhists, Taoists, and Confucians alike. Shitala Mata in India, Bisagit in Borneo, and Shapona or Soponna, god of smallpox among the Yoruba peoples of West Africa whose worship crossed the Atlantic with the slave trade, were other members of the smallpox pantheon.

Probably the oldest and certainly among the best known was the Indian goddess Shitala Mata. Her origins can be traced back at least 2000 years, likely as a pre-Hindu folk goddess. In the Hindu religion she is considered to be the wife of the great god Shiva, the Destroyer, but she has been variously worshipped under different names by Jains and Moslems as well as Hindus. A wrathful and vengeful deity, she has temples devoted to her all over India, and an annual festival has traditionally been held on her feast day.

In the Christian world a fifth-century bishop of Rheims, canonized as St. Nicaise after martyrdom at the hands of the omnipresent Huns, was adopted as patron saint of smallpox because he had survived the disease, through holy practices, a year before his death. Though he has never been widely recognized, prayers to

St. Nicaise for intercession against smallpox are found in the literature, and an altar dedicated to him exists in the great Rheims Cathedral.

Throughout history and up to our own time, the association between deity and disease has been at best a mixed blessing. As will be seen later, Shapona in Africa and Shitala Mata in India were formidable factors to be contended with. More pervasively, however, even in cultures we tend to view as more sophisticated, the premise that smallpox was a visitation of God's will on the victim raised serious societal barriers to the application of preventive measures. Into the twentieth century, charges of tampering with divine intent have had to be overcome.

Meanwhile, through the long struggle physicians and others have sought to describe the disease, deduce its cause, treat its sufferers, and prevent its spread. Hippocrates may have been among its first biographers, although it is not clear whether he was describing smallpox or other contagious diseases, a common problem in the early writings. Galen described a smallpox-like plague in the second Christian century, and the theory that he borrowed from the Greeks—that diseases, including smallpox, are caused by imbalances among the four humors—prevailed in Europe for centuries.

Rhazes, a Persian-born physician writing in the tenth century, was the first in the Western world to clearly distinguish smallpox from other rash-producing contagions like measles. The term *variola* was first applied to the disease Rhazes described in the eleventh century. Brilliant though he was as an observer, however, Rhazes wrongly attributed the cause to a tendency of the blood to ferment; therefore, his recommended treatments included bleeding and excessive heat. Another course of therapy, whose origins are lost in the past but which persisted remarkably and was still being practiced until quite recent times, was the "red treatment," which required that the patient be clothed in red, housed in red surroundings, or even bathed in red light.

Over the years beliefs concerning the causation of smallpox blew with the prevailing winds of medical thought. Epidemics of smallpox and other diseases were variously blamed on changes in the ambient atmosphere, on specific "seeds" of disease called *seminaria* by Fracastorius in the sixteenth century, on "animalcules" following the invention of the microscope, on "corpuscles" of solid matter invading the body like a poison, and, of course, on punishment for sin.

Each theory naturally generated its own countermeasures. If you feared miasmas in the atmosphere, you tried to clean up the air or move to where it was better; if you feared divine retribution, presumably you tried to clean up your life. But empirical evidence gradually accumulated that supported specific measures. Observation that the disease was transmitted by face-to-face contact led to the practice of isolating victims and avoiding unnecessary exposure. Observation that clothing and other effects and the corpses of victims were sources of infection led to increasing care in their handling and disposal.

Most important in the long run was the observation that those who survived the disease were subsequently immune to it. This knowledge led to the two courses of action—inoculation and vaccination—that ultimately brought an end to smallpox. It is important to distinguish between the two.

Inoculation, now more commonly called **variolation**, was done by inserting smallpox virus from a previous human patient into the skin of a susceptible person. Its purpose was to actually cause a very mild case of smallpox. The individual inoculated could transmit smallpox to others as though he or she had been naturally infected. In the great majority of inoculated persons, the illness and rash were slight, and they had lifelong immunity thereafter.

Vaccination, introduced by Jenner in 1796, was based on the related but different fact that immunity to smallpox could be induced by infection with a different disease—cowpox. The procedure was similar but the injected material was derived not from a smallpox patient but from a bovine with cowpox.

The only evident advantage of variolation over vaccination was that, provided the patient survived, variolation conferred lifelong immunity, whereas vaccination required periodic repetition. The advantages of vaccination, far outweighing this drawback, were that those vaccinated did not develop smallpox or transmit the disease to others; that the rash almost never appeared; that the symptoms, if any, were extremely mild; and, most importantly, that the risk of death from vaccination was minuscule, one or two per million, whereas the risk of death for inoculated persons was at least in the range of 1-3 percent.

Unlike those of vaccination, the origins of variolation reach far back in time. It had undoubtedly been practiced in India, China, and Africa for many centuries. Early in the embattled eighteenth century, it was introduced into North America and Europe and was widely practiced in many other parts of the world. In France it was in favor, out of favor, and then reinstated when smallpox attacked the royal household.

Controversy was variolation's constant companion. In successive periods leaders of medical and scientific opinion were often arrayed on both sides, depending in part on whether or not inoculation was compatible with their respective theories of smallpox causation. The practice also furnished an arena for theological and ethical argument since it not only represented "tampering with God's will" but also involved considerable risk for many who might not otherwise contract the disease naturally.

Variolation had been introduced into England and adopted by the royal family by 1722. In 1721, in connection with a devastating epidemic in Boston, Cotton Mather observed that the attack rate was much higher among whites than among blacks, who had brought the practice of variolation from Africa. Mather sought to popularize the practice in colonial America without success. Later in the century British troops at Quebec, better protected than their more numerous

colonial attackers, successfully defended the city during a smallpox epidemic occurring at the time of the battle.

The debates continued in the nineteenth century even after Jenner's far-safer vaccination method had been thoroughly proved, as some die-hard variolationists persisted in their views. By the twentieth century, vaccination was generally accepted as the method of choice in most parts of the world, and smallpox was clearly on the decline in those countries where it was widely practiced. Even so, small but highly vocal antivaccinationists persisted in some places including, paradoxically, England.

THE ALLIANCE FOR ERADICATION

The World Health Organization

The World Health Organization (WHO) was established as one of the specialized agencies of the United Nations immediately after World War II. Its governing body, the World Health Assembly, comprises the principal health officials of its member countries, which now number more than 165. The assembly meets annually, generally in Geneva, Switzerland, where the WHO Secretariat is located. WHO is supported by the member governments, whose assessments are based on a formula related to their population and gross national product. The United States has been the largest single contributor to WHO since its inception.

WHO is not the oldest official international health organization. That distinction goes to the Pan American Sanitary Bureau, founded in the early years of the twentieth century as an instrument for collaboration among the governments of the Western Hemisphere in combatting such epidemic diseases as yellow fever and malaria. With the formation of WHO, the Pan American Sanitary Bureau, now more generally known as the Pan American Health Organization (PAHO), became WHO's Regional Office for the Americas, though it retains considerable autonomy and an additional funding base through the Organization of American States.

WHO provides technical cooperation on request to the member governments. It maintains an office in almost every country, and WHO field staff generally work in very close concert with the staff of each ministry of health. It maintains six regional offices: for Europe in Copenhagen, for Africa in Brazzaville, for the Eastern Mediterranean in Alexandria, for Southeast Asia in New Delhi, for the Western Pacific in Manila, and for the Americas, PAHO headquarters in Washington.

The WHO Secretariat in Geneva is headed by a Director General, elected for a five-year term or terms by the World Health Assembly. Its staff, at headquarters, in the regional offices, and in the field, is small. It is made up of leading experts, recruited worldwide, in the various medical, scientific, technical, and administra-

tive fields required in the solution of health problems. Although WHO's services are available to all countries on request, its priorities are necessarily those of the developing world, where the needs are most urgent. The WHO staff, augmented by collaborating centers and cooperating institutions in many countries, represents a reservoir of expertise on which nations may draw.

In addition to offering technical assistance to member governments in setting and achieving their several health objectives, WHO is also an instrument for achieving global consensus on health-related policies and priorities. In this role WHO was successful in its earliest years in promulgating universal acceptance of a definition of health that extends beyond the mere "absence of disease" and implies a positive state that permits individuals to achieve self-fulfillment. More recently, together with the United Nations Children's Fund (UNICEF), WHO has affirmed a worldwide goal of Health for All by the Year 2000, toward which its efforts and those of its member governments are directed.

But health, however defined, is inextricably interwoven with social, economic, and cultural threads, and no official intergovernmental organ can be completely divorced from prevailing political currents. For these reasons WHO has faced a formidable task in developing consensus on policies and concerted action for their implementation. The success of the global smallpox eradication effort, outstanding in any context, is especially remarkable projected against this backdrop. WHO's presence and guidance were indispensable to its accomplishment, and the achievement ranks as one of the organization's finest.

Centers for Disease Control

The Centers for Disease Control (CDC) is one of the operating agencies of the U.S. Public Health Service (PHS). Headquartered in Atlanta, Georgia, CDC grew out of a unit established during World War II with the highly specialized mission of protecting military bases and related parts of the southeastern region of the country against the danger of malaria epidemics; this threat was posed by the widespread presence of mosquitoes capable of transmitting the disease in an area experiencing an influx of war-related industries and of military recruits from all parts of the United States who had never been exposed to malaria.

At war's end this Malaria Control in War Areas unit was assigned a broader national mission and renamed the Communicable Disease Center, thanks to the foresight of a public health statesman named Dr. Joseph W. Mountin. Dr. Mountin, an Assistant Surgeon General of the PHS, envisioned a network of Federal "centers of expertise" to deal with specific clusters of public health problems.

In the United States the fundamental responsibility for the health of the public rests with the several states. Therefore, the charge of the newly formed CDC was to assist the state health departments on request in dealing with communicable disease problems in emergency situations and, over the longer term, through

research, manpower development, laboratory support, and other means of enhancing state capabilities. Though the circumstances and needs were different, the role was analogous in many ways to that of WHO as a reservoir of expertise for its member governments.

Through the 1950s and early 1960s, CDC acquired broader responsibilities, including the administration of Federal grants to the states for a variety of disease control purposes. Through the venereal disease control and immunization assistance programs, a pattern of collaboration evolved whereby public health advisors recruited by CDC were assigned to the states to work with their state counterparts in carrying out day-to-day program activities. Both this pattern and many of the individuals who gained practical field experience in this way were to prove readily adaptable to the needs of smallpox eradication in the developing countries of Africa and Asia.

Meanwhile, the Epidemic Intelligence Service (EIS) was initiated at CDC in 1951 and developed under the leadership of Dr. Alexander D. Langmuir. Created in an atmosphere of concern about biological warfare, the EIS quickly proved that it met a need for physicians and other health professionals trained and skilled in epidemiology. This corps was made available for assignment to the states and also for rapid dispatch on request to the scene of an epidemic or disease outbreak either in the United States or abroad. Epidemiology CDC-style, with its emphasis on quick response, intensive surveillance, identification of patterns of occurrence, and vigorous follow-up, became a powerful force in global smallpox eradication. It continues to have a major influence on public health practice in relation to problems far removed from infectious diseases, its original focus.

CDC's name has changed over the years, from Communicable Disease Center to Center for Disease Control (1970) and Centers for Disease Control (1980), to reflect its widening responsibilities. While retaining its primacy in infectious diseases, it has also become the principal prevention arm of the U.S. Federal Government across a broad spectrum of public health programs dealing with chronic disease and injury control, family planning, health-related aspects of human life-styles, and occupational and community environments.

CDC's mission and funding are primarily domestic. But increasingly over the years, it has developed an international presence. Individual CDC experts were working closely with foreign colleagues from the agency's beginnings. However, the Smallpox Eradication Program of the 1960s was its first major institutional venture into international health and remains in many ways one of its best.

U.S. Agency for International Development

CDC's full-scale participation in the global smallpox program was made possible initially through funding support of the U.S. Agency for International Development (AID). AID, a component of the U.S. Department of State, conducts and

supports bilateral activities between the United States and individual foreign countries. Health is only one part of AID's broad mission to bring U.S. assistance to the developing nations in many fields related to their development. In smallpox eradication, as will be seen, CDC's expertise in health was brought into partnership with AID's economic and legislative charter.

The agency now known as AID began in 1947 as the Economic Cooperation Administration (ECA). It was established as an independent executive agency to implement the Marshall Plan, a worldwide program first of postwar reconstruction and then of economic development initially proposed by Secretary of State George C. Marshall in the administration of President Harry S. Truman. Like CDC, the agency's name changed over the years to match its mission—from ECA to ICA (International Cooperation Administration) to AID. By the time of its collaboration with CDC in the 1960s, it was working almost entirely with the developing world and had become a part of the Department of State.

BATTLE LINES

The Nineteenth World Health Assembly, meeting in Geneva in 1966, for the first time formally adopted a regular budget for smallpox eradication. A year later the Twentieth Assembly adopted a resolution calling for a global program to eradicate smallpox. The United States and the USSR were both among the governments cosponsoring the resolution. The CDC/AID program in West and Central Africa, launched the same year, was a U.S. contribution to this worldwide effort.

This official declaration was not the first call for concerted international action against smallpox. The Pan American Sanitary Bureau had approved an eradication campaign for the Americas in 1949, at a time when the disease was no longer present in North and Central America, and the resultant program had experienced mixed success in the South American countries where smallpox was still endemic. In 1958 WHO adopted a resolution sponsored by the USSR to augment eradication efforts, but lacking a specific deadline and specific support, the program had relatively little impact.

Nor was smallpox the first disease targeted for eradication. Yellow fever and yaws had both been proposed for eradication. With considerable fanfare WHO had proclaimed a goal of worldwide malaria eradication several years before. But the intransigence and adaptability of the malarial mosquito in developing resistance to pesticides, and of the malaria parasite in developing resistance to drugs, had caused the organization to back down to a much less optimistic objective of malaria control. The resulting disillusionment left many in WHO reluctant to go out on a similar limb again, especially with a disease still endemic and infecting millions of victims annually in more than thirty countries. Dr. Karel Raska, an infectious disease expert from Czechoslovakia on the WHO staff in Geneva, is credited with keeping the aspirations for smallpox eradication alive.

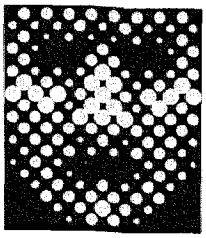
Meanwhile, both variola major and variola minor were very much alive, despite the availability for more than a century of the basic means for their extinction. Vaccination campaigns ebbed and flowed through the first half of the twentieth century, even in the most advanced countries. In 1925 the United States reported 43,000 cases, more than any other country except India. Most of these were the milder variola minor, but epidemics of variola major occurred in four U.S. cities that year. Sixty-five cases of smallpox, with twenty deaths, were reported in Seattle in 1945, and twelve persons were infected in New York City in 1947, two of whom died. Eight cases in Texas in 1949, with one death, were the last smallpox cases reported in the United States.

Enough demonstrable progress was being made to suggest that eradication might be a feasible goal. Sweden in 1895 was the first large country to be smallpox free, although it is possible that Ceylon, now Sri Lanka, may have eliminated the disease in the early 1800s. The disease disappeared in Austria in the 1920s, and England, the USSR, and the Philippines—among others—were free of endemic smallpox in the 1930s. Canada, the United States, and numerous others joined the list in the 1940s, although in an increasingly small world the presence of smallpox anywhere constituted a potential menace everywhere.

Also, technical progress was being made that brought the goal within reach. The development of effective freeze-dried vaccines eliminated the necessity for refrigeration, which had been an insuperable obstacle in much of the tropical world. Jet injectors, adapted for the purpose by the U.S. military and CDC in the early 1960s, made possible the immunization of thousands of persons by relatively few personnel in a short time, thereby greatly enhancing the success of mass campaigns.

Thus, when the World Health Assembly issued its call in 1966 and 1967, the necessary technology was in place and the goal was at least theoretically achievable. It was, nevertheless, a bold challenge. In 1966 the disease had been reported in forty-four countries and was endemic in at least thirty-three of them. For every one of the 131,000 reported cases, it was reliably estimated that 100 actually occurred. The smallpox map at the start of the campaign showed that the disease was present across southern Asia from Afghanistan to Malaysia and Indonesia, throughout most of Africa south of the Sahara, in the giant South American countries of Brazil and Argentina, and in scattered locations in Europe and the Middle East.

Most champions of the eradication goal agreed that what was needed to assure ultimate success was a smashing victory in an area where the disease was heavily endemic and where geographic and other conditions were particularly challenging. The campaign in West and Central Africa, designed and carried out by CDC with AID support under the WHO banner, was intended to fulfill this need. With its successful conclusion in 1970, the ultimate objective of global eradication was clearly achievable, though by no means easily or surely attainable.



2 PREPARATIONS

CDC MEETS SMALLPOX

"An Eye on Smallpox"

Dr. Alexander Langmuir, founder and guiding light of the Centers for Disease Control's (CDC's) Epidemic Intelligence Service (EIS), chose one young medical officer from each incoming EIS class to be his special aide-de-camp. In 1961 the honor and accompanying burden fell to Dr. J. Donald Millar. One of Langmuir's first instructions was to "keep an eye on smallpox; see if you can make sense of the trends."

Millar, like most U.S. physicians of his generation, had never seen a case of smallpox. The last natural outbreak in the United States had occurred in the Rio Grande Valley in 1949. During the period 1958-1962, twenty-eight suspect cases were identified in the United States, but none of them proved to be the real thing.

Langmuir, on the other hand, had met the enemy face to face. In 1958 a large smallpox outbreak struck East Pakistan, now Bangladesh, and foreign assistance was requested. Langmuir telephoned Washington and volunteered to lead a group of Public Health Service (PHS) officers, including several from the EIS, supported by the U.S. International Cooperation Administration (ICA), the pre-

decessor of the U.S. Agency for International Development (AID). CDC's role was primarily to check on the reliability of data being relayed from the field to the central Pakistani government. This event, seemingly isolated at the time, was among CDC's earliest ventures into international epidemic aid and was a precursor of things to come.

Millar in 1961 dutifully scanned the world's medical literature for smallpox references and plotted long-range trends. In the winter of 1961-1962, five outbreaks occurred in the British Midlands and Wales, all traced to importations from Pakistan. Over sixty persons contracted smallpox, and several died. Significantly, nearly two-thirds of these cases were hospital acquired, as hospital personnel, patients, or visitors in the hospitals in which the original patients were treated became infected.

Similar histories in subsequent importations to England, Germany, and other European countries made it evident that for the developed world, where smallpox was no longer endemic, hospitals were the areas at primary risk. Smallpox had become an occupational hazard for hospital workers and a nosocomial problem for patients. Review of the immunization status of hospital personnel in the United States revealed a frightening situation: many had not been vaccinated in thirty years. Accordingly, CDC and the American Hospital Association developed an information program urging immunization of hospital staffs.

In 1962 while in Indonesia on a malaria control mission, Millar saw smallpox cases at first hand. Dr. D. A. Henderson, then head of the Surveillance Section in Langmuir's Epidemiology Branch, asked Millar to collect and bring back smallpox specimens for testing in CDC's laboratories with the new fluorescent antibody diagnostic technique. Millar found some fifty cases in a hospital in Bandung, providing him with greater smallpox experience than any of his CDC colleagues except Langmuir and the group that had recently visited Pakistan. He brought home the samples as requested.

On his return Millar was put in charge of a Smallpox Surveillance Unit in Henderson's section. By 1963 the unit contained four additional physicians—Drs. Ronald R. Roberto, John M. Neff, Thomas M. Mack, and J. Michael Lane. Formation of the unit was spurred, in part, by a major smallpox scare involving New York State and Toronto, Canada. A fourteen-year-old boy in the early stages of smallpox arrived in New York City from Brazil and traveled by train to Toronto via Buffalo. CDC placed more than 1,000 people under surveillance, including those who had ridden with the boy in the train and taxis. Henderson and Millar went to Toronto to examine the patient.

This episode, demonstrating that jet travel was changing the rules on disease importation, provided impetus for the development of clinical diagnostic skills. EIS officers were dispatched to look at suspect rashes. One such incident, in New Mexico, provided the entrance onto the smallpox scene of another of the

leading *dramatis personae* later on—Dr. William H. Foege, then an EIS officer in Colorado, who was sent to investigate.

The fledgling Smallpox Unit received widespread attention, bordering on notoriety, in connection with a suspected importation to Washington, D.C., from Ghana. The patient, a thirty-one-year-old Ghanaian woman, arrived in New York from Accra on May 7, 1965. She proceeded directly to Washington, where she was hospitalized on May 20 with many signs that could be characteristic of smallpox. The case was designated as presumptive smallpox on the basis of clinical, epidemiological, and laboratory evidence. More than 1,000 persons were identified as direct, indirect, or secondary contacts. All were vaccinated and placed under surveillance. Work schedules were interrupted; vacations were postponed; many lives were considerably disrupted. And since all of this was taking place in Washington, D.C., on the doorstep of the Federal Government and at the news vortex of the country, visibility was sudden and overwhelming.

Actually, the ballots were mixed from the beginning as to whether or not the presumptive case was a true case of smallpox. Diagnosis was complicated, among other things, by the woman's extensive use of calamine lotion on her rash. The CDC team—Millar, Neff, and Lane—had serious doubts on the basis of their clinical examinations. However, as has been noted, their combined direct experience with the disease was extremely limited. A senior physician with extensive smallpox experience, Dr. James Leake, was consulted and expressed the tentative conclusion that it was, in fact, smallpox.

Meanwhile, the CDC laboratory had expressed probable confirmation of the smallpox diagnosis, based on several different tests that were available at that time. But the smallpox laboratory, which later evolved into one of the world's primary reference centers under the direction of Dr. James H. Nakano, was at that time new to the smallpox arena. Dr. Nakano himself had worked extensively with the poliomyelitis virus. Moreover, the tests available then for rapid identification of smallpox, including the use of electron microscopy, were new and not yet fully evaluated. In the event, the first laboratory diagnosis proved to be a false positive. Several weeks later, after the original patient had recovered and no secondary cases had appeared, the diagnosis was formally changed to chickenpox.

This episode highlighted a series of discussions between CDC and a remarkable clinical pediatrician named Dr. C. Henry Kempe concerning the desirability of maintaining routine vaccinations in the United States. Millar and his colleagues had been repeatedly proclaiming the importance of maintaining a basic level of immunity and a continuous watch against importation of the disease by travelers. Kempe, who had worked with smallpox in India and who saw many vaccine complications in his pediatrics department in Denver—a national referral center for such cases—made impassioned pleas to stop routine smallpox vaccinations. He claimed that between 1948 and 1965 there had been 200-300 child deaths in the United States due to the complications of vaccination and only one death from smallpox itself.

After the suspected importation from Ghana, Kempe was highly critical of CDC's handling of the situation. While praising the public health actions taken by CDC to contain the possible spread, he was scornful of the laboratory error on which the sustained misdiagnosis was based, and especially of the widespread publicity that left the general impression that "the case from Ghana" was truly smallpox even after it had been disproved.

In retrospect, Millar has said, "Henry Kempe was a zealot, and he turned out to be right, but he wasn't very precise about it." His studies of complications lacked the denominators needed to serve as a basis for a major change of immunization policy. Within two years, Lane and Neff had gathered more-rigorous data, which showed conclusively that smallpox vaccinations did indeed produce a toll that could no longer be justified. These studies were supplemented by efforts to quantitate the risk of introduction of smallpox from outside the country and to estimate the possible size of resulting outbreaks. When these activities showed that the risk of vaccination outweighed its benefits in the United States, CDC became a vigorous proponent of the view that routine smallpox vaccination should be stopped, as will be seen in chapter 4. At the same time it gave renewed vigor to the effort to eliminate the source of the disease in developing countries.

Meanwhile, the technology required for mass immunizations under difficult field conditions, essential for any realistic approach to smallpox eradication, was being developed. The CDC Smallpox Unit became increasingly involved in this chain of action.

The U.S. Army had developed the jet injector after World War II to help meet its continuing needs for mass immunization of recruits. The first jet injectors gave subcutaneous injections, whereas smallpox vaccinations at that time were still given by multiple punctures, creating a traffic jam in the immunization clinics of military camps. Therefore, a directive was given to develop intradermal jet injection for use with smallpox vaccine. Mr. Aaron Ismach at Fort Totten, Long Island, a civilian employee of the U.S. Defense Department, was assigned this task, and by 1962 was beginning to test an intradermal nozzle on his colleagues and volunteer recruits. D. A. Henderson asked Dr. Myron G. Schultz of CDC to meet with Ismach and check out the jet injector. This began a long, fruitful collaboration with Ismach, who became one of the behind-the-scenes heroes of the smallpox saga.

Gathering Field Experience

In 1963 a CDC medical team used a jet injector supplied by the Army to control a diphtheria outbreak on an American Indian reservation near Yakima, Washington. Both the population of the reservation and residents of Yakima were quickly organized and efficiently vaccinated. Subsequently, as the Army Medical Corps needed tests to determine smallpox "take rates" at various vaccine dilutions, the help of the CDC Smallpox Unit was requested. Millar, sensing

the enormous potential of the jet injector for smallpox control and eventual eradication, accepted enthusiastically. Thus, between 1963 and the spring of 1965, the Smallpox Unit conducted studies, first at the Atlanta Federal Prison and Reidsville (Georgia) State Prison and subsequently in Jamaica, Tonga, and Brazil.

Between July and September 1963, 100,000 Jamaican children under age twelve were immunized in a campaign against diphtheria, tetanus, whooping cough, and measles. The jet injectors used depended on a source of electricity. Their generators required sophisticated maintenance. Oil leaks were a common problem, as was the need for spare parts.

On the basis of this field experience, the Smallpox Unit urged the Army to develop a mechanical jet injector that would not be dependent on electricity, on the premise that such a device would be essential for mass campaigns in rural areas of developing countries. Once again Aaron Ismach delivered the goods—a foot-powered injector called "ped-o-jet," which enormously enhanced the potential mobility of an immunization team and reduced the woes of maintenance.

Additional studies in Jamaica in 1963 and in prison populations provided valuable data on desirable dosage levels and dilutions of smallpox vaccine. But questions persisted that required observations of stable populations over a period of years. A serendipitous visit to Atlanta by the Prince of Tonga, a Polynesian kingdom in the mid-Pacific, provided an ideal opportunity. The Prince agreed to welcome a CDC team, and Drs. Ronald Roberto and William Foege plus Mr. William Higgins and Dr. Pierce Gardner were dispatched. Despite their colleagues' taunts about their "hardship duty in a tropical paradise," they encountered formidable problems of access to people on outlying islands and in the mountainous interiors. Nevertheless, more than 60,000 Tongans were vaccinated. For data-collection purposes they were divided into four groups, three of which were immunized with the ped-o-jet. The optimal vaccine dilution for the intradermal injection was determined.

An invitation from the Pan American Health Organization (PAHO) to demonstrate the jet injector in Brazil gave the Smallpox Unit an opportunity to work in an area with endemic smallpox under difficult operating circumstances. Brazil, by virtue of its size and its common borders with almost every other South American country, was clearly the key to eradication in the Western Hemisphere. The attack phase of the Brazilian government's campaign had been moving slowly. Moreover, CDC had calculated that Brazil was by far the most likely single source of importation of smallpox into the United States. These factors made the invitation to take part in the PAHO program doubly welcome, and Millar and Neff were made available.

Millar went first to Peru, which had been smallpox-free for several years and was now experiencing an epidemic imported from Brazil. He and his Peruvian coun-

terparts found the disease gradually proceeding, essentially undetected and uncontrolled, from the jungle areas of the Brazilian frontier to the metropolitan setting of Lima. Once cases reached the capital city, hurried containment activities were undertaken in Lima, but classic smallpox outbreaks were occurring in villages. In their trip report Millar and Neff reemphasized the critical importance of Brazil as the keystone of eradication efforts and urged improved surveillance, epidemiology, and training programs in both countries.

On the basis of their report, Dr. David J. Sencer, who had become CDC's Acting Director, wrote a memo to the Surgeon General of the PHS on November 5, 1964, outlining a program for smallpox eradication in the Americas by 1970 or perhaps earlier. In the subsequent months the extent and nature of potential support from various sources were discussed in PAHO and the PHS.

Meanwhile, in early 1965 the team led by Millar evaluated the jet injector, under extremely challenging field conditions, in the Federal Territory of Amapá, a remote area in the tropical rain forest of northeastern Brazil. A mass campaign was carried out in the territorial capital, Macapá, and other studies were done in outlying villages. The results proved the superiority of the foot-powered jet injector in many ways and confirmed it as the instrument of choice for the subsequent campaigns in West Africa. As an important by-product, the success of the activity demonstrated the feasibility of eradication to Brazilian authorities, thereby helping to upgrade the priority they accorded to this goal. One member of the CDC team at Amapá, Dr. Leo Morris, a statistician-epidemiologist, was later to return to Brazil to play a key role in their eradication efforts.

Thus, in addition to its rapidly growing worldwide reputation in epidemiology and surveillance, by early 1965 CDC had established itself as an organization with the practical capability to deal effectively with smallpox in field conditions. At this time other events were taking place that would quickly shift the attention of the Smallpox Unit from its initial area of interest in Latin America to the vast reaches of West Africa.

WEST AFRICA

The setting for the West and Central African smallpox eradication campaign comprised, in 1967, twenty countries with a combined population in excess of 100 million. The geographically contiguous region is bounded on the west by the Atlantic Ocean, on the north by the Sahara Desert, on the east by the Sudan, and on the south by the Congo basin.

It is a region of widely diverse ecologies. Humid tropical coastal areas with prolonged rainy seasons gradually give way to grasslands, the savannah of the West African interior, and thence to the flat, arid sub-Saharan region of the Sahel characterized by spiny bushes, stunted trees, and sparse, sporadic rainfall.

The peoples inhabiting this territory are fully as disparate as the geography. The short, stocky coastal peoples are largely Christians or believers in animistic faiths. The taller people of the savannah, mostly farmers and herders, are predominantly Muslim; in fact, it is conjectured that the Muslim religion stopped at the borders of the humid forests because their horses and cattle were so susceptible to tropical diseases prevalent there, especially African trypanosomiasis (sleeping sickness). Subsistence farming characterizes the region, with nomadic herding prominent in the Sahel.

These diverse peoples are divided into hundreds of tribes, some with fewer than 100,000 members and others numbering millions. Most have their own language or dialect and culture. Traditional tribal boundaries overlap the more recently imposed national borders, resulting in great complexity of administration and frequent conflicts. Patterns of leadership are complicated among religious, secular, military, and governmental factions, and unscheduled changes of government have happened often in several of the emerging countries.

As might be anticipated, transportation and communications presented formidable challenges at the time of the eradication program. Paved roads were few. Those that did exist generally stretched from the coast into the interior, with virtually no cross-connections even between the coastal cities. Secondary roads were rutted, poorly maintained, and guaranteed to punish any vehicle severely. Railroads were scarce and, like the roads, ran generally from the coast to the interior, with service subject to long delays. Telephone systems were unreliable at best, and most intercountry calls, even between neighboring countries, were routed through London or Paris. Similarly, the newly emerging national airlines might connect the respective African capitals with Europe more readily than with their neighbors.

Despite these barriers, West Africans have been noted as travelers and traders for centuries. Some trade patterns may date back continuously to prehistoric times. The marketplace is the universal relaying point for news as well as goods. There is also a long tradition of migratory labor, which, in recent times, has led to extremely rapid urban growth, primarily in the coastal cities. Abidjan, in Ivory Coast, grew from a village of 5,000 inhabitants in 1921 to a city of 180,000 by the time the eradication program began. Lagos, Nigeria, grew from 100,000 to 665,000 in the same span and is now a much larger metropolis.

The recent political history of the region has one all-pervading common denominator: a colonial past and emergence into independence. Of the countries in the program at the outset, all but one—Liberia, independent since 1847—became sovereign nations between 1957 and 1966. Four of them had been British colonies (The Gambia, Ghana, Nigeria, and Sierra Leone). The other fourteen had been French (Cameroon, Central African Republic, Chad, People's Republic of the Congo, Dahomey, Gabon, Guinea, Ivory Coast, Mali, Mauritania, Niger, Senegal, Togo, and Upper Volta). This fact of history divided

the region into an Anglophone and Francophone dichotomy. The British and French political and administrative structures, which had been superimposed on a mosaic of tribal and theocratic societies in the previous century, strongly influenced the structural patterns of the emerging nations.

In the former British colonies, the authority of the tribal chiefs had been supported and fostered. The civil structure was essentially decentralized. This had important ramifications for the smallpox eradication program, for it meant that support of the principal tribal chiefs was as vital to success as that of civil authorities. In some places, such as Nigeria, support of the paramount chiefs proved to be indipensable.

Where the French superstructure had prevailed, the power of the traditional chiefs had been largely subordinated to a centralized government. Accordingly, in the former French colonies, the civil structure extending down to the village level was the key to communication with the people.

A third type of structure was presented by two countries, Guinea and Mali, where socialist governments were installed at the national level. There, the authority of traditional leaders had largely been superseded by a socialist political party organization, and therefore, linkage with the villagers was sought through party workers.

Differences in colonial heritage affected patterns of delivery of health services. In the former British colonies, influenced by the missionary model made popular by Dr. David Livingstone and others, the structure was highly decentralized. Rural dispensaries operated by Africans provided basic drugs and occasionally vaccines, although the emphasis was generally on curative services. Smallpox vaccinations were usually performed episodically, in response to epidemics. Such clinics and small hospitals were numerous in some areas and scarce in others and might be under either governmental or missionary direction. Only in Ghana and Sierra Leone was there a tradition of mobile teams providing services outside the clinic setting.

By contrast, the former French colonies had a tradition of applying health measures in the field through the use of mobile, multipurpose "prospection teams." The *Service des Grandes Endemies* (SGE), as the organization was called, had evolved in the 1920s and 1930s in French West Africa and the area formerly known as French Equatorial Africa under the leadership of Dr. Eugene Jamot. SGE, which emphasized prevention, provided basic health services in rural areas, with teams moving systematically through each country following plans that would allow them to reach each village once every two or three years.

Administration of smallpox vaccine was one of the functions of the mobile teams. In those countries where the system worked especially well, notably in Ivory Coast and French Equatorial Africa, smallpox cases were few or nonexistent by 1966.

With the approach of independence, the centralized public health systems of the two Francophone subregions (French West Africa and French Equatorial Africa) became subdivided into autonomous national units. It was quickly evident, however, that some of the key institutions and services could not be supported solely from national budgets. Moreover, there was a need for a regional coordinating body to cope with communicable diseases that cross national frontiers. In the West Africa subregion, the *Organization de Coordination et de Coopération pour la Lutte contre Grandes Endemies* (OCCGE) was created to help meet these needs for Dahomey, Ivory Coast, Mali, Mauritania, Niger, Senegal, Togo, Upper Volta, and Guinea. France, which subsidized the organization through grants plus equipment and personnel, was made a European member. A permanent secretariat for OCCGE was established in the city of Bobo-Dioulasso, in Upper Volta (now Burkina Faso). Its first director-general was a French military official, General Pierre Richet.

OCCGE was limited in its ability to shape health policy by the intensity of nationalistic sentiments, but it did provide important services, including the conduct of prevalence studies and the training of paramedical personnel. A parallel organization, the *Organization de Coordination pour la Lutte contre Endemies d'Afrique Central* (OCEAC), was subsequently established for the countries formerly comprising French Equatorial Africa plus the Cameroon, with another French military physician, Colonel René Labusquière, as its secretary general.

THE SMALLPOX/MEASLES CONNECTION

Curiously, it was a program of immunization against measles that opened the door for smallpox eradication in West Africa. At the time of independence in the early 1960s, measles rather than smallpox was the childhood disease most feared throughout most of the region. It struck children almost universally; very few reached their second birthday without being infected. Its death rate was at least 10 percent and in some instances still higher, especially in populations already suffering from malnutrition, tuberculosis, and other infections. It was not surprising, therefore, that the political leadership of the newly emerging nations, eager to demonstrate that independence would enhance the quality of life of their people, would be keenly interested in any protection against measles that might be forthcoming.

In 1960 the ministers of health of four of the new nations visited the United States on a U.S. State Department Leadership Grant. On their itinerary was a visit to the Division of Biologics Standards, which was then a part of the National Institutes of Health (NIH) in Bethesda, Maryland. At the Division of Biologics Standards, Dr. Harry Meyer was working on an attenuated strain, known as Edmonston B, of a measles vaccine under development but not yet licensed for use in the United States. The strain had proved safe and effective, but because it caused a frequent occurrence of high fever, it had been used only in conjunction with simultaneously administered gamma globulin.

Dr. Paul Lambin, Minister of Health for Upper Volta, immediately seized upon the enormous potential value, both medically and politically, of a measles vaccine for his country. Meyer, for his part, was interested in an opportunity to field-test the Edmonston B strain in Africa. Although at this stage the vaccine had already been tested on over 20,000 children in the United States and in other countries around the world, there was a need to ascertain its effects on African children in Africa. Lambin accordingly requested that a study be conducted in his country, and in 1961 with support from the NIH, Meyer and his colleagues studied a group of 600 children in Upper Volta. They showed that the vaccine could be administered without gamma globulin with safety and efficacy.

Greatly pleased with the results, Dr. Lambin asked the United States to provide support for measles vaccination of all young children in his country. Between November 1962 and March 1963, the mobile, multipurpose health teams of the SGE of Upper Volta vaccinated more than 700,000 children, assisted by Meyer and his associates. The results were dramatic. Reported cases of measles declined sharply, and for the next two years, they remained far below previous recorded levels.

The other member countries of OCCGE became quickly and fully aware of the successful program. The organization accordingly asked AID to support additional national programs. AID, for both humanitarian and international political reasons, agreed. Thus, it was arranged for Dr. Meyer to set up demonstration projects and direct training programs in six more countries (Dahomey, Guinea, Ivory Coast, Mali, Mauritania, and Niger) in late 1963. In 1964 AID allocated $1.5 million for the provision of vehicles, jet injectors, and enough measles vaccine to immunize 25 percent of the children between the ages of six months and six years. The campaigns began in late 1964.

Expanding the project from a study to a national initiative in effect removed it from the normal span of activity of NIH, which is the primary biomedical research arm of the PHS. As a consequence, as the mass campaigns began, AID turned for technical assistance and support to CDC as the PHS agency chiefly concerned with carrying out disease control and prevention programs. In December 1964 Dr. Lawrence K. Altman of the Epidemiology Branch in Atlanta was asked to observe the programs as they were evolving and report on their progress. His original six-week assignment lasted six months, during which time Altman strove mightily to cope with the chaotic situation he found at almost every turn. Altman was followed in the field by Drs. J. Michael Lane and Ralph H. Henderson of the Smallpox Unit.

Altman's visit represented CDC's first official entry into partnership with AID on the West African scene. His observations, relayed back to Atlanta in a series of vivid reports befitting a man who would later become a leading science journalist, presented in microcosm the enormous logistical, technical, and administrative problems that would be faced and overcome in the subsequent eradication

campaigns. The vehicles supplied by AID were too big, poorly designed for the task, and virtually impossible to maintain for lack of U.S.-made parts in the Francophone hinterland. Refrigeration for the measles vaccine, which then had to be maintained at low temperatures, was woefully inadequate. Jet injectors frequently didn't work. Field teams were inadequately prepared to cope with mundane problems of equipment repair. Perhaps most crucial of all, administrative support was inadequate or nonexistent when most needed, both within the countries, where it was complicated by vestiges of colonial administration, and between field and headquarters.

Despite these problems, however, AID's enthusiasm for the program remained high. Assistance was offered to four additional countries (Cameroon, Central African Republic, Chad, and Togo) to begin measles programs in 1965-1966. CDC was asked to assign nine medical officers for six months, and those who were selected found themselves scurrying about Francophone Africa repairing trucks, jet injectors, and generators and wrestling with administrative obstacles. There was no time for epidemiology. Those who participated in the measles campaigns at this stage found West Africa endlessly fascinating and the program endlessly frustrating.

CDC's manpower resources were being severely stretched, however. As AID envisioned still more measles programs and called on CDC for still higher levels of assistance, it seemed to D. A. Henderson and his colleagues at CDC that the gain was not worth the investment, for several important reasons. First, benefits of a measles immunization campaign, at best, would be temporary: measles, unlike smallpox, did not then qualify as a likely candidate for eradication. Therefore, the programs would have to be repeated at intervals of a few years into the indefinite future. Second, since measles vaccine was very expensive, it was unlikely that any donor countries would continue support for measles control indefinitely and even more unlikely that the developing countries could afford it on their own. Campaigns would tend to raise public expectations that could not be fulfilled. Therefore, though CDC was reluctant to say no to AID's request, the prospect of a heavy continuing investment of limited manpower resources without a finite goal and sufficient support seemed a most unsound public health policy.

Meanwhile, events were occurring that would bring the prospect of global smallpox eradication into focus. As we have already seen, by early 1965 CDC had completed a series of studies that demonstrated that intradermal administration of smallpox vaccine was effective and practicable using the foot-powered jet injector with the newly developed nozzle. The new technology had proved highly successful in difficult circumstances in Brazil.

Then on May 18, 1965, as a result of patient backstage persuasion by staff members of the PHS led by Dr. D. A. Henderson, President Lyndon Johnson's White House issued a press release stating: "President Johnson announced today that he has instructed the U.S. Delegation at the World Health Assembly

to pledge American support for an international program to eradicate smallpox completely from the earth within the next decade."

Two months after this expression of commitment at the highest level, CDC proposed to AID that the two pieces be put together—that the measles control effort in West Africa to which AID was already extensively pledged be married to a smallpox eradication program to take a giant step toward fulfillment of the expressed intent of the President and the stated objective of the World Health Organization (WHO).

It was this linkage of smallpox eradication with measles control, on a regionwide basis, that made the entire program sensible and feasible. The inclusion of smallpox eradication fully justified to CDC the more extensive investment of its public health resources, which by law were primarily intended to be used to protect the health of the American people. Its acceptance was heralded in November 1965 by another White House press release that stated, in part:

> Plans for campaigns to protect 105 million people from smallpox and measles in 18 African countries were announced today by the White House. . . . AID and the PHS staff are beginning consultations with African and WHO officials on plans for the campaign, its acceptability to African countries and their willingness to contribute to the program.

Between the two White House statements had come five months of hard planning and negotiation. The proposal was far from modest. It represented a much greater U.S. commitment than had previously been envisioned. In essence the plan, drafted by CDC staff during the summer of 1965 and formally transmitted to AID on August 20, called for an eighteen-country program of five years' duration. All necessary commodities were to be provided, and CDC technical staff would take part at country level, at CDC headquarters in Atlanta, and at a proposed regional office in Africa.

AID was confronted with a set of difficult decisions. On the one hand, it was already committed to a measles vaccination program in eleven countries. Technical assistance was required, and the only adequate source of such assistance was PHS. But PHS was unwilling to make the commitment unless two conditions were met. First, smallpox eradication must be included. Second, to make smallpox eradication truly possible, the program must encompass the entire region; to do less would be to assure continuous reintroduction of the disease.

AID accepted the combination of smallpox and measles for sixteen countries with a combined population of about 46 million. But Nigeria and Ghana, with a combined population of 59 million, were not included in AID's plans because, in the words of an AID memorandum of July 19, "the total scope of the African problem is too great for any one donor to undertake its solution." Yet these two countries, and especially Nigeria, which was both the giant and the crossroads of

the region, were absolutely essential if regionwide eradication was to be achieved and sustained.

Both PHS and WHO were strongly in favor of the CDC plan. In late August two key WHO officials, Assistant Director-General Milton Siegel and Dr. Karel Raska, Director of its Division of Communicable Diseases, visited Washington to discuss the proposal. In early November WHO's Director-General, Dr. Marcolino Candau of Brazil, met with AID and CDC staff. The source of support, on a scale large enough to include Ghana and Nigeria, was the critical unresolved issue; WHO reluctantly acknowledged that its own resources were inadequate to fill the gap.

As discussions dragged on, crucial days and months were passing. If capable medical staff were to be brought on board by the summer of 1966, past experience showed that they needed to be recruited and commitments made to them no later than the fall of 1965. September passed, and then October, with no decision. A meeting of the ministers of health of the OCCGE countries was scheduled for late November, and participation in that meeting by Drs. D. A. Henderson and Henry Gelfand was considered essential to begin developing plans for the following year. A memorandum of November 10 from Henderson and Gelfand to the PHS Office of International Health concluded gloomily:

> Prospects of success for this program are already fading as a firm decision to undertake this activity is deferred. If decisions on the part of AID for full support of the 18-country program cannot be reached by November 15, the Public Health Service would be forced to withdraw such implied commitments as have been made and . . . discussions regarding the technical feasibilities would have to be re-explored from the beginning.

Happily, this worst-case scenario was not enacted. The decision was made, the proposal accepted. The world's first coordinated regional program for smallpox eradication was officially endorsed and proclaimed by the Presidential statement already cited.

All that remained now was to do it. And all that needed to be done in the thirteen months between acceptance of the proposal in late November 1965 and the target date for launching the program in January 1967 was (1) to work through complex and sometimes sensitive negotiations with each separate country, (2) to develop workable relationships between two U.S. agencies (CDC and AID), (3) to accommodate the international bureaucracies of WHO Geneva and its fiercely semi-autonomous Regional Office for Africa, (4) to resolve minor but nagging technical problems related to vaccines and their administration, (5) to work out an actual plan for field work, and not incidentally (6) to recruit, train, equip, transport, and install in unfamiliar territory a sizable team of health professionals and their families.

It was a tall order. That it was filled, and on time, represents a remarkable achievement.

NEGOTIATIONS

On November 23, 1965, the day the President's press release announcing the program was issued, Henderson and Gelfand plus Dr. Warren Winkelstein, a CDC consultant, and Dr. Clayton Curtis, Medical Director of the Africa Bureau of AID, were en route to West Africa. Their first stop was Ouagadougou in Upper Volta. Up to the moment of departure, they were not sure they would have anything to say. But thanks to approval at the eleventh hour, Curtis and the U.S. Ambassador were able to announce to the meeting of health ministers of the OCCGE countries that the United States would support a five-year smallpox eradication/measles control program for the region, funded by AID and directed by CDC. The OCCGE ministers expressed their approval of the proposal and pledged their countries' support.

Between November 23 and December 17, the U.S. team was able to discuss the program with sixteen of the eighteen countries originally included in the plan. After the OCCGE meeting they attended a technical meeting of the OCEAC countries and made special visits to Guinea, Liberia, Nigeria, and Sierra Leone. The Gambia and Ghana, the two countries not visited because of time constraints, conveyed to the respective U.S. embassies their willingness to take part as well.

The People's Republic of the Congo, a member of OCEAC, posed a diplomatic problem. At the time the United States had no formal relationship with this country. OCEAC insisted, however, that all of its members be included in the regional program, and AID agreed to support the program in the Congo as well.

Ironically, despite endorsement from the very highest sources, including the White House, many U.S. officials in the West African countries were less enthusiastic about the program than were the national governments. This reluctance stemmed in part from a philosophical problem intrinsic to the entire U.S. program of foreign aid.

Economists in policy-making positions felt that economic growth was the key to development. According to this line of thinking, the critical measures were increases in gross national product and per capita income; health and general improvement in the quality of life would follow as natural consequences of economic aid. Therefore, social programs in general—and health programs in particular—were downgraded during the early 1960s. This philosophy, as it was reflected in the field, had caused health officers to leave AID in frustration, feeling they had no hand in policy formulation.

The philosophical problem was compounded by a very practical consideration. A health program like the proposed smallpox/measles campaign required some expenditures by the national governments that had to come from very meagre budgets. The most significant of these, which could not be covered by AID funds, was for gasoline, even then extremely expensive in Africa and obviously

essential to get vehicles into the field. This problem was ultimately solved when Dr. Candau, the WHO Director-General, offered to support some of these costs out of WHO funds. In the event, in thirteen of the countries, WHO purchased gasoline-fueled, U.S.-provided vehicles in a bilateral assistance program.

This crucial decision was a concrete expression of an important change in WHO's posture. As has been noted, support for smallpox eradication had tended in the past to be more rhetorical than real. But the Nineteenth World Health Assembly, on May 13, 1966, voted to include the Smallpox Eradication Program in the regular WHO budget. This significant bureaucratic event formally legitimized and institutionalized the activities of the program. It culminated long years of patient persuasion by the believers in the concept both within and outside the organization, notably Dr. Raska, head of the Communicable Diseases Division in Geneva, whose contribution has already been mentioned.

The suspense was by no means over, however. On his visit to the United States in November 1965, Dr. Candau had asked PHS Surgeon General Luther L. Terry to assign an American medical officer, specifically Dr. D. A. Henderson, to direct a strengthened WHO smallpox program. Henderson himself viewed this prospect with mixed feelings. His ambivalence was based in part on reluctance to leave the recently approved CDC/AID program, of which he had been both principal architect and advocate, and in part on uncertainties about the strength of the WHO commitment.

Henderson was already on record with a set of recommendations for shoring up the WHO program. These included the necessity for strong central guidance, adequate financing, and capable staff in adequate numbers at headquarters and regional levels. The initial WHO response to these prescriptions had been less than enthusiastic. Nevertheless, both Geneva and Washington agreed that Henderson was the man for the job. As a commissioned officer in the PHS, he could not refuse a direct assignment, and in any case it was evident that a strong hand in Geneva would be essential to the program's success, a success to which Henderson was deeply committed. Ultimately, he agreed.

Meanwhile, the WHO structure provided other challenges to be overcome. WHO is strongly regionalized. Its six regional offices are semi-autonomous, and headquarters frequently defers to the regions on matters related to both policies and programs. The regions, in turn, are reluctant to intervene directly in the internal health affairs of the member countries. Their general operational posture in 1966 was to respond when asked, but not to initiate.

WHO's Regional Office for Africa (AFRO) had been founded in 1951 with headquarters in Brazzaville, then the capital of French Equatorial Africa and now the capital of the People's Republic of the Congo. To perhaps an even greater extent than the other regional offices, AFRO was characterized by rigid adherence to protocol.

The Smallpox Eradication Program, by its nature, was therefore not destined to be popular in Brazzaville. It carried the initial burden of having been initiated in Geneva. Its U.S. base of support was viewed with suspicion. To be successful, it would require flexibility and speed of communication between Geneva, the program, and the countries involved. Obtaining necessary acceptance from AFRO was further complicated by the fact that Americans could not easily get into Brazzaville because of the lack of diplomatic relations between the United States and the People's Republic of Congo, rendering face-to-face communication quite difficult.

To overcome these obstacles, Henderson and Dr. George I. Lythcott, a black American pediatrician experienced in the developing world who had been recruited by CDC to become director of the proposed regional program office in Nigeria, met with AFRO Director Dr. C. A. Quenum early in 1966. Henderson, in his report to Raska on this visit, stated:

> Dr. Quenum was very pleasant and cordial. He listened attentively while we presented the program and asked several pertinent questions. Although at no time did he evidence great enthusiasm, he expressed his accord with our approach and methods, and indicated his interest in having WHO personnel cooperate in the conduct of the program.

The needed link with AFRO might not be strong, but it was in place.

Within a month after the first sessions with the African leaders, CDC had prepared a sixty-page document, subsequently accepted with minor changes by AID, outlining specific program objectives, needs, and costs for personnel and commodities, country by country. U.S. assistance was originally projected to cost a total of $47 million over a five-year period. (In fact, the total U.S. expenditure was only $31 million.) The measles vaccination component accounted for about 40 percent of the total. Additional expenditures for local costs were estimated to average $1.7 million per year, an amount that would have swamped WHO's proposed regular budget for smallpox. Fortunately, the countries themselves eventually bore most of these expenses.

The document declared the eradication of smallpox to be the primary objective, with measles control as a secondary goal. It also proposed longer-term objectives including, in each country, the establishment or improvement of ongoing mobile disease control services, the establishment of a system of disease surveillance, and the development of simplified statistical sampling techniques to permit rapid assessment of disease problems.

PROGRAM PREPARATIONS: CDC

In January 1966 the Smallpox Unit was moved organizationally from the Surveillance Section of the Epidemiology Branch into the Office of the CDC Director.

This move, though not universally popular within the organization, was deemed necessary for managerial reasons. The Smallpox Eradication Program was a unique venture for CDC. It provided the agency with its first formal operational involvement in international health, and it would be operating on what was for CDC a grand scale. To succeed, it would need to draw on CDC resources across the board, using a matrix management approach that could best be carried out from the level of the Office of the Center Director.

J. Donald Millar, who had headed the unit since its inception in 1962, had departed in the summer of 1965 for a long-deferred year of postgraduate study in London. In December, with the West Africa program finally blessed, D. A. Henderson relinquished his post as Chief of the Surveillance Section, in which the unit had been housed, and assumed direction of the (CDC) Smallpox Eradication Program until Millar's return. He brought with him his deputy, Dr. Leo Morris, a veteran of the smallpox activities in Brazil, and was joined by Drs. Henry Gelfand, Ralph Henderson, and Bernard Challenor, the last two of whom had already been recruited into the Smallpox Unit. The key post of administrative officer was filled by Mr. Billy G. Griggs, who had already demonstrated extraordinary managerial ability in other CDC programs.

The task facing this newly created team was formidable. A master plan had to be put together, costed out, and "sold" to the other participating agencies. A detailed plan for each country, known in the jargon as an E-1, had to be developed and negotiated. This in turn served as the basis for the program agreement, which, when signed, constituted the formal, detailed, bilateral commitment between the United States and each developing country partner. Gelfand, Ralph Henderson, and the recently recruited George Lythcott crisscrossed West and Central Africa in the first months of 1966 developing these plans and drafting these program agreements.

This task was complex. First, each AID mission had to approve the proposal. Then, the national government needed to give preliminary approval. In Lythcott's words: "Every country was different in approach. . . . There could be a problem with the host country or with the U.S. AID mission or the Embassies. Some gave the program a carte blanche, while others met any U.S. involvement with suspicion." Finally, the detailed program agreements were to be signed. This critical step had to be postponed, however, not because of problems with the countries, but because of the painfully slow progress through the Congress of the Foreign Assistance Act, upon which appropriations for the entire program depended.

July 1, 1966, was the target date for bringing on board the staff that would carry out the program in the field, in the projected regional office at Lagos, Nigeria, and in Atlanta. Plans called for two basic types of personnel. Medical officer-epidemiologist advisors would help provide overall direction of the program's development and execution. Nonmedical advisors, called operations officers,

would be responsible for logistics including the critical tasks of equipment maintenance and repair, supplies, and financial matters. The prototype for the medical officer was the young physician whom CDC had been recruiting into the EIS; for the operations officer, it was the college-graduate public health advisor, who had proved so valuable in CDC assignments to state health departments for disease control programs.

The accent was on youth. Many of those recruited were in their twenties, and nearly all under forty. In part, this reflected the nature of CDC as a young organization with youthful leadership. It also reflected the perceived needs for intense commitment and stamina to carry out extensive and often exhausting work in the field. Further, it satisfied African health officials who wanted not just advice but active participation. Some African health administrators were initially skeptical about the operations officers' lack of medical credentials, but the latter group's performance quickly removed these doubts.

In the original plan the regional office to be situated in Lagos, Nigeria, was to constitute a reservoir of expertise for the region; its staff was to include a regional epidemiologist, an equipment specialist, a statistician, a health educator, and a virologist to supervise production of vaccine and run diagnostic tests. The regional office was seen as having line responsibility for program development and evaluation, as well as problem-solving and trouble-shooting, with CDC headquarters in Atlanta having responsibility for liaison with AID and WHO headquarters in Geneva and for general program supervision. During the course of the campaign, a number of these responsibilities were redefined to improve the efficiency of field operations.

One operations officer was recruited for each country, plus one for each of the four regions into which Nigeria was subdivided. Medical officers were recruited for each Nigerian region and for each of the larger countries. In the case of the smaller countries, one medical officer was to serve for two or three. Most of the physicians were recruited from outside CDC, whereas nearly all of the operations officers had at least a few years' prior experience in CDC domestic programs.

Fortunately, the hiring of needed staff had been authorized before the appropriations were actually "in the bank." Otherwise, given the excessive delay in Congressional approval of the Foreign Assistance Act, the program would have been delayed for at least another year. As it was, the full team for Africa was brought on board in Atlanta on July 5, 1966, to begin their intensive training program.

Medical officers began their training by taking part in the EIS course, although they were not appointed as EIS officers per se. Operations officers received 2-1/2 weeks of automotive training at the Chrysler Corporation Training Center in Atlanta to learn everything possible about the Dodge trucks that had been selected for procurement. Later, the physicians took a mini-course in automotive mechanics, and the operations officers in epidemiology. In addition, both groups

received training in elementary statistics from Leo Morris, heard lectures on basic epidemiology by Drs. Gelfand and Bernard Challenor, and were given laboratory orientation and management training.

In the evening, in addition to many informal meetings, there were French lessons for some. Thanks to gifted teachers and highly motivated students, the assignees to Francophone countries gained sufficient fluency to be able to function effectively on arrival in Africa.

After the conclusion of the EIS course, the two groups (medical officers and operations officers) trained together. They were given lectures on tropical diseases and West African health care systems. D. A. Henderson, Neff, Gelfand, and Millar presented various clinical and epidemiological aspects of smallpox, while Ralph Henderson, Challenor, and Lythcott lectured on measles control. Aaron Ismach conducted sessions on the use, repair, and maintenance of the ped-o-jets. Orientation sessions were presented on the roles of the State Department, AID, and the U.S. Information Agency in West Africa and on how the smallpox/measles program was expected to relate to these organizations. In addition, the trainees received general overviews of the history and cultures of West Africa.

During the spring and summer of 1966, a manual for field operations was prepared at CDC, which later became the basis for the WHO *Handbook for Smallpox Eradication in Endemic Areas*. The designers of the CDC smallpox/measles program, and D. A. Henderson in particular, opposed a heavily didactic approach that would attempt to formulate policies and prescribe actions in anticipation of field situations. Their operating philosophy was to allow for operational and tactical decisions to be made in the field, within the framework of overall strategic decisions made at headquarters.

This approach proved to be sound, and during the course of the campaign, each country evolved its own distinctive smallpox/measles program based on local realities. The manual written in 1966, however, served as an important resource for the training program and as a point of departure for concepts that were continuously modified in the quest for global smallpox eradication.

In the light of later events, it is interesting to note that during the training program the basic strategy of a mass vaccination campaign to interrupt the transmission of smallpox was never seriously questioned or debated. It was assumed that given an effective vaccine, a means of rapid mass vaccination, a technique to assure a high take rate, and an effective assessment method, the strategy would work in West Africa. Dr. William Foege, who was in Atlanta as a CDC contract employee to serve as a training consultant during the course, after a tour at a missionary hospital in Eastern Nigeria, had written in Nigeria in 1965:

> There is no substitute for adequate vaccination, and a mass vaccination campaign must be considered. The technical problems are well in hand and

> two people plus volunteer help can vaccinate 10,000 people in two days with 20 dollars worth of vaccine. However . . . execution of the plan must await more information and large amounts of organization.

Surveillance, the keystone of CDC-style epidemiology as developed and promoted by Alexander Langmuir and his disciples and colleagues, was given emphasis in both the first year's training course and the manual and still greater emphasis in the second year. It was anticipated, correctly, that whereas the need for vaccination would be accepted everywhere, the need for epidemiological surveillance and assessment would be little understood and often undervalued by most participating countries and especially by those influenced by French military medicine. Demonstration of the value of surveillance, and its subsequent widespread adoption in various disease control activities, was an important by-product of the eradication program.

The 1966 training course in Atlanta served as an opportunity to begin to build interagency cooperation. Drs. Hans Mayer and Ivan Ladnyi, WHO smallpox intercountry advisors stationed in Africa, spent several weeks in the sessions. Then, on August 31, 1966, the smallpox/measles staff received a telephone call from Dr. Marcolino Candau, Director-General of WHO. Speaking from Geneva, Dr. Candau said:

> The program which you are working to develop in the 19 African countries is a working model of the fully organized smallpox eradication campaign which we aim to launch on a much wider basis. It will constitute a major part of the entire global program, and, therefore, your task in ensuring its success is of critical importance. If not pioneers in time, you are at any rate pioneers as regards the size and potential importance of the program you are handling.

Participants viewing the training course in retrospect gave it generally high marks:

- "When comparing my Peace Corps training and the Smallpox/Measles Training, the Peace Corps approach was more general and more culturally oriented than technical. The CDC training was job-oriented. . . . The training was good for accomplishing the mission."

- "The extensive truck and ped-o-jet training was essential, since we did our own repairs. Nothing prepared us culturally for Chad, but we didn't have culture shock."

- One participant probably spoke for all his colleagues when he said: "The management, language, and mechanical training were very good, but we also developed a lasting *esprit de corps*. It was an exciting time."

Once the course was over, the trainees were ready to go. So were their young families, located in temporary housing in Atlanta. Unfortunately, the cliff-hanging was not yet over. In the wistful words of one CDC employee: "I guess we thought when the course was over we would back up a bus to CDC and send them off. It didn't work out that way."

One hindrance, already noted, was the slow progress of the Foreign Assistance Act through the Congress. The program agreements with the individual countries could not be signed until the appropriation was absolutely assured, even though most of them were ready to go and had gained the necessary acceptance in Africa.

A series of unforeseen technical problems arose that further complicated the launching of the program. One of these related to the choice of the measles vaccine. There were two contenders, produced by competing manufacturers. One was the Edmonston B-strain vaccine, which had been used by Harry Meyer in the Upper Volta program in 1961 and had been the vaccine of choice in the African programs during the intervening years. The other, more recently licensed, was based on the Schwarz strain. The latter had the advantage of producing less frequent and less severe reactions. It also, however, induced lower initial levels of antibody. Preliminary evidence indicated that the two vaccines conferred equal immunity, though some believed the effect of the Schwarz strain might not be as long-lasting.

Several West African countries requested the Edmonston B-strain vaccine, encouraged by a vigorous sales campaign by the manufacturer. Investigators in Nigeria and Senegal, among others, argued for the Schwarz strain on the basis that the higher fevers induced by the Edmonston B strain could be harmful in a population of children many of whom were already ill and undernourished. CDC staff preferred the Schwarz strain and felt strongly that it was highly desirable logistically to use only one vaccine for all countries. Ultimately, the Surgeon General of the PHS settled the issue in favor of the CDC position. However, the problem had not only cost time and energy but also had raised doubts in the minds of several U.S. and African officials that required patient explication.

Another unforeseen problem related to the licensure of smallpox vaccine for use in the jet injector. The responsible agency, the Division of Biologics Standards of NIH, had a standing principle that products intended for injection must be fully sterile. Vaccinia virus, as produced for many years for administration through the scratch of a needle, could not be rendered totally bacteria-free, although tests could assure that none of the remaining bacteria were pathogenic. Since the objection was based not on perceived risk but solely on principle, higher authorities in both the United States and WHO finally decided that, for purposes of this program, practical necessity would rule over principle. This hard-won resolution was welcomed with great relief by the program planners, who found it impossible to envision regionwide eradication, much less worldwide, without the use of the jet injector.

Procurement of vehicles and their spare parts was a problem which, though not responsible for delays in launching the program, had posed a stiff challenge. British or French vehicles that were in common use in West and Central Africa would have offered the best solution, especially since spare parts were widely

available and local mechanics were familiar with their maintenance needs. But AID procurement policies required the purchase of U.S.-made products, and CDC was unsuccessful in its attempt to secure a waiver.

It was decided that standard-model pickup trucks rather than custom-designed vehicles were preferable for reasons of cost, and Dodge trucks were competitively selected. Refrigerators needed to maintain measles vaccine at low temperatures were bolted to the bed of the trucks. The intensive automotive training provided at the Chrysler Corporation facility in Atlanta was the best available answer to the problem of maintenance and repair. In addition, spare parts had to be procured and stockpiled country by country, and the quantities had to be guessed at since no record had been compiled by any agency to provide guidance as to needs in African field conditions. As was to be expected, some of these guesses were better than others. But during the course of the campaign, the vehicles were improved, and the transportation system was strengthened.

Housing arrangements for the CDC teams and their families presented another continuing challenge. In some countries, where U.S. embassy and AID staff were sympathetic and cooperative, the problem was quickly resolved. In others it was not. It was particularly sticky in Nigeria, the site for the regional office, where the need was greatest and the resistance on the part of U.S. authorities the most obdurate. With housing for nearly half of the entire technical staff hanging in the balance, the program's administrative officer, Billy Griggs, traveled personally to Lagos, where his success in quickly locating highly satisfactory quarters was a source of considerable surprise and chagrin for the resident and resistant Americans.

This, however, was only one of the problems confronting the program at its outset in Nigeria. As we have seen, by virtue of its enormous size and strategic location at the crossroads of the region, Nigeria was the hinge upon which the success of the entire program would swing. Moreover, its Principal Medical Officer, Dr. Adeniji Ademola, was a leading health statesman of Anglophone West Africa and a powerful supporter of the program from the outset. Under his leadership, the country had developed its own smallpox eradication plan, which was compatible with the CDC strategy.

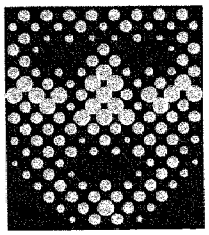
But the country was in turmoil. In January 1966 a military coup had overthrown the previous civilian authorities. Seven months later a second coup occurred, accompanied by extensive loss of life. The Ibo peoples of Eastern Nigeria were threatening to secede.

Not unnaturally in a country already in the throes of an impending civil war, the program agreement necessary to launch the smallpox eradication/measles control program was not high on the government's list of priorities. Dr. Ademola had endorsed it enthusiastically, but he could not obtain the approval of General Y. Gowan, the Supreme Commander and Chief of State, whose signature was

required. Efforts of the WHO country representative and the U.S. Ambassador were similarly unavailing.

Dr. George Lythcott flew to Lagos on a "brief visit" that was to extend for six frustrating weeks. Exercising his formidable diplomatic skills, and invoking Nigerian pride in regional leadership as his leading argument, Lythcott exhausted every conventional channel without succeeding in bringing the matter to General Gowan's attention. Finally, fate took a hand. Through the wife of a friend, Lythcott obtained an introduction to General Gowan's fiancée. She arranged an early-morning meeting with the General. Within half an hour Lythcott had his signature and was able to fly back to Atlanta that same evening.

The Nigerian program agreement was signed on October 6, 1966, and the big Nigerian contingent was at last on its way. By January 1, 1967, the long-proposed starting date, personnel, supplies, and equipment for the West African Smallpox Eradication/Measles Control Program were in place in most of the participating countries, with the others soon to follow. The prologue was over. The show was on the road.



3

VICTORY IN AFRICA

PLAN OF BATTLE

Beachhead and Minefields

In October 1966 the Centers for Disease Control (CDC) forces, consisting of some forty medical and operations officers and their families, began their departure for Africa. In Millar's words, written twenty years later:

> It was not an orderly embarkation; they left in abrupt jolts and starts over four months, in a pattern dictated by unsigned international agreements, unfinished housing arrangements, incomplete security clearances. . . . Forty families lived through an abundant expression of Murphy's Law.

Murphy's handiwork was evident on both sides of the Atlantic. For the forty families, fretting for weeks at an Atlanta motel with their household goods in storage and their minds set for the overseas adventure, each succeeding day of delay was a new frustration. Millar, just returned from his year of study in London, recalls this period in the autumn of 1966, dealing daily with these highly understandable frustrations, as the most painful part of the entire affair.

Meanwhile, the mills of international accord were grinding exceeding slow. Lythcott's diplomatic *tour de force* in getting the needed signatures on the

Nigerian program agreement was critical, but it was only one of sixteen agreements that were required. In the Francophone countries especially, it became evident that consent in principle to undertake a program of smallpox eradication/measles control was much more readily achieved than agreement on specific operational plans.

Dahomey and Niger would not sign the program agreements until they had full assurance from the World Health Organization (WHO) that funds would be provided for fuel and travel. Ivory Coast officials objected to the document's wording, which appeared to suggest that Ivory Coast had done nothing about smallpox before the new program began. Also, they did not want to be forced to use the jet injectors. Mali had some misgivings about the reporting requirements. Mauritania had concerns about its financial obligations. Almost everywhere ministries had to be prodded to complete negotiations, but after much cajoling agreements with these countries were eventually signed. By mid-December 1966 only The Gambia, Senegal, and Upper Volta remained unsigned among the countries scheduled to begin their programs in 1967.

The Gambia objected to the absence of a full-time person to run the program, an objection that was understandable historically in this tiny Anglophone country completely surrounded by Francophone Senegal, but one which could not be accommodated. In Senegal the program agreement got bogged down in the bureaucracy. In Upper Volta, Dr. Hubert Sansarricq, the head of the *Grandes Endemies*, was not endorsing the program because he was highly skeptical about the feasibility of eradication and felt strongly that smallpox should not receive the highest priority.

Finally, in March 1967, the last of these program agreements was signed, after laborious discussion, in Senegal—five full months after the October 1 target date. Dr. Thomas Drake, who had been sent on ahead of his family to expedite the process, experienced a hard initiation to a bureaucracy left over from French colonial days. He found the Ministry of Health so compartmentalized that he was serving as liaison between a "technical bureau" and an "administrative bureau." Senegalese economists, like some of their American counterparts, feared that decreasing child mortality without accompanying gains in economic development might be detrimental to the country as a whole. At last, with the intervention of the U.S. Ambassador and the forceful suggestion that resources earmarked for Senegal might be diverted elsewhere, the documents were signed. And at very long last, the Drake and Helmholz families were able to bid farewell to motel living in Atlanta and begin their assignment.

Reluctant and cumbersome bureaucracies constituted only one of a number of problems confronted by the "innocents abroad." The politics of the region posed another set of problems. Nigeria was on the brink of civil war. Mali and Guinea were politically anti-Western and suspicious of U.S. intentions. Mauritania was allying itself with the Arab world against what it viewed as a U.S.-Israeli conspiracy.

On a personal level, adequate housing was still a problem, particularly acute for a variety of reasons in Nigeria. The Lagos Regional Office itself was forced for a frustrating period to operate out of a staff member's apartment. The provincial governments of Nigeria had not arranged acceptable lodging for CDC personnel assigned to the Western and Northern Provinces, despite prior assurances. Supplies needed to launch the campaign were slow in coming. Worst of all in terms of morale, some personnel were not being paid correctly in the early days. These early months were times to try men's, and women's, souls. The cynical expression "WAWA," standing for "West Africa Wins Again," was ringing ominously true. Millar has confessed that at this stage even he "wondered if we had bit off more than we could digest."

Nevertheless, despite the sea of troubles of which the foregoing are only a sampling, the campaign actually began to roll at the very beginning of 1967, barely thirteen months after its formal approval had been announced. Many—including some of the strategists at CDC—had argued for a more gradual start, affording time for feasibility studies, field tests, and above all a more adequate initial understanding of the epidemiology of smallpox and measles in the West African region. Millar, on reviewing an early iteration of the master plan while on his study tour in London, had written to D. A. Henderson, then in Atlanta:

> There should be more to smallpox eradication than shooting vaccine under the skin. . . . I was disappointed in not finding it clearly spelling out that priorities based on epidemiologic appraisal must govern not only detail of execution but more importantly, the development of initial strategy.

But the argument to strike quickly and hard, championed most forcefully by Henderson himself, had won out. According to this view a number of factors had suddenly come together that, if allowed to cool, might never be kindled again. These included a global will to do the job as expressed by the World Health Assembly and institutionalized by the WHO Secretariat, a political and economic commitment expressed by the United States and supported by resource allocations, and the availability of the skilled manpower and appropriate technology necessary to get the job done.

Strategy and Flexibility

Accordingly, the plan of attack was based not on time-tested certainties but on best available assumptions. Some of these proved, in the event, not to be true. But flexibility was built into the program's operational style and consciously sought in the people recruited to carry it out. As a consequence, the program in action was highly responsive to midcourse corrections.

Appropriately, it was Millar himself who, as program director, was flexible enough to subsequently adopt and push through the major midcourse correction on the basis of field epidemiology that came to be known as Eradication Escalation (E^2). In retrospect, he has acknowledged: "The Smallpox Unit at times was too

scientific and academic. We would have waited until 1968 or 1969 to become operational. . . . We could have studied it to death."

By January 1967 the die had been cast. Millar had returned and resumed directorship of the program in Atlanta, now established as the Smallpox Eradication Program in the immediate office of CDC Director David J. Sencer. D. A. Henderson had gone to Geneva, at WHO's earnest entreaty and Surgeon General William H. Stewart's directive, to head up the WHO unit—a "temporary" assignment that was to last almost through the achievement of global eradication. Communication along this Atlanta-Geneva axis, with both principals born and bred in the CDC briar patch, was among the secrets of success of the enterprise. Without it, confusion could have been many times compounded.

The proposed strategy for the national programs as they got under way at the beginning of 1967 was strongly influenced by a successful campaign conducted in Bolivia by Dr. Harold Frederiksen. It called for vaccination of population groups at assembly points, following sessions with local civil authorities and tribal leaders to gain their support. The vaccination locations were selected to minimize the distance people would have to walk in order to participate, with eight kilometers considered a maximum. Vaccination teams generally consisted of five or six persons arriving in a single vehicle. The teams usually worked in three-week stretches, followed by seven- to ten-day rest periods.

The intent was to immunize everyone against smallpox and all children between the ages of six months and four years (originally six years) against measles. It was occasionally possible to vaccinate as many as 10,000 or more in a single day, but the going average ranged between 750 and 3,000 for smallpox, with only about one-fifth as many for measles. Urban areas required special planning, and in some instances spectacular success was achieved—some 750,000 people were vaccinated in Ibadan, Nigeria, during one ten-day period, by twelve teams assisted by volunteers from such diverse organizations as universities, churches, and the police.

To the greatest extent possible, ongoing assessment was built into the plan, although it was not uniformly achieved in the various countries. Small teams revisited villages about seven days after the vaccinations were done and examined a random sample of the population in an attempt to assure that coverage was adequate and most vaccinations were successful. By 1968 many of the countries were performing formal assessment surveys. Later in that year, special surveys covering broader areas in five countries were carried out under the direction of Dr. Ralph Henderson, Deputy Director of the Lagos Regional Office. The methodology used was later adapted and applied by WHO worldwide in assessing immunizations, nutrition status, and other health indicators.

Surveillance as a guiding principle distinguished the West Africa program from earlier smallpox vaccination efforts. As fostered by Langmuir, D. A. Henderson,

and their cohorts at CDC since the 1950s, it required routine, systematic collection of data; concurrent analysis and interpretation; and the prompt initiation of action to respond to the needs thus identified. Surveillance was an unfamiliar concept to most of the health personnel of the West African countries, and many, especially those brought up in the French colonial medical system, were slow to adopt it and reluctant, at the outset, to allocate to it the necessary resources. Yet, with a level of zero cases as the only acceptable goal, it became increasingly evident that vigorous surveillance was critically important to the success of the endeavor. Strategically, surveillance in most countries had been initially expected to play a subsidiary role to mass vaccination. But as the number of cases declined, surveillance and follow-up containment actions were indispensable in eliminating the remaining foci of infection.

Collaboration and Communication

If international and interagency coordination had been important and difficult in the planning stages, it became even more so as the program got under way. Relations between CDC and WHO's African Regional Office in Brazzaville were officially amicable but not productive. The two WHO technical advisors for smallpox in the region, assigned to Mali and Liberia, were severely restricted in their ability to travel, and in Mali during the early days there appeared to be two totally separate smallpox programs—the U.S. Agency for International Development (AID)/CDC's and the WHO advisor's. As has been noted, WHO did make a critical contribution by underwriting local costs at the request of some of the countries, but the processing of these requests was almost the only direct contribution of WHO's African Region to the twenty-country African effort in the early stages. Some WHO personnel participated in CDC training programs, and the agencies jointly sponsored a major conference in Lagos, Nigeria, in 1969. That these limited successes occurred at all was primarily due to the presence of D. A. Henderson, new on the ground in Geneva, and his clear-channel communication with Millar in Atlanta.

Collaboration with the two French-supported regional organizations, the *Organization de Coordination et de Coopération pour la Lutte contre Grandes Endemies* (OCCGE) and the *Organization de Coordination pour la Lutte contre Endemies d'Afrique Central* (OCEAC), steadily improved and became extremely useful despite certain basic differences in philosophy and approach. The directors of the two organizations helped resolve problems of implementation and intercountry communication between their member governments. OCEAC performed an indispensable service as intermediary between the program and the People's Republic of the Congo, a nation that had no diplomatic ties with the United States. Later, beginning in 1968, OCCGE was to play a similar role in Mauritania.

Ironically, some of the toughest and trickiest problems of collaboration arose between the two U.S. agencies—CDC and AID. As has been seen, several of the

AID missions were less than enthusiastic about the prospects for the program in its planning stages, and the arrival of the CDC personnel and their families played to a very mixed reception. Part of the problem stemmed from the two agencies' persisting difference of opinion as to relative priority between the two diseases, measles and smallpox.

Issues of supervision and control were also close to the heart of the matter. Understandably, many AID country directors and operations personnel assumed that the smallpox/measles program, like other AID-supported activities, was ultimately the responsibility of AID and that, therefore, personnel carrying out the project should be under the direct supervision of the AID missions. CDC personnel, on the other hand, went to the field assuming that their line of supervision traced back to CDC in Atlanta via the program's Lagos Regional Office and that their relationship with AID field staff was on a coequal basis. The point had never been clarified in the training sessions held during the summer of 1966.

Dr. Ralph Henderson, assuming his duties as Deputy Director of the Lagos office, ran into the problem in Chad, where it was particularly bothersome. In the words of this memorandum for the record, he found the AID Affairs Officer to be "extremely capable, young, aggressive (in the positive sense)" with four years of African experience. The AID man's first comments were "to the effect that CDC was really bungling in their effort to take over this program." Then, continues the Henderson memo, "with my usual 'cool' and diplomacy, I completely lost my temper and let fly a stream of imprecations." Happily, once the air was cleared, it was possible to settle operational problems "in a friendly and cooperative atmosphere" involving Henderson, the AID official, and the CDC team in Chad.

In late January 1967, Millar, Gelfand, and Griggs from CDC met in Washington with Dr. A. C. Curtis and other AID officials. This session drew up general guidelines and concluded, in Millar's words, that "in each country, satisfactory resolution will ultimately depend on a mutual understanding between the personalities involved." With the passage of time in the field, such understanding generally evolved, accompanied by a healthy respect and often warm friendships.

An additional set of coordination problems involved the three levels of CDC activity: headquarters, Lagos, and the field personnel. It was soon apparent that the original plan, placing line responsibility in the Regional Office with most communications flowing systematically through it in both directions, was impracticable. One reason was that although Lagos was the "hub" of West Africa in many ways, the wheel lacked a number of important spokes. Communication with the smaller Francophone countries was poor. Air travel and air freight in and out of Lagos were painfully slow and uncertain. Then, with the outbreak of full-scale civil war in Nigeria in 1967, the burden on an already

uncertain communications network became unbearable. Smallpox cables in the system of the U.S. State Department necessarily received low priority in competition with political cable traffic in and through Nigeria. Field personnel, unable to tolerate delays mounting to weeks in matters of immediate local urgency, began increasingly to communicate directly with Atlanta. Lythcott cited communications problems as the single most frustrating aspect of the program in the early months. Field personnel became more and more uncertain of "who was supposed to do what to whom."

Accordingly, the guiding principle of flexibility had to be invoked once again. The problems were discussed, strenuously and repeatedly, notably at the regional conference in Ghana in June 1967. Clear protocols were needed as confusion about communications channels continued to exist, sometimes with bruising effects on personal relations. The field personnel were compelled by circumstances to contact the office most likely to be quickly responsive, and Lagos and Atlanta strove mightily to reduce unnecessary duplication and wounded feelings to a minimum.

It was clear, however, that a substantial change was required, and it was made with the guidance and blessing of CDC Director Sencer. The new system was analogous to the domestic relationship between CDC and field assignees, with the Regional Office providing staff services and facilitation. By the end of the first year, the Lagos office was functioning effectively in contacts with national governments and in mounting special studies and assessments. Operational responsibility, logistics, and policy formulation were based in Atlanta. Information sharing became everyone's responsibility, with the result that new approaches and alternative methods found useful in one country were quickly available for adaptation or adoption as appropriate throughout the region.

MARCH TOWARD ZERO-POX

Regional Summary

The Smallpox Eradication Program in West and Central Africa was conceived and to a large extent executed as a coordinated regional effort. Indeed, it was understood from the start that the only goal worth achieving—eradication—could only be accomplished in that way.

At the same time, however, the regional program was made up of twenty individual national programs. Each country started at a different point of departure; proceeded at its own pace; had its own special needs, constraints, and resources; and in many cases posed its own unique problems. For this reason an overall account of the program on a strictly chronological basis would be difficult to follow and would run the risk of losing both technical detail and anecdotal enrichment. In this account, therefore, an attempt has been made to present a

quick overview of the regional program's progress and then to narrate the story country by country.

Measuring the success of the program in its simplest and most important terms, the incidence of smallpox in West and Central Africa was reduced from multiple thousands of cases per year at the beginning of 1967 to zero cases by June 1970. The last case of smallpox was identified in Nigeria in May of that year, and intensive surveillance for a long period thereafter confirmed the verdict. Thus, eradication was achieved in 3-1/2 of the allotted 5 years.

When the program began, based on 1966 estimates, at least seven of the twenty countries contained areas with a sustained high incidence of endemic smallpox—a rate of at least one case per 100,000 population per year. These seven were Dahomey, Guinea, Mali, Niger, Nigeria, Sierra Leone, and Togo. They were, indeed, among the most heavily infected countries in the world, several of them having rates in excess of those of such notorious smallpox strongholds as India and Bangladesh.

Most of the other countries of the region, though not meeting the standard of high endemicity, were experiencing frequent importations of smallpox across their borders. Several of these intercountry outbreaks will be described in the subsequent reports on national programs.

By January 1969 the list of countries with endemic smallpox had been reduced to five: Dahomey, Guinea, Nigeria, Sierra Leone, and Togo. Then Guinea became smallpox-free in February, and Sierra Leone and Togo in May 1969. Dahomey recorded its last case in September. Early in 1970 plans were under way to celebrate the ultimate triumph in Nigeria, but like the "false Armistice" that had sent millions cheering into the streets of Europe and America in October 1918, these were proved to be premature by the detection of a stubborn outbreak in March. Finally, in May, the celebration was legitimized, although months of intensive surveillance were required to make sure.

A grand total of 153.5 million smallpox vaccinations had been administered in the region by the end of 1972, a number considerably in excess of the total estimated population of the region at that time. During 1971 and 1972 emphasis was given to immunizing of children born since the initial mass campaigns and of those who had been missed. More than 28 million measles vaccinations were also performed during the course of the program.

In view of the formidable problems already discussed that confronted the program at its outset, plus others such as the political turmoil and armed conflict described in the country-by-country reports, it is genuinely remarkable that a ceremony observing the 25-millionth vaccination could be held in Ghana in January 1968, just over a year after the inception of the campaign. It was, by eye-witness acounts, quite an affair. Ghana was chosen as the site because U.S. Ambassador Franklin Williams, a long-time friend of George Lythcott, pledged

his embassy's full support of the event. James O. Lewis, the CDC operations officer in Ghana, found himself for the first time in his career worrying about such matters as who should sit next to whom and whose automobile should be given precedence. Fortunately, the embassy staff, more experienced in this line of work, was generous with its help.

The U.S. delegation was to include PHS Surgeon General William H. Stewart, CDC Director David J. Sencer, Program Director Millar, Dr. Benjamin Blood of the Surgeon General's international health staff, and Dr. George Lythcott from the Regional Office. Also on the guest list were most of the health ministers and other leaders from both Anglophone and Francophone countries in the region, plus a distinguished array of tribal chiefs from Ghana. Ambassador Williams told Sencer that this was an "eighteen-chief durbar," and he had never before seen more than a fifteen-chief durbar.

The site chosen was a soccer field at a location known as Mampong-Akwapim. Shelters had been erected to protect the dignitaries from the fierce African sun. On the appointed morning of January 15, Jim Lewis experienced some apprehensive moments because, as the international visitors arrived, there had been no signs of the Africans. Then, to the beat of a drum, the Paramount Chief appeared followed by lesser dignitaries and throngs of villagers. Many of the chiefs were resplendent in gold robes. Sencer recalls the chiefs walking across the dusty field, shaking hands, and presenting their calling cards.

The chiefs were ceremoniously vaccinated, and then a young schoolgirl named Rebecca Ansah Asamoah received the "official" 25-millionth vaccination. Appropriately and predictably, in Sencer's words, she "screamed bloody murder." The ceremony proceeded in a joyous atmosphere of music, dancing, and clouds of dust.

The observance was widely reported in the world press. Photos of it were used on African postage stamps. It provided the intended political boost for the program and also served the important purpose of strengthening regional solidarity. French General Pierre Richet, Secretary General of OCCGE, called in his speech for a crusade against smallpox in the spirit of the march across Africa in which he had participated with General LeClerc in World War II, prior to their reentry into France.

For the U.S. delegation the ceremony at Mampong-Akwapim was the beginning of a whirlwind African tour. The U.S. military attaché from Senegal had made a DC-3 available, and on the following day Stewart, Sencer, Millar, Blood, and Lythcott had breakfast in Abidjan, Ivory Coast; lunch at Monrovia, Liberia; and dinner at Freetown, Sierra Leone: all accompanied by the respective U.S. ambassadors and ministers of health. The next morning they proceeded to Bamako, the capital of Mali, and thence to Mopti, a provincial capital on the Niger River. There, in the company of the Minister of Health and the Governor of the province, they enjoyed a late breakfast featuring delicious local fish and excellent

Scotch whiskey. From Mopti they were driven to the homeland of the Dogon tribe, celebrated dancers and makers of masks, for a day, again to borrow Sencer's words, of "dancing and vaccinating" and a night of sleeping under the stars.

Surgeon General Stewart and Dr. Blood left the caravan and returned to the United States from the next port of call, Niamey in Niger, but Sencer, Millar, and Lythcott went on to Togo, to Dahomey, and eventually to Nigeria for a ceremony observing the 10-millionth vaccination in the Nigerian program, at which a local chief gave an erudite speech on the history of smallpox in Nigeria. Throughout the trip Sencer recalls being especially gratified by the skill and sensitivity with which the CDC personnel were handling the subtleties and complexities of partnership with their African hosts and counterparts.

Eradication Escalation—"E^2"

Administration of 25 million smallpox vaccinations in the first year testifies to the pace and intensity of the mass immunization campaign. Measurable results were beginning to show up. By the first quarter of 1968, the total number of reported cases in the region had declined by about one-third as compared with the first quarter median for the years 1960-1967. But enthusiasm was tempered by the certainty that many cases were going unreported, and the goal of zero-pox, absolute eradication, seemed far away. It was during 1968, in many ways the turning-point year, that the strategy of surveillance and containment, which came to be known at first as Eradication Escalation, or E^2, was introduced not to replace but to supplement mass vaccination.

The principal architect of E^2, Dr. William H. Foege, had served as an EIS officer in Colorado from 1962 to 1964. He then left CDC to become a medical missionary with the Lutheran Church and was in Eastern Nigeria in that capacity when the smallpox/measles program began in 1967. CDC's assignees to Eastern Nigeria, Dr. David M. Thompson and Mr. Paul R. Lichfield, worked closely with him until they were withdrawn, under harrowing circumstances, when civil war broke out and Eastern Nigeria sought to secede as the independent country of "Biafra." Foege remained behind briefly as an advisor to the "Biafran" government, which, remarkably, continued to pursue the smallpox/measles program despite the war. Later in 1967, the church evacuated the Foege family. Foege himself, unable to return to "Biafra" from a conference, first worked in Northern Nigeria and then joined the headquarters staff of the Smallpox Eradication Program in Atlanta at Millar's invitation.

Early in 1968 Foege proposed to Millar that he believed a change in strategy would enable them to "break the back of smallpox in 1968." The data, some of which came from elegant epidemiological studies conducted in Pakistan by Dr. Tom Mack and his colleagues, clearly showed that occurrence of smallpox reached a low point in October, at the end of the wet season. By launching an

all-out attack to search out, surround, and contain all outbreaks by intensive vaccination during this seasonal low point, the chains of transmission might be permanently severed. Preventing one case at that time of year was equivalent to preventing many more during the seasons when smallpox was much more prevalent.

This seasonality of occurrence was one of several factors suggesting that a surveillance-containment strategy could succeed. Another was the fact that cases of the disease were highly visible, readily detected by laymen. Its spread, especially in rural areas, was slower than expected, and cases were proving to be relatively easy to trace, especially by a field staff experienced in case tracing in venereal disease, the domestic U.S. program from which many operations officers had been recruited.

Millar was understandably reluctant to revise radically the strategy of mass vaccination which, by 1968, had gained great momentum and was showing positive results. But the E^2 concept was based on persuasive evidence that the epidemiology of smallpox was different in some ways from the assumptions on which the strategy had been built. Moreover, a surveillance-containment approach had been tried with success by Foege himself in Eastern Nigeria as a means of making maximum use of limited vaccine supplies. Millar, Foege, and Lane presented the idea to the regional meeting of Smallpox Eradication Program staff at Abidjan in May 1968. It initially received mixed reviews, being considered by some "another crackpot headquarters scheme." At least one medical officer, Dr. Donald Hopkins, agreed to give the idea a full-scale try. He had been assigned to start the program in Sierra Leone, one of three countries where programs were initiated during the second year. Sierra Leone, at the time the most heavily infected country in the region and the world, reached zero-pox within nine months. Eventually, all the countries in the region still experiencing endemic smallpox adopted E^2 as a major adjunct to mass vaccination. There is little doubt that the movement toward eradication was indeed escalated, and its attainment hastened.

Country Reports

The observance of the 25-millionth vaccination and the initiation of E^2, both of which occurred in 1968, have been taken out of chronological sequence because they were events of regionwide significance. Henceforth, this account proceeds country by country, grouping some of the smaller ones, and the attempt is made to present a consecutive story within each; however, in some cases, notably Nigeria, even this temptingly simple approach cannot be faithfully followed. Also, the twentieth and last country included in the program, Equatorial Guinea, is not discussed in this account. OCEAC provided supplies, equipment, and administrative and surveillance assistance to Equatorial Guinea, but neither CDC staff nor other U.S. personnel had a direct role in the eradication program there.

It must be further noted that the following are necessarily abbreviated and highlighted, and the availability of good anecdotal material, or lack thereof, may result in a skewed picture of the relative importance of the separate programs. Let it be established at the outset that each was indispensable to the achievement of the goal.

The narratives begin with Nigeria and then return to that huge, complex, war-torn country for the finale as the last case of smallpox in West and Central Africa was tracked down in 1970.

Nigeria

The signing of the Nigerian program agreement in October 1966 launched the program in a country whose 51 million people represented nearly half the population of the entire region. It was a country, moreover, that at that time was the location of more than 40 percent of the region's reported smallpox cases and the source of recurring reinfection of the countries on its borders. Administratively, the country was divided into four regions, each with considerable autonomy, plus a federal district at Lagos. Initial program operations were confined to two of the regions pending formal agreements with the other two.

In Eastern Nigeria on December 4, 1966, while Foege, Thompson, and Lichfield were preparing for a pilot program, they were notified by a missionary that a smallpox outbreak was occurring in Ogoja Province, near the northern border of the Eastern Region. The area was relatively sparsely settled. The last known smallpox epidemic there had occurred in 1950. In August 1966 a man who had been exposed in the North introduced the disease to the area. By November at least fifteen cases had developed.

The CDC team rode into a village in the Yache area on motor bikes to investigate. Very limited supplies of vaccine were on hand. Their first thought was to use what they had as a delaying action. Missionaries were asked to visit villages searching for smallpox cases, and some of them were taught to vaccinate, giving priority to villages and families that actually had smallpox. "In retrospect," Foege wrote, "we did a logical thing of surveillance and containment. We had no insight into what we were doing except getting vaccine into as many people as we could." In the final analysis, by the time adequate supplies were available, the outbreak was over. It had been contained.

This Ogoja episode foreshadowed many later events leading to the eventual success of E^2. Its significance was not immediately recognized, but many deem it to be an epidemiological benchmark and one of the most important turning points of the global eradication effort.

Meanwhile, a more substantial epidemic was building in Effrium, a farming area thirty miles north of the urban center of Abakaliki, near the border of Northern

Nigeria. The first case was reported during the week of December 10, 1966. Ten more were reported during the last week of the month, and the epidemic peaked five weeks later when 146 patients were admitted to isolation camps. By June 1967, when the epidemic was finally snuffed out, 754 cases had been recorded with 180 deaths.

Many things were learned from this experience. Chief among them was the need for a greatly improved and streamlined case-reporting system. For example, isolation camp records revealed that between January 1 and February 4, 1967, a total of 286 persons were admitted with smallpox; during that period not a single case was reported from Abakaliki to the Ministry of Health. Accordingly, the Eastern Nigerian authorities, working in concert with the CDC team, set up a new reporting system that bypassed several layers of the preexisting arrangement. As a result it was possible to plot outbreaks promptly on maps and direct the early vaccination efforts to where they were most urgently needed.

Once the African teams were trained in the use of ped-o-jets, they performed superbly, according to Lichfield, and competed vigorously among themselves to see who could set up the fastest and do the best job. When it was determined, using the new surveillance system, that most cases were occurring along the northern border of the Eastern Region, the pilot vaccination efforts moved swiftly. Studying the maps that revealed the steady flow southward, Foege postulated that if the outbreaks in the northern tier could be nipped in the bud, all subsequent outbreaks in the Eastern Region might well be prevented.

Political turmoil was steadily increasing. On May 30 the population of Eastern Nigeria, predominately members of the Ibo tribe, which had suffered bloody pogroms in the North, seceded from Nigeria to form the independent nation of "Biafra." Remarkably, although a "shooting war" broke out between the Nigerian and Biafran armies, the smallpox eradication effort continued on both sides. Vaccine was transferred from Nigerian to Biafran health authorities during cease-fires especially arranged for that purpose, and specimens from two suspected smallpox cases in Biafra were flown out to be evaluated in the Lagos laboratory. The common endeavor managed to transcend the war.

As the situation became increasingly volatile, the U.S. Department of State decided that all U.S. dependents should leave Eastern Nigeria. Paul Lichfield, at the airport in Port Harcourt on a blistering hot day to put his wife and two very young children on the plane, found himself marched the length of the airport at gunpoint and taken to a back room over a temper-flaring incident involving a locked suitcase. He was planted on a chair under the guard of a thirteen- or fourteen-year-old "soldier" with a huge M-1 gun, who had been told, "If he gets off the chair, shoot him." Time dragged by. Lichfield had visions of the plane's taking off without his wife and babies, who would then be forced to stay in Biafra. Finally, after one attempt to leave had made it clear to Lichfield that the boy-soldier had every intention of carrying out his orders, Bill Foege arrived with

a U.S. Embassy man and a Biafran officer. Apologies were exchanged, and the episode had a happy ending.

Subsequently, Lichfield, Foege, and Dr. Thompson left Biafra for a regional conference in Accra, Ghana, making their exit by canoe across the Niger River, and were not allowed to return. Foege himself later spent two days under armed guard. Being closed out of Biafra, he volunteered to work elsewhere in Nigeria. He had no sooner arrived in Sokoto Province, in Northern Nigeria near the border with Niger, when police arrested him, transported him back to the regional capital of Kaduna under guard, and interrogated him intensively about his work in the Eastern Region. He was released on condition that he return immediately to Lagos. Foege later pointed out wryly that this experience refuted for all time the myth that it was difficult to locate a person in the rural North.

During the Biafran War there was great concern that smallpox might be transmitted unchecked through that war-torn society. This did not happen, although the region suffered savagely from famine and severe measles epidemics. As soon as conditions permitted, epidemiologists searched diligently for signs of smallpox on both sides of the frontier. None were found, either among the residents or the refugees. In retrospect, it was evident that the intensive vaccination program around Enugu had eliminated the last focus of smallpox in Eastern Nigeria, and the tight federal noose around the region prevented the seasonal importations of cases from the North.

By early May 1967 the mass immunization campaign was under way in the Federal District of Lagos. On May 10 a Lagos housewife was the millionth person to be vaccinated. Finding that the urban residents were not as likely as their rural counterparts to travel to where vaccinations were being given, roving vaccination teams roamed the streets of Lagos neighborhoods to seek out the unvaccinated.

In the Western Region, the regional capital city of Ibadan was the site of a spectacular accomplishment. In July 1967 in ten working days, 757,308 smallpox vaccinations and 69,068 measles immunizations were given by twelve vaccination teams, using sixty ped-o-jets and fifteen trucks. This virtuoso performance was made possible by a mammoth publicity campaign using posters and mass media, promotion in local churches, and close cooperation with the University of Ibadan, voluntary agencies, and the local police, who helped out with crowd control.

Elsewhere in the West, the village of Shaki, near the border with Dahomey, was found to be involved in cases affecting four countries. A two-year-old girl from Shaki was diagnosed in Upper Volta as having smallpox. In Shaki itself, one person had become ill with smallpox upon returning from Ghana, and another case occurred in a man from Dahomey. Meanwhile, Dr. David B. Melchinger and Mr. Jim Lewis of the CDC Ghana team reported that an outbreak in Salari, Ghana, had originated in Shaki. Dr. Ralph Henderson commented, "This makes

a merry little cycle of reimportation. No wonder everyone claims to get their smallpox from everyone else." No stronger case could be made for the necessity of the all-out regional approach.

Almost 57,000 vaccinations were given in the town and district of Shaki in a mass campaign organized by Dr. Margaret E. Grigsby and Mr. Lloyd W. Wade of the Western Nigerian team. These were among the 9.5 million immunizations performed in Nigeria by the end of 1967.

Vaccination activities in the Western Region did not benefit from the strong leadership of tribal chieftains because, unlike the emirs in the predominantly Moslem Northern Region, the Yoruba chiefs lacked the power and prestige to command total compliance among their more individualistic tribesmen. As a result, turnouts at vaccination sites were often disappointing. Resistance to vaccination was encountered because of worship of a local god of smallpox, described in detail in the section on Dahomey and Togo. Moreover, local health officials in this area tended to give low priority to surveillance and follow-up. The Western Province continued to record cases until 1970, and the area remained a difficult challenge for eradication.

Nigeria's Mid-West Region was a war zone. Benin City was captured by the Biafrans and then retaken by federal troops. At the outbreak of the war, Ibo members of the Mid-West Region vaccination teams had fled to the East to join their kinsmen in Biafra, taking supplies and equipment with them.

There were cultural problems as well. Dr. Stanley Foster, senior advisor to the national program, visited the Mid-West in January 1968 and found numerous reasons for the low levels of participation. Some persons avoided vaccination because they suspected it was part of a plot to tax them. Others refused vaccination on religious grounds or because they feared that the fever caused by vaccination would prevent them from working during the planting season. Household gods were invoked as a reason to refuse vaccination. In general, the campaign suffered from a lack of strong leadership by local chiefs, some of whom had not been adequately consulted, and from a very limited health education effort. Despite all these problems, however, and the persistent fear that civil strife would reintroduce the disease, only one case of smallpox was reported in the Mid-West in 1968 and that proved to be the last confirmed case in the region.

Contingency plans had been drawn up in case the Biafran army mounted a successful push on Lagos. This situation never materialized, but the Regional Office did have one brief, sudden exposure to the "hot war." One night in October 1967, a modified Fokker Friendship aircraft, which belonged to the Nigerian Air Force and had been hijacked by Biafran sympathizers, made an abortive bombing run on Lagos, apparently aiming for the Dodan Barracks, which housed the Nigerian Military Government Headquarters and the residence of the Commander in Chief, General Gowan. Curiously, Dr. Stan Foster

had used the same plane a few days before for a trip to Benin. On the night of the air raid, the plane dropped a couple of bombs, which appeared to be homemade items akin to Molotov cocktails, and then exploded in midair. The force of the explosion, at 1:30 A.M., shattered the windows of the Regional Office and two apartments occupied by staff members. One person was struck by flying glass but was saved from injury by a heavy robe. It was subsequently reported that the remains of five "white mercenaries" and four Africans were recovered from the wreckage of the plane.

The Northern Region was the major battleground for the war against smallpox in Nigeria. Vast in area and characterized by a poor road network, limited communication, and a large population, the region was the homeland of the Hausa tribesmen, who were famous as traders and travelers throughout Africa. As has been noted, the North was the source for repeated exportation of smallpox cases into other parts of Nigeria and neighboring countries as well.

From the viewpoint of the smallpox eradication forces, however, the North was blessed with a social system that made very high levels of vaccination coverage easy to attain. Moslem leaders known as emirs wielded enormous autocratic power over many of the people. The British, recognizing the strength of this traditional tribal leadership, had ruled this region during Nigeria's colonial times indirectly, by means of a system of native authority that was far stronger than their usual civil authority. Thus, as Foege observed, whereas in the rest of Nigeria a health education program had to convince everyone of the need to be vaccinated, in the North it had only to convince the emirs.

Mass vaccination in Northern Nigeria began in Sokoto Province in July 1967. The emir himself received the first ceremonial immunization. Then twenty-four teams started in the northeastern corner and moved systematically westward. The native authorities selected vaccination sites and notified village headmen two days in advance. The emir provided additional incentive by declaring that anyone not vaccinated was subject to a five-pound fine. Not to be outdone, the emir of neighboring Katsina upped the fine to ten pounds.

On the first morning Stan Foster was in Sokoto, he was astonished to find 6,000 people in line at the vaccination site at 6:00 A.M. For religious reasons, men and women were vaccinated separately; after receiving their injection, the men would go home and bring the women. Assessment teams, following the vaccinators at seven- to fourteen-day intervals, found coverage rates above 95 percent in Sokoto Province. When these figures were relayed back to Atlanta, they were viewed with great skepticism. Dr. Mike Lane recalls, "We were sure they were doing it wrong or fudging the data." It was the first time CDC had met the awesome power of absolute traditional rule.

Regardless, smallpox in the North did not surrender easily. Some of the smaller emirates were less enthusiastic or at any rate less successful in turning out their

people. Moreover, some groups, notably the nomadic herdsmen known as the "Cow Fulani," were outside the sway of the emirs. They and their fellow tribesmen, the sedentary Fulani, constituted pockets of susceptible persons.

The Kolgo District of Sokoto Province was vaccinated in November 1967 with an assessed coverage rate of 96.9 percent. But Gerere Hamlet in that district, made up of Fulani farmers and herders, was located eight miles from the nearest vaccination site, and only 7 of its 203 inhabitants made the long walk to be immunized. In January 1968 the five-year-old daughter of a herder contracted the disease while returning from an area where smallpox was still endemic. This began an outbreak of sixty-two cases that lasted until April, when the hamlet was vaccinated with freeze-dried vaccine.

This outbreak further confirmed the growing conviction that, contrary to previous assumptions, smallpox in Africa was a disease of relatively low communicability that could sustain itself for many months in small enclaves of susceptible persons, even in areas where general immunity levels were very high. It also served to demonstrate that the program in Northern Nigeria needed reinforcements. Three additional CDC personnel were assigned to the region, logistical support was strengthened, the reporting system was overhauled in conjunction with local health authorities, and a series of EIS officers from CDC were brought in for sixty-day assignments.

By late 1968 Kano, the ancient trading center of Northern Nigeria, was the only remaining urban area in that region with endemic smallpox. Kano's estimated population of 300,000 was marked by a high degree of transiency, consisting largely of laborers in search of work. On a single day 27,183 persons were counted entering the city on four main highways, and 21,686 were observed leaving. It was evident that rural areas were continuously reseeding Kano with smallpox. To deal with this problem, early in 1969 road blocks were set up on five main roads, and in twelve days over 60,000 previously unvaccinated people were immunized. By the end of March 1969, smallpox had been eliminated in Kano State.

Between March and July 1969, only five to sixteen cases were recorded each month for all of Nigeria. After July no further cases were reported in Nigeria for the remainder of 1969, although an average of ten rumored cases were investigated each month. As 1970 dawned, victory in West Africa's largest and most complex national campaign seemed at hand. The elusive tenacious virus had a few surprises left, however, as will be seen when Nigeria is revisited at the end of this chapter.

Ghana

Ghana, the second most populous nation of West Africa, with a population of 8.1 million at the time, had been the first of Britain's West African colonies to

attain independence. Its first president, Kwame Nkrumah, had been overthrown by a military coup in February 1966, not long before the launching of the program, and it was considered a particularly important country in terms of U.S. foreign policy. Initially, the program had been welcomed in Ghana more for its measles than for its smallpox component. The country held special significance for Dr. Lythcott, who had worked there for four years in the NIH West African Research Laboratories and who had been a friend since boyhood of the U.S. Ambassador, Mr. Franklin Williams.

In comparison with most of West Africa, Ghana was blessed with one of the best organized health services, under the direction of Dr. Frank Grant, and a good network of all-weather roads. One of two such Anglophone countries in West Africa, Ghana had had active mobile teams in colonial times under the direction of Dr. B. B. Waddy, an Englishman who admired the work of the French General Jamot. A far-better-than-average disease reporting system was in place, and between 500,000 and 1 million persons were being vaccinated with British-made smallpox vaccine each year at hospitals, at health centers, and by mobile teams in rural areas.

As a consequence of these vaccinations and prompt attention to outbreaks, no more than 251 cases of smallpox had been reported in any single year since 1953, at a time when many far less populous countries of the region were regularly recording more than 1,000 cases. Like Nigeria, on a much smaller scale, however, Ghana was of special importance because, in the words of operations officer James O. Lewis, "Ghana seemed like one big bus station for West Africa," with a steady flow of travelers and migratory workers.

The smallpox/measles program was launched in Accra, the capital city, in February 1967, in conjunction with a trade fair that brought exhibitors from thirty-two countries. A vaccination team gave 105,000 smallpox and 8,000 measles immunizations at a special exhibition booth. Among those vaccinated were Lieutenant General J. A. Ankrah, the Ghanaian Head of State, and other political and traditional leaders.

While this activity was going on, cases of smallpox were reported in the Newtown section of Accra beginning on February 8. Within hours vaccination teams were at the site. Road blocks were set up, and anyone entering or leaving the area was vaccinated. A total of about 9,000 people were vaccinated immediately after the first case was discovered. The outbreak and the swift response helped to convince Dr. Grant and his colleagues of the importance and capability of the Smallpox Eradication Program.

As cases continued to occur in the crowded slum districts of Accra—a total of some eighteen cases between February and May—Grant made the decision to vaccinate the city. Twenty ped-o-jets were hand-carried on loan from Lagos by Dr. Stan Foster, who returned with smallpox scabs for testing in the Lagos

laboratory. The scabs were covered with calamine lotion—an interesting flashback to the celebrated "smallpox case" imported from Ghana to Washington, D.C., in 1965.

At the outset of the program, Dr. Bernard Challenor was medical officer for Dahomey and Togo and was serving in Ghana as well because of the delayed arrival of the Ghana assignee. His request for medical help, relayed by Lythcott to CDC, brought the first two of many EIS officers who were to come to West Africa on temporary duty to take part in the eradication activities.

During the first half of 1967, there were outbreaks in four communities outside Accra. As a result outbreak control took precedence over mass vaccination. Then in mid-September, immediately after the arrival of Dr. David B. Melchinger as medical officer, an outbreak at Bawku in the Upper Region of Ghana was fought by a combination of selective containment and mass vaccination at markets on major roads. The last case in the area was reported on November 4. Meanwhile, on October 9, a smallpox death had been reported in the port city of Takoradi, far to the south. Again, containment and mass vaccination were used.

In 1967 Ghana recorded a total of seventeen outbreaks with 114 cases. During 1968, 24 cases were reported in six outbreaks, all of them traceable to importations from Togo. With Ghana now free of endemic smallpox, the national mass vaccination effort proceeded slowly but steadily and was completed in 1970.

Ivory Coast and Liberia

The two countries west of Ghana along the coast of the Gulf of Guinea, Ivory Coast and Liberia, were essentially smallpox-free when the program began, except for occasional importation. Ivory Coast had carried out a successful mass vaccination program of its own. Liberia had been assisted by the support of a private voluntary organization.

In Ivory Coast, a comparatively prosperous country with a population in 1967 of about 4 million, as many as 4,656 cases of smallpox had been recorded in 1961. In that year a national mass vaccination program was initiated under the highly competent direction of a Frenchman, Medicin-Colonel Gaston Binson of the Institut d'Hygiene in the capital city of Abidjan. In the next three years, 3.6 million persons were vaccinated with a French freeze-dried vaccine, and many more in a follow-up campaign. Incidence of the disease fell swiftly to only twenty-seven reported cases in 1965 and ten cases in 1966.

Colonel Binson was confident as the West and Central African program began that the only smallpox threat to his country came from outside, from four contiguous countries where the disease was still endemic. That threat materialized in February 1967 when a Peul tribesman from Upper Volta infected a fellow passenger on a bus while traveling to his native village in Ivory Coast. Two

secondary cases developed at the hospital to which the Peul traveler was taken. When these cases were reported to Abidjan, Colonel Binson was certain that they could not be smallpox, but he allowed CDC operations officer Robert C. Hogan to investigate. Hogan felt that the symptoms were compatible with smallpox and sent material to the laboratory for confirmation. The colonel never officially reported the cases, but two visitors to one of the Ivory Coast patients subsequently returned ill to their home in Upper Volta, where an outbreak occurred and spread through several villages.

With the offer of U.S. assistance, Ivory Coast did conduct an additional national vaccination program, combining it in the later stages with the measles immunization program, which had originally been separate. No further cases of smallpox occurred to sully Colonel Binson's and Ivory Coast's distinguished record.

Liberia, with a population of 1.4 million, had reported more than 1,100 cases of smallpox in 1961. The following year a religious organization known as Brother's Brother undertook a mass vaccination program, chiefly in the more accessible and populous areas. Some 775,0000 vaccinations were reported to have been given in a five-month period. Because of lack of supplies, a highly diluted vaccine was used. In 1963 WHO assisted Liberia in a more systematic effort using an undiluted vaccine. Although the program's progress was slow, incidence of smallpox declined to only forty reported cases in 1965, thirty-two cases in 1966, and six in 1967.

Liberia was one of the three countries in which the CDC program began a year later. This latest mass vaccination effort also progressed slowly, but only five cases were recorded in 1968 and none thereafter.

Senegal, The Gambia, and Mauritania

The three countries forming the northwestern extremity of the West African Region reported no cases of smallpox after the launching of the program in 1967. The last cases recorded in the area had been a localized cluster of seventy-six cases in Mauritania in 1966; however, since none of these were ever confirmed by a physician and there was no recurrence, it is possible that they may not have been smallpox cases at all—chickenpox would seem a more probable diagnosis in retrospect.

In Senegal in 1967 the *Service des Grandes Endemies* (SGE), consisting of nearly 300 personnel working through well-organized mobile prevention teams, had been providing good services for a number of years. About 20 percent of the population was being vaccinated each year with French-made freeze-dried smallpox vaccine of good quality. With the advent of the U.S.-supported program, it was decided to use the new supplies and equipment to strengthen the preexisting program, whose mobile teams were scheduled to visit each village about once every three years. From 1967 to 1969, 2.6 million smallpox vaccinations were given, and no cases of the disease were discovered.

The Gambia, a tiny country only 16 kilometers wide and 320 kilometers long along the Gambia River, is completely surrounded by Senegal, except for a narrow coastline bordering the Atlantic Ocean. It had a population of about 330,000 in 1967, with unrestricted movement across the long border with Senegal. The country had performed mass vaccinations against smallpox only once, in 1963 following an outbreak of fifty-two cases. The effectiveness of the vaccine used in that program was questionable since it had required refrigeration, which was not uniformly provided.

The CDC-assisted program, begun in June 1967, completed a countrywide mass vaccination effort in ten months, administering 350,000 smallpox vaccinations and 81,000 measles immunizations. No cases of smallpox were discovered after the program began. In addition, The Gambia had the distinction, unique worldwide at that time, of completely interrupting indigenous measles transmission for more than two years.

The Gambian field supervisor, a very bright and energetic public health worker named Mr. Kebba A.M. Sanneh, attributed the success of the program to a number of factors, including thorough training of the three vaccination teams, careful scheduling and attention to advance publicity, strong support of the teams by headquarters staff, and thoughtful attention to local customs. As an example of the latter, when local ceremonies required it, boys were vaccinated "in the bush," and the girls privately in a compound. Mr. Sanneh expressed special appreciation for the support of the CDC team of Dr. Thomas Drake and Mr. Robert C. Helmholz, who were based in Dakar, Senegal, and for their willingness to share the hardships of living conditions in the field.

Mauritania presented a very different set of challenges. The country is vast and largely desert, and its population of 1.1 million was widely dispersed and predominantly nomadic. Its SGE was made up of seven mobile teams of five members each, but after 1962 most senior staff had left Mauritania, and preventive activities subsequently diminished drastically. With the provision of U.S. assistance, the intent was expressed to rebuild the SGE and include smallpox and measles vaccinations among its responsibilities.

Mauritania quickly proved, however, to be the most politically difficult of the all countries of the region. The Islamic Republic of Mauritania aspired to full membership in the Arab League. To demonstrate its solidarity with the Arab cause, the Mauritanian government severed its relationships with the United States and expelled all American officials at the outbreak of the Six-Day War between Egypt and Israel in June 1967.

Prior to that time Mr. Thomas A. Leonard, the CDC operations officer, had been wrestling with logistical problems occasioned by the country's geography and nonexistent infrastructure. The vehicles needed for the program had been offloaded at the wrong port and had to be shipped by rail and driven across 300

brutal miles to the capital of Nouakchott, where they finally arrived in predictably dire condition. Everything that could leak, leaked, and everything that could fall off, fell off. The cold chain essential for measles immunization seemed impossible to maintain.

Leonard remained optimistic, however. He wrote to the Regional Office: "Other vaccinating programs . . . have managed to beat the opposition presented by geography, climate, and communications. Given time and some tricks, I feel we can too."

Alas, he was not given time. At his first field project, in the remote desert town of Nema 600 miles from the capital, he was aroused from the obligatory noonday rest by an armed soldier, who informed him that all Americans were to leave the country in twenty-four hours. Located where he was, this was flatly impossible. Two days later he was flown under guard to Nouakchott and thence, thanks to the intervention of French pilots he had befriended, to Dakar, Senegal, in a private plane. He arrived in Dakar with no money, no passport, and worst of all, no idea of what had happened to his wife and three young children. Happily, they arrived safely in an automobile convoy that had been hastily formed by other U.S. personnel in the Mauritanian capital. Lythcott said later that the long period with no news of the fate of the Leonards was the most anxious time he spent as regional director. The U.S. Ambassador to Mauritania, Mr. Geoffrey Lewis, wrote to express his admiration for "the courage both Leonards displayed."

After this unceremonious U.S. eviction, WHO eventually picked up the Mauritanian program using, by agreement, U.S. vaccines and equipment. Dr. Hans Mayer, WHO intercountry smallpox advisor for Western Africa, moved from Liberia to Mauritania in May 1968, and after seven months' preparation, the program began in January 1969. Some 426,000 smallpox vaccinations were given in that year. However, no cases of smallpox were detected in Mauritania after 1966.

Mali

Bordering Mauritania to the east and south along a frontier of more than 1,000 miles is the sprawling landlocked country of Mali. Mali's populaton of 4.7 million in 1967 was almost entirely concentrated in its southern half, in the savannah pasture lands below the Sahara in the semi-desert Sahel. A self-proclaimed Marxist state with strong ties to the USSR and the People's Republic of China, Mali was expected at the outset of the program to be the most difficult of all the countries of the region in which to develop effective working relationships.

So at first it proved to be. Dr. Pascal J. Imperato and Mr. Jay S. Friedman, the assigned medical and operations officers, found themselves frustrated by rigid travel restrictions, whereby any trips outside the capital city of Bamako required long advance approval, and by endless quibbling over the terms of the project agreement. The director of Mali's SGE, which since 1962 had not been receiv-

ing support from France and was in some disarray, refused to report smallpox cases to Dr. Imperato, informing instead Dr. Jeri Nedvidek, the WHO advisor who had been assigned to the country in 1965. For a time it appeared that there were two totally separate and competing smallpox programs in Mali.

A national smallpox vaccination program had been under way since 1962, with some WHO assistance beginning in 1964, but its progress was painfully slow. In fact, a WHO assessment team in 1965 had described the prospects of eradication as "bleak." Reported cases were declining, however, from a level of 1,521 in 1962 to 281 in 1966. With the availability of U.S. assistance, it was decided to reconstitute eight mobile teams that would include smallpox and measles vaccination among their responsibilities. But procedural, operational, and political problems seemed insuperable.

At this point the AID mission director notified a high-ranking Malian official that Dr. Lythcott was coming to assess the program and that serious consideration was being given to pulling the program out. The President of the country, Mr. Modibo Keita, becoming aware of the problem and recognizing the political as well as public health value of a successful mass immunization campaign, issued directives. The travel restrictions and other harassments mysteriously disappeared.

Imperato and Friedman began investigating outbreaks in April 1967 in southeastern Mali. They found that smallpox in that area was primarily a pediatric disease, that the reporting system was woefully inadequate, and that the disease smoldered and spread slowly even where no containment action had been taken and immunity levels were low. One outbreak of four months' duration recorded a total of only seventy-one cases.

As the program proceeded it became evident that the hinterlands of Mali contained a fascinating tapestry of tribal and cultural threads. There were the Tuareg, a nomadic people known for their fierce independence and rigid caste system in which the blacksmiths, very low in the caste structure, were known to practice variolation using acacia thorns as a defense against smallpox. There were the Minianka, fetish worshippers held in contempt by their Moslem neighbors; the Dogon, famous for their unique art style, who lived in rugged country often inaccessible to vehicles, traditionally shunned vaccination, and would hide in rocky aeries whenever strangers appeared; the Bosso fishermen, who plied their trade along the banks of the Niger and Bani rivers and often were reachable only by boat; and the Peul herdsmen, constantly on the move, avoiding roads and villages except to sell cattle or milk.

Designing and executing a strategy to vaccinate all these groups was an organizational and logistical challenge of the first order. Imperato and Friedman collected information from fishing cooperatives, from anthropological studies of the Dogon, and from veterinary specialists who helped control rinderpest in cattle and whom the Peul trusted. In the villages of the sedentary population, they sought and received cooperation from the political party workers.

Once begun, the vaccination program in Mali moved swiftly to a successful conclusion. More than 500,000 vaccinations were performed in a two-month period beginning in October 1967 in the east-central area. Only 392 cases were discovered in 1967, far less than expected, and nearly half of these occurred in a cluster of five tiny villages with an aggregate population of 3,700. Following the mass campaign in the smallpox-endemic border areas, two further outbreaks were found, with a total of forty cases, in March 1968. When no further cases were found or reported anywhere in the country for the next six months, it appeared that Mali had achieved eradication, although many people remained to be vaccinated.

But in November 1968, in a two-country collaborative search to track down the source of an Upper Volta outbreak that appeared to have originated in Mali, clear evidence was found of an epidemic that evidently had been smoldering in a very remote area—ten kilometers from the nearest road—since late 1967. Pockmarks indicative of recent smallpox were found on sixty-five persons, the last of whom had become ill a month before the team's arrival. After this episode only one further case was recorded in Mali, and this one, in a member of a migrant tribal group, appeared to have been contracted in Niger. In fact, throughout the period, some three-fourths of all the smallpox cases encountered in Mali had originated with the nomadic Tuaregs and Peuls.

Upper Volta and Niger

Eastward from Mali are two other large landlocked countries, Upper Volta (now known as Burkina Faso) and Niger. Upper Volta, the smaller of the two in area, had a 1967 population of 5.1 million fairly evenly dispersed through its territory. Niger, like Mali containing vast desert and semi-desert regions in the North, had 90 percent of its population of 3.7 million concentrated near its southern border in a narrow belt along the Niger River. Also like Mali, Niger had substantial numbers of pastoral nomads who traveled great distances during the dry season. Most of Upper Volta's inhabitants were farmers living in small villages.

Upper Volta, as has been noted earlier, was the headquarters of the regional health organization, OCCGE, and had been the site of a major measles campaign in the early 1960s. Its SGE, directed by a French military medical officer, was among the most efficient in West Africa. The country had conducted a national smallpox vaccination campaign in 1962. Disease surveillance and assessment of coverage were not practiced, however, and were thought by some officials to be unnecessary, a point of contention as the CDC team of Dr. Christopher D'Amanda and Mr. William J. White, Jr., began its work in April of 1967.

Recorded cases of smallpox in Upper Volta had been brought down from 1,550 in 1962 to a low of 8 in 1964 and then had risen again to a level of 69 in 1966. But as D'Amanda and White began to carry out vigorous surveillance activities,

the number of discovered cases rose to 195 in 1967. As the campaign progressed, the number declined to 100 in 1968 and reached "zero-pox" in 1969. Most of the cases in 1967 occurred along a north-south travel route used by pastoral nomads. In 1968, however, all 100 cases were found in villages near the borders with Mali and Niger.

Because the SGE of Upper Volta gave low priority to outbreak investigation, D'Amanda and White "saddled up their Dodge trucks and were on their way" whenever a report came in. This rapid response stimulated the reporting and surveillance system, which, combined with the mass vaccination efforts in the hands of the multipurpose teams, achieved eradication by the end of 1968. The last outbreak recorded in Upper Volta occurred in October of that year in a small village near the border with Mali, from whence the first case had come. Vaccination of this and neighboring villages snuffed it out.

Niger presented a more formidable problem. Unlike Mali and Upper Volta, its national vaccination campaigns of the early 1960s had not significantly reduced the occurrence of the disease. The level of 1,023 cases reported in 1966 was almost identical to that in 1962. Part of the problem was due to proximity to the areas of Northern Nigeria with high levels of endemic smallpox, and part, probably, to the use of vaccines rendered ineffective by improper storage.

The CDC-assisted program, directed by Dr. Donald J. Moore and Mr. Anthony R. Masso, started rapidly. By the end of 1967, some 43 percent of the population, a total of 1.6 million people, had been vaccinated. Of special concern to Moore and Masso and to the Niger program staff were an estimated 530,000 nomads, whose travels made them likely vehicles for disease transmission. A major effort was made to reach 150,000 of them who gathered each year in a pasturage 600 kilometers from Niamey, the country's capital city. But heavy rains made the roads virtually impassable. Elsewhere, savage sandstorms tore up tents and equipment, and the nomads tried to evade the vaccination teams for fear they were tax collectors in disguise. All these factors combined to render this well-conceived strategy difficult to execute.

Variolation, practiced by the Tuaregs as a means of protection wherever smallpox was endemic, seemed instead to be a factor in maintaining the endemicity of the disease. Moore wrote that he "could detect no clinical difference between smallpox acquired by variolation and that acquired by contact." At Moore's urging, local governmental officials ordered that variolation be stopped, but, in fact, only the eradication of smallpox could eliminate variolation completely.

Masso and Dr. Mike Lane, visiting Niger from CDC's Atlanta headquarters, traveled for two days along brutal roads to track down one reported outbreak. They finally located an encampment where a group of thirteen forlorn people had been left behind by a clan of Peul herdsmen until they were free of smallpox. Two infants and three adults had variolation scars. At least five of the children

evidently had recently had smallpox. Lane was astonished that such a small, totally isolated group could sustain a smallpox outbreak for an extended time, contrary to all prior assumptions about the behavior of the disease.

Meanwhile, the mass campaign administered another 1.2 million vaccinations in its second year in Niger, and an additional 936,000 in 1969. Smallpox incidence declined sharply in the second half of 1968 and did not increase again. A total of twenty-eight cases were recorded in 1969, but all were believed to be the result of importations from Nigeria.

The OCEAC Countries

The vast area known until 1960 as French Equatorial Africa now comprises five countries: Chad, Central African Republic, People's Republic of the Congo, Cameroon, and Gabon. These nations, all members of the OCEAC regional health organization, constituted the eastern tier of the West and Central African Smallpox Eradication/Measles Control Program, bordered on the north by Libya, on the east by the Sudan, on the south by Zaire, and on the west by Niger, Nigeria, and the Atlantic Ocean.

Coordinated by OCEAC, which was then directed by Medecin-Colonel René Labusquière, each of the five countries had a well-established SGE with efficient multipurpose mobile teams whose numerous responsibilities included smallpox vaccinations. Using freeze-dried vaccine produced in France, the five countries had reduced smallpox incidence dramatically in the early 1960s, and only two cases, both in Cameroon, were reported in the entire area in 1966. With intensive surveillance, more than 200 cases came to light in 1967, 119 in Cameroon and 86 in Chad. The last occurrences of the disease in the OCEAC area were three cases recorded in Cameroon in 1969.

The operational philosophies of OCEAC, deeply rooted in the French military tradition, conflicted with those of CDC in two fundamental ways. First, the CDC plan called for the formation of special mass vaccination teams to move swiftly through the countries, whereas OCEAC wished to place full reliance on their prospection teams. Second, OCEAC saw little need for the assessment and surveillance activities that ranked high among CDC's priorities. In practice, the mass vaccination activities were largely conducted by the SGE teams, strengthened by the addition of U.S.-provided materials and equipment, while the CDC advisors working with local officials generally took the initiative in investigating suspected cases.

People living in the rugged Mandara Mountains of northern Cameroon were subject to continuous reinfection from northern Nigeria. The Kirdi tribe, known to the French as the montagnards, lived in small, widely scattered settlements. They crossed and recrossed the Nigerian border at will, and, indeed, many were found to maintain homes on both sides of the frontier. This cherished freedom of

movement enabled them to avoid taxation and also, unfortunately, vaccination. There were also instances of entire villages crossing the border to celebrate the millet harvest with Nigerian fellow tribesmen.

Dr. Arlan L. Rosenbloom and Mr. John P. McEnaney, the assigned medical and operations officers, spent considerable time with the SGE team in Mokolo, the largest town in the mountain region of Cameroon, to help achieve higher vaccination coverage rates and enhance surveillance and investigation. After patiently getting to know the Kirdi and their habits, they made use of that omnipresent phenomenon, the market, to extend vaccination coverage. Almost 20,000 people were vaccinated in the first ten days of a program tied to the schedule of local market days.

Containment activities were carried out in the district of Golda, north of Mokolo, during the latter half of 1967. A total of forty-nine cases were eventually recorded, with twenty-one deaths, an unusually high fatality rate attributed by Dr. Rosenbloom to the presence of famine in the area before the October harvest.

In November 1967 an outbreak was reported in a region of northern Cameroon just across the border from the capital city of Fort-Lamy in Chad and hundreds of miles from Cameroon's capital of Yaounde. Dr. Bernard Lourie, the CDC medical officer in Chad, and Dr. Pierre Zeigler, Director of Chad's SGE, crossed the border to investigate. They found another slow-burning epidemic that evidently had its origin neither in Cameroon nor Chad but in Nigeria. As well as being another example of smallpox's potential for slow transmission in West Africa, this episode was an excellent example of intercountry cooperation made possible by the regional program.

Civil strife in the desert reaches of northern Chad made the execution of the program there dangerous as well as difficult. Rebels, identifying the vaccination campaign with the government against which they were in revolt, ambushed one SGE team, killing a laborer, wounding a chauffeur, disabling one Dodge truck, and setting fire to another containing vaccine and ped-o-jets. Later, in another episode in 1968, a French physician was killed in the course of his work. Understandably, the teams refused to work outside city limits in the North.

As a consequence, Lourie was forced to report reluctantly to Millar that they had been able to perform only 214,000 vaccinations in the area since June 1967 and would probably fall short of the 600,000 needed for full coverage. Given the circumstances, the 214,000 represented a considerable achievement, and since smallpox did not occur in the North, the very chancy enterprise of smallpox containment in a war zone was never required in Chad.

There were, however, smallpox problems at Lake Chad, a large inland body of water located where Chad, Niger, Nigeria, and Cameroon come together. All four countries have a piece of the shoreline, the largest section belonging to

Chad itself. The area includes thousands of floating islands, made up of matted networks of papyrus plants with long roots, insecurely attached to the bottom, often drifting for miles. Boudouma fishermen occupied these islands for varied lengths of time and tended to migrate across the lake.

On June 28, 1967, British medical missionaries reported fourteen cases of smallpox and three deaths, the first cases reported in this area in two years. The smallpox/measles program rented a pontoon plane to investigate. The plane landed near the larger islands, and the investigative team performed many vaccinations. However, Dr. Lourie reported that a special problem occurred with the ped-o-jets: when the vaccinator stamped down, the machine tended to sink through the boggy surface of the island. Mats were devised to prevent this unfortunate happening.

This outbreak, like so many others in Central Africa, appeared to have stemmed from a person returning from a visit to Nigeria. Eventually, a total of eighty cases with twenty-one deaths were found in seven villages in Chad. Intensive vaccination of the Lake Chad area continued through October, and during the period some 80,000 vaccinations were performed. No further outbreaks occurred.

Guinea and Sierra Leone

Two neighboring countries on Africa's great western bulge, Guinea and Sierra Leone, were among the three nations (the other being Liberia) where the smallpox eradication/measles control program had a deliberately delayed start, not getting under way until late 1967. At that time Sierra Leone had the distinction of having the highest reported smallpox rate in the world, with 68.3 cases per 100,000 population. Guinea ranked second at a level of 40.2 per 100,000.

During the negotiation of the project agreements, Dr. Henry Gelfand had found Sierra Leone enthusiastically receptive to starting a smallpox eradication program. He had been met at Freetown Airport by the country's Principal Medical Officer, Dr. Boyce, who said: "Dr. Gelfand, my people are dying of smallpox and you must start the program here. We have waited too long."

In the People's Republic of Guinea, a politically radical state from which the U.S. Peace Corps had recently been expelled and where travel by Americans was severely restricted, Gelfand had insisted upon and, to everyone's surprise, been granted permission for the CDC advisors to travel outside the capital as a prerequisite for his signing the program agreement. Throughout the life of the program, after a period during which they felt they were "on trial," smallpox eradication personnel were singled out for special treatment in comparison with other Westerners in Guinea.

Training in Atlanta during the summer of 1967, the teams destined for Sierra Leone and Guinea had the advantage of CDC's first year of field experience and the added benefit of the presence of Foege, Thompson, and Lichfield, all re-

cently evacuated from Eastern Nigeria. On arrival in the field, CDC teams found that both countries were in the midst of cyclical epidemics that had raised the number of cases well above normal levels. Indeed, Sierra Leone had sent a cable urging that its team be dispatched immediately, even while they were in training that summer.

Dr. Donald R. Hopkins and Mr. James N. Thornton, the CDC advisors for Sierra Leone, were pressed to start mass vaccination activities immediately on their arrival in September-October 1967. Their field teams were made up of about forty excellent workers from the Endemic Disease Control Unit, who had recent experience in a program of yaws control. This unit had been formed originally in the 1930s to combat African sleeping sickness. Five vaccination teams, an advance team, and an assessment team were deployed. The program also benefitted greatly from the leadership of Mr. Alfred Kargbo-Reffell, a Sierra Leone health inspector just returned from study in England.

Once the mass vaccination program was under way, Hopkins began to give special attention to containment of epidemics. Then, when the E^2 concept was proposed at the regional conference in Abidjan in May 1968, it was Hopkins who most enthusiastically accepted and adopted what some of his compatriots considered a "crackpot headquarters notion." Millar has subsequently credited Hopkins' swift and highly effective demonstration of the E^2 concept with a significant acceleration of the achievement of "zero-pox" throughout the region.

Unlike Guinea, where every activity was carried out through the channels of government and the ruling political party, Sierra Leone had a much more decentralized structure requiring support of tribal chieftains and a more freewheeling surveillance and containment system using private health care providers, missionaries, Peace Corps volunteers, and anyone else whose interest could be enlisted. A monthly newsletter, *The Eradicator*, was initiated to keep all these people aware of and enthusiastically involved in the progress of the program. It served to bolster the spirit of the vaccination teams by giving widespread recognition to their work and dedication. In one typical excerpt, after describing a particularly arduous campaign in a remote area, *The Eradicator* declared: "In spite of these hardships . . . the teams went about their tasks with a dedication, proficiency, and spirit which would be the envy of health workers throughout the world." This issue of *The Eradicator* was careful also to "give special thanks to the people of the Kono District for their cooperation and assistance in achieving coverage against smallpox and measles."

Outbreaks associated with special funeral ceremonies for prominent smallpox victims was an unusual feature of smallpox transmission in Sierra Leone. One such outbreak resulted in thirty-three cases among contacts at the funeral, including all the men who participated in preparing the corpse for burial, and an additional ninety-seven cases due to further spread. In another episode the six women who washed the corpse of a forty-year-old woman who was head of a local secret society all contracted the disease, and six additional cases were

found among contacts. Such secret societies and similar funeral arrangements probably led to outbreaks elsewhere in the West African Region, though these were the best documented.

The November issue of *The Eradicator* urged everyone to work extra hard to eradicate smallpox from Sierra Leone in 1968, since only two chiefdoms in the southern part of the country were reporting smallpox at that time. This ambitious goal was not met, but intensive surveillance and containment efforts were applied to ten outbreaks during the early months of 1969. On April 5 of that year, the last case was discovered. Sierra Leone had gone from the most heavily infected country in the world at the beginning of 1968 to zero-pox just sixteen months later.

In Guinea there had been widespread outbreaks of smallpox in 1966 and 1967. Both the people and the government recognized the urgency of the need for assistance, but because of the radical political environment, the CDC team of Dr. Joel G. Breman and Mr. Donald R. Malberg had to demonstrate that they were both highly professional and apolitical before gaining acceptance. Once they passed the test, however, the program was warmly supported. The socialist party structure, through which they worked in organizing the campaign, proved nearly as successful as the emirates of Northern Nigeria in promoting rapid, nearly universal coverage.

Vaccination teams were recruited on a regional basis and headed by senior nurses. Once the concept of assessment was accepted, assessment teams using a cluster sampling system devised by Dr. Ralph Henderson followed the vaccinators on a very systematic basis, with excellent results. Levels of immunity achieved by vaccination usually exceeded 80 percent and often 90 percent, with active follow-up of the unvaccinated aided by party leaders.

The mass immunization program in Guinea began in December 1967 at Conakry, the capital, and by March of 1968, 180,000 of its 250,000 inhabitants were vaccinated. By October all the residents of Conakry and the areas bordering Sierra Leone had been reached, including most of the areas then known to be infected with smallpox.

From July 1968 through January 1969, a special surveillance team carried out investigation and containment of outbreaks. Only eight outbreaks with a total of seventy-five cases were found, most in very small villages near the border with Sierra Leone where five of the outbreaks were thought to have originated. A major effort was made to achieve close communication between the programs in the two adjoining countries, often using the channel of the respective U.S. embassies.

In Guinea active epidemiological surveillance was carried out during the season of heavy rains, beginning in October when smallpox transmission normally was at

its lowest point. In November an outbreak of fifty cases was recorded at Boké. The last smallpox outbreak in Guinea, with a total of twelve cases, was found in January 1969.

D. A. Henderson, who was in a position to speak authoritatively from WHO headquarters in Geneva, has written about the achievements in Guinea and Sierra Leone. He said that their interrupting transmission in fourteen and sixteen months, respectively, after having had the highest incidence rates in the world, "greatly encouraged regional and global smallpox programme staff" and generated confidence that "comparable successes could be achieved in other parts of the world."

Dahomey and Togo

Two small Francophone countries located between Ghana and Nigeria on the Gulf of Guinea provided some of the most stubborn challenges to the Smallpox Eradication Program and harbored the last cases recorded in West Africa until the final flare-up in Nigeria. Dahomey (now known as Benin), with a 1967 population of 2.5 million, and Togo (1.8 million) were highly unstable politically during their first decade of independence: two significant coups occurred in Togo, and six in Dahomey. Partly as a result of this political turmoil, preventive health services had become virtually nonexistent by 1967. To a greater extent than in most Francophone countries, power resided in local tribal chieftains rather than civil authorities.

Substantial numbers of smallpox cases were occurring in both countries each year, largely in the more heavily populated southern areas near the coast. Resistance to vaccination was encountered here and in adjoining sections of Western Nigeria to a much greater extent than elsewhere in the region. A principal cause of this resistance was the lingering worship of a god of smallpox, known variously as Shapona, Saponna, Sakpata, or Sagbata, and the presence of a hereditary fetish priesthood.

Shapona had been well established in the pantheon of the powerful Yoruba tribe of Western Nigeria when Europeans arrived in West Africa in the seventeenth century. One of his titles was translated "Overlord of the Earth," and Yoruba legend had it that he exercised his dominion by wielding smallpox as his weapon of divine displeasure. His sway extended into Dahomey and Togo, and the CDC team found it to be particularly active among the Fon tribe in those two countries. Dr. Bernard Challenor, the CDC medical officer for the two countries, reported that strong cultural resistance to vaccination was still present among an estimated 4-5 million Shapona worshippers. Many villages had their own shrine, as did the major city of Abomey, Dahomey.

The hereditary priests, or fetisheurs, were believed to have the power to prevent or induce the disease. They had traditionally practiced variolation, using material derived from pulverized scabs of smallpox victims, in ceremonies that took place

a few weeks after the onset of the disease in a village. Foege, in a daylong visit to a chief fetisheur, found him to be extremely knowledgeable about smallpox epidemiology, including such factors as its seasonality and age distribution. He also found a "residency" program in place whereby young men spent three years learning the trade. The fetisheurs, by custom, inherited all the possessions of a patient who died of smallpox; thus, they had a considerable disincentive for cooperating in a vaccination program. It is also noteworthy that many of the fetisheurs, and members of their immediate families, had received inoculations themselves. Mr. Gordon E. Robbins, the health education advisor attached to the Regional Office in Lagos, found in a study that resistance to vaccination in some places was also based on public suspicion of governmental teams, with accompanying fears of taxation and military conscription.

The eradication program began slowly in Togo, and 1967 was in many ways a frustrating year for Challenor and the operations officer, Mr. Andrew N. Agle. Bureaucratic problems and disinterest on the part of some officials delayed the onset of the program. The vaccination teams were disgruntled about leaving the capital city, Lomé, and undertaking arduous work in the field. There was disharmony and distrust between local civil authorities and tribal leaders.

Despite these problems, 605,000 vaccinations were recorded in Togo in 1967. But numerous outbreaks continued to occur even in areas through which the vaccination teams had passed. Challenor and Agle investigated an outbreak in November in the village of Togblekope, located only sixteen kilometers from the capital and whose population had had two opportunities to be vaccinated: once in the pilot project in January and again during the regular campaign in October. They found eight persons with smallpox, seven of whom were being hidden in the bush. Containment vaccinations initiated to stop the outbreak uncovered an alarming number of unvaccinated villagers. Attempts by local officials to invoke police authority by taking tribal chiefs into custody until their people were vaccinated were unavailing and caused further strife.

The turning point in Togo came when Mr. Agle met with the country's Director-General of Health, who immediately made Dr. G. F. Glokpor responsible for the smallpox/measles program. Glokpor attended a training session at CDC, in which he became a passionate convert to the doctrine of surveillance-containment. On his return, he and Agle established an E^2 program with an active surveillance-containment system, firefighting teams, and greatly improved reporting. Health workers, teachers, and tribal and governmental authorities all were urged to report cases.

As an initial consequence, the number of reported smallpox cases rose dramatically from a total of 332 in 1967 to 784 in 1968, the latter figure establishing Togo temporarily as the country with the second highest incidence rate in the world. Thereafter, however, the number plummeted to 83 confirmed cases in 1969, all in the first five months of the year. By June 1969 Togo was smallpox-free.

The Dahomey program was slowed initially by the government's decision to deploy separate teams for measles and smallpox. This decision was later reversed, with considerable improvement in efficiency and reduction in cost. In August 1967, soon after the program began, a special study of a small outbreak carried out by Dr. Ralph Henderson of the Lagos staff highlighted the very slow spread of the disease. Ten weeks after the onset of the first case, only twenty-eight cases were found in a villge of 300 persons, despite the fact that only 15 percent of the children and 54 percent of the total population had been successfully vaccinated. The outbreak appeared to have terminated spontaneously, although many susceptibles remained.

An outbreak in the village of Hon, investigated by Challenor and Mr. Jeannel A. Roy, the Dahomey operations officer, appeared to be directly related to the presence of the fetisheurs. Lingering over a nine-month period, the outbreak included over 100 cases and forty deaths. House-to-house vaccinations were necessary. Vaccinators encountered locked doors, and frequently residents had to be pursued into the bush. Finally, the local chief, losing faith in his fetisheur, organized his elders to help round up the villagers.

Despite the problems, the Dahomey program recorded 702,000 vaccinations in 1967 and 990,000 in 1968. Reported cases declined from the very high level of 815 in 1967 to 367 in 1968. With the aid of a mobile group of twelve young health workers on motor bikes, called "*les douze*," reported outbreaks were quickly investigated and contained. Dahomey at first appeared to have interrupted transmission in January 1969, but in July an infant from Dahomey was diagnosed as having smallpox in a Togo dispensary near the border. Teams from both countries, headed by Agle and Roy, swiftly converged on the area. In all, fifty-five additional cases were located in Dahomey in the next two months. In September the last case was detected, which until March 1970 was presumed to be the final case in West and Central Africa.

Nigeria Revisited

In early 1970 national and CDC staff were preparing to celebrate the accomplishment of smallpox eradication in West and Central Africa within a mere three-year span. Despite diligent pursuit of rumored outbreaks, the cases in Dahomey in September 1969 remained the last confirmed occurrence.

One episode in 1969 had seriously marred the general feeling of exhilaration, the tragic death of Dr. G. A. Ademola, director of Nigeria's national program and one of the true pioneers of smallpox eradication. He had visited CDC and devised a plan for eradication in his country well before the advent of U.S. support and had cooperated to the fullest through all the difficult times in Nigeria. He was murdered by an intruder in his home. His neighbor, Dr. Stan Foster, had tried in vain to save him. Dr. Ademola's presence at the final triumph would be keenly missed.

But the moment seemed at hand. The newsletter of the E^2 program in Nigeria announced in its issue of early January 1970: "Eradication having been successfully escalated, summary number 34 terminates the series." A celebration was planned for the end of March, and Foster was preparing to attend an international conference to announce eradication. Then, on March 21, a fourteen-year-old girl was admitted to the infectious disease hospital in Kaduna, in north-central Nigeria, with an unmistakable case of smallpox.

Andrew Agle, who had been transferred from Togo to manage the changeover of the Nigeria program to a maintenance activity, visited the hospital immediately. The patient was an unvaccinated Yoruba girl from the village of Amayo in Kwara State, some 400 kilometers away. Kwara was an area with a generally low coverage rate, although vaccination programs had been carried out between December 1968 and July 1969.

Intensive investigation by state, national, and CDC personnel, including house-to-house vaccination campaigns, revealed sixty additional cases in Amayo and twelve more in a neighboring village. The outbreak had evidently been smoldering since the previous October. Nine additional cases were found in Ilorin, the capital of Kwara State, the last one on April 22, 1970. Smallpox transmission may have been going on there for more than a year.

Just as the Amayo-Ilorin outbreaks were being controlled, two more cases were discovered 150 kilometers south in Lagos, the national capital, in late April and early May. To contain these outbreaks all contacts were vaccinated, and intensive surveillance was conducted to search for hidden cases.

Finally, another two cases were recorded in the town of Shagamu, between Lagos and Ibadan. The first patient, a forty-five-year-old unvaccinated male, developed a rash on May 6. The second, a twenty-seven-year-old female neighbor, had smallpox diagnosed on May 21, 1970. These proved to be the final smallpox cases in Nigeria and in West and Central Africa.

Sobered by these flare-ups after the battle seemed won, the program carried out rigorous surveillance activities and pursued every rumored case. After May 1970 every lead proved to be false. Zero-pox in West Africa had been achieved.







OFFICE OF WHITE HOUSE PRESS SECRETARY

Austin, Texas
Tuesday,
November 23, 1965

Plans for campaigns to protect 105 million people from smallpox and measles in 18 African countries were announced today by the White House.

The plans result from President Johnson's pledge of May 18, 1965; "This Government is ready to work with other interested countries to see to it that smallpox is a thing of the past by 1975."

AID and the PHS staff are beginning consultations with African and WHO officials on plans for the campaign, its acceptability to African countries and their willingness to contribute to the program.

The smallpox eradication program is being designed to fit within plans of the World Health Organization (WHO) to eradicate smallpox throughout Africa and the rest of the world within 10 years.

The eradication program would help prevent the possible reintroduction of smallpox into the United States and other smallpox-free countries. The smallpox activity would run concurrently with a measles control program in the same area.

The AID contributions would consist of technical assistance, vaccines, and jet injectors, which can inoculate 1,000 persons an hour. Vehicles, field supplies, freezers, and refrigerating equipment would also be provided under the AID plan.

Local costs and operational personnel would be supplied by the individual countries cooperating in the program.

Operational responsibility for the project would be assumed by the U. S. Public Health Service in cooperation with AID.

A measles control program has already been implemented by AID in 11 African countries, all of which are included in the 18 to be covered in the smallpox project. The 18 countries* are Cameroon, Central African Republic, Chad, Dahomey, Gabon, Gambia, Ghana, Guinea, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo and Upper Volta.

Africa is one of the world's major areas of smallpox incidence. Approximately 25 percent of those stricken by the disease there become fatalities. According to WHO, the 18 African countries are among the 45 countries that are the principal sources from which smallpox infections are spread to other parts of the world.

Measles is also one of the principal causes of death and disability in African children. A death rate of 20 percent is not unusual and rates have run as high as 50 percent. In the area concerned, around 21 million children under the age of 6 are susceptible to measles.

*Subsequently an offer of assistance in the form of vaccine and equipment was extended to Congo (B). This assistance is provided through the regional African health organization, OCEAC.



Smallpox god with monkey skull



Bilkisunnessa collects her reward money for reporting the last naturally occurring case of variola major.

世界衛生大会 決議
RESOLUTION OF THE WORLD HEALTH ASSEMBLY
RÉSOLUTION DE L'ASSEMBLÉE MONDIALE DE LA SANTÉ
РЕЗОЛЮЦИЯ ВСЕМИРНОЙ АССАМБЛЕИ ЗДРАВООХРАНЕНИЯ
RESOLUCION DE LA ASAMBLEA MUNDIAL DE LA SALUD

NINETEENTH WORLD HEALTH ASSEMBLY

WHA19.16
13 May 1966

ORIGINAL: ENGLISH AND FRENCH

SMALLPOX ERADICATION PROGRAMME

The Nineteenth World Health Assembly,

Having considered the report of the Director-General on smallpox eradication[1] and the recommendation of the Executive Board thereon; and

Noting that particular emphasis has been placed on the need for co-ordination of individual countries' smallpox eradication programmes,

1. DECIDES that the participation of the Organization in the smallpox eradication programme should be financed from the regular budget of the Organization;

2. URGES countries which plan to strengthen or initiate smallpox eradication programmes to take the necessary steps to begin the work as soon as possible;

3. REQUESTS Member States and multilateral and bilateral agencies to provide adequate material support for the realization of the programme;

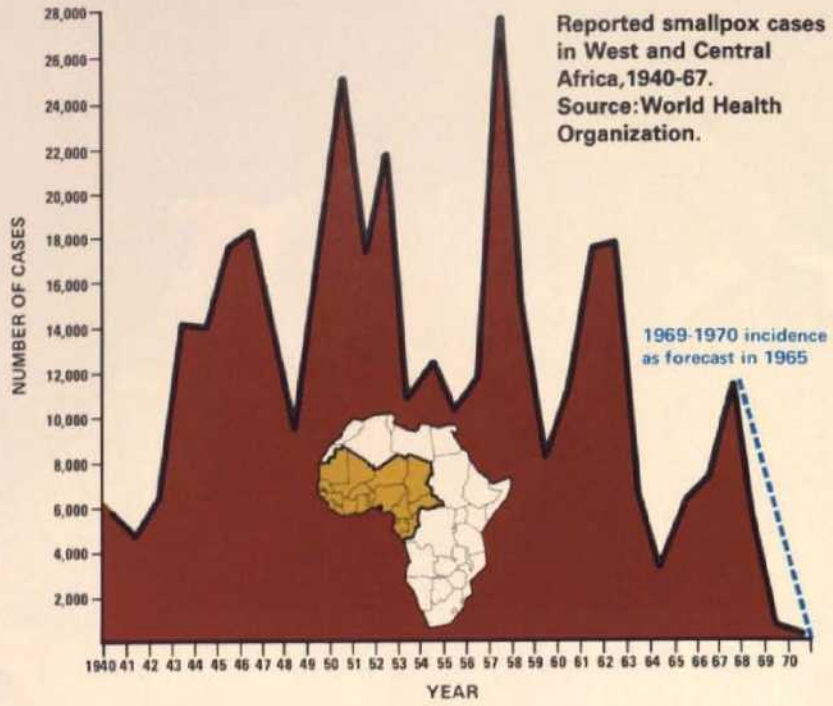
4. DECIDES that, in the part of the programme financed by the Organization either from the regular budget or from the Special Account for Smallpox Eradication, the following costs may be met:

(a) such supplies and equipment as are necessary for the effective implementation of the programme in individual countries;

(b) such services as may be required in individual countries and as cannot be made available by the governments of such countries; and

5. REQUESTS the Director-General, in co-operation with all Members, to initiate action to carry out a world-wide smallpox eradication programme and to submit a report to the Executive Board at its thirty-ninth session and to the Twentieth World Health Assembly.

[1] Document A19/P&B/2.

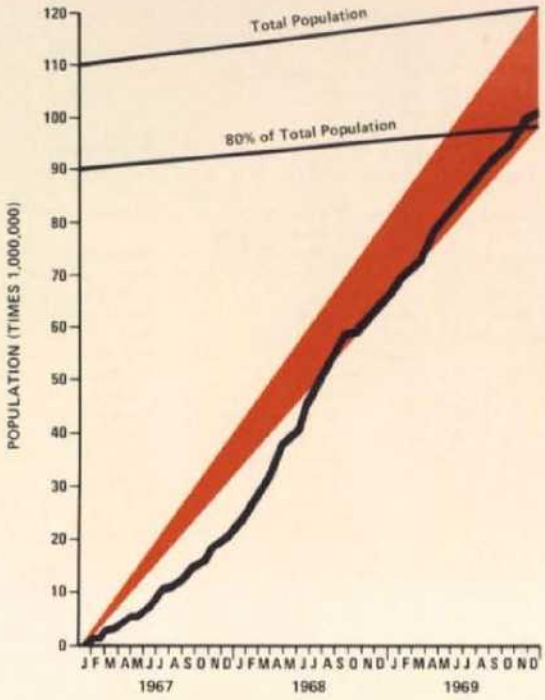


Reported smallpox cases in West and Central Africa, 1940-67. Source: World Health Organization.

Smallpox vaccinations (in thousands). Smallpox Eradication Program, West and Central Africa

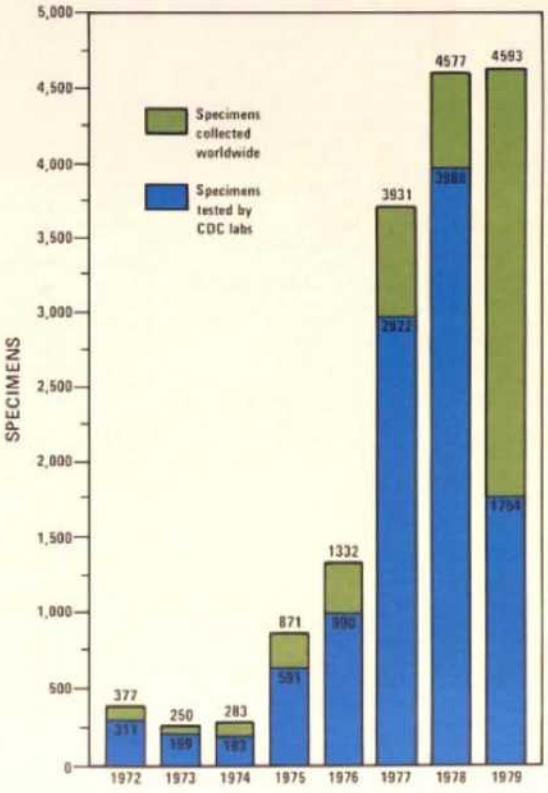
Country	Year						Cumulative vaccinations Jan., 1967-Dec., 1972	Est. pop. in 1975 (Millions)	Year of last smallpox Case
	1967	1968	1969	1970	1971	1972			
Central African Republic	381	405	477	508	558	427	2,756	1.78	1963
Chad	1,387	1,345	1,322	1,182	977	666	6,879	4.03	1968
Congo	162	581	312	617	288	73	2,033	1.32	1966
Dahomey (Benin)	702	990	934	849	448	184	4,107	3.10	1969
Equatorial Guinea	NA*	NA	82	238	15	6	341	.32	1960
Gabon	225	146	175	201	105	138	990	.53	1965
Gambia	231	147	40	40	20	3†	481	.51	1966
Ghana	1,342	1,988	2,094	1,909	1,052	481†	8,866	9.86	1968
Guinea	1,068	2,063	1,434	1,453	1,200	1,100†	8,318	5.54	1969
Ivory Coast	1,580	1,756	1,582	548	619	67	6,152	6.70	1967
Liberia	44	231	398	191	120†	268†	1,252	1.54	1968
Mali	1,043	1,472	1,193	516	56	111	4,391	5.67	1969
Mauritania	NA	NA	430	288	193	297	1,208	1.32	1966
Niger	1,610	1,166	936	1,297	850	776	6,635	4.56	1969
Nigeria	9,560	23,494	16,155	8,702	5,362	5,454	68,727	75.02	1970
Senegal	383	1,468	762	330	507	124	3,574	5.00	1967
Sierra Leone	0	965	1,154	258	93†	100†	2,570	2.98	1969
Togo	605	608	922	467	507	166	3,275	2.23	1969
United Republic of Cameroon	1,611	1,996	1,693	1,443	3,250	2,215	12,208	7.26	1969
Upper Volta (Burkina Faso)	2,040	2,208	1,338	1,026	1,568	632	8,812	5.90	1968
Total‡	23,972	43,030	33,431	22,062	17,788	13,288	153,575	145.17	

*NA = not available.
†Incomplete and/or provisional.
‡Totals do not sum up because figures are rounded off.



Cumulative smallpox vaccinations as related to the estimated total population, West and Central Africa smallpox eradication/measles control program area.

Red area shows pre-program estimates of cumulative number of vaccinations that would be given; thick line shows cumulative number of vaccinations actually given.



CDC's laboratory contribution to the global effort

CDC smallpox diagnostic laboratory staff in 1967, shortly after renovations for the new maximum containment laboratory had been completed.



CDC Smallpox Program Participants

Adams, Vernon, M.D.
Adcock, David E.
Agle, Andrew N.
Alexander, Charles
Alfaro, August A.
Allman, Kenneth
Andrews, John S., M.D.
Appleton, Fred
Arnold, Richard B., M.D.

Baldwin, Robert J.
Barbour, Alan, M.D.
Bassett, David C.
Bentley Jean C.
Berall, Jonathan, M.D.
Berg, George M., M.D.
Bernier, Roger H., Ph.D.
Berry, Frank K.
Bingham, Patricia G.
Bishop, Patricia
Bloeser, Carl H.
Blumenthal, Daniel, M.D.
Bond, Paul A.
Bourke, Anthony T., M.D.
Boyd, Barbara A.
Boyd, Robert A.
Bradley, Martin R., M.D.
Brar, Mukhtiar
Breman, Joel G., M.D.
Brink, Edward W., M.D.
Brix, Jack
Brody, Jacob A., M.D.
Broske, Stuart P., M.D.
Brown, Denise R.
Brown, Larry K.
Brown, Robert
Bunn, Jack C., M.D.
Burger, Ronald C.
Burke, Ralph
Burk, John R., M.D.

Carvell, Delbert
Challenor, Bernard D., M.D.
Charter, Russell S.
Claquin, Pierre, M.D.
Clark, Jean Jordan
Cockburn, T. Adrian, M.D.
Cohen, Regina
Connell, Fred, M.D.
Conrad, Gary
Conrad, J. Lyle, M.D.
Cooley, Jane M.
Copeland, Wallace
Craig, Marian S.
Crane, Delores Cochran
Crankshaw, Richard L.
Crippen, Peter H.
Curtis, Gerald

D'Agnese, John J.
D'Amanda, Christopher, M.D.
Davenport, Joan F.
Daves, Jeanie Britt
Davis, Cornelia, M.D.
Davis, Daniel
Davis, Elmer
Davis, Hillard
Dawson, Chandler R., M.D.
DesPrez, William L.
Deubner, David, M.D.
DeWeese, Luther E.
Dix, Dennis J.
Donoho, James E.
Drake, Thomas, M.D.
Drescher, John J.
Drotman, Peter, M.D.
Duerden, Edward F.
Dull, H. Bruce, M.D.
Dunn, Frederick L., M.D.
Dyal, William W.

Economidis, Thomas
Eddins, Donald L.
Ellis, Robert J.
Emerson, Robert
Evans, Harmon H.
Evans, Robert C.
Ewen, Neal H.

Farer, Laurence, M.D.
Feld, Bernard
Ferrazano, Gabriel, M.D.
Fischman, Paul, M.D.
Fitzgerald, Stephen A.
Flanders, Gerald P.
Foege, William H., M.D.
Folland, David, M.D.
Fontaine, Robert E., M.D.
Forney, David L.
Forrester, Willis R.
Foster, Stanley O., M.D.
Francis, Donald P., M.D.
Freedman, George I.
Freemont, James M.
Friedman, Jay S.
Frye, Mary Cameron

Garcia, Luis A.
Garrett, Woodrow A.
Gelfand, Henry M., M.D.
Gentry, Nina (Novak)
Gibson, James, M.D.
Giordano, Joseph F.
Godfrey, Harry R.
Goldstein, Joel A., M.D.
Grazis, Peter A.
Greenberg, Richard, M.D.
Greenley, John W.
Griggs, Billy G.
Grigsby, Margaret E., M.D.
Guinan, Mary, M.D.
Gunter, David L.
Gunter, Dupree
Guyer, Bernard, M.D.

Harrison, Evelyn F.
Helmholz, Robert C.
Hemmert, Wynn, M.D.
Henderson, Donald A., M.D.
Henderson, Ralph H., M.D.
Hendricks, Fay
Herrmann, Kenneth L., M.D.
Herron, Charles A., M.D.
Hess, James P.
Heymann, David L., M.D.
Hicks, James W.
Hill, Carl C.
Hogan, Robert C.
Hogelin, Gary
Holloway, Brian P.
Hopkins, Donald R., M.D.
Horne, Thomas
Howard, Richard D.
Huber, Charles
Huber, William
Hudgins, Michael P., M.D.
Hudson, Janice
Hughes, John, M.D.
Hull, Harry F., M.D.
Hutchins, Deane L., M.D.

Imperato, Pascal J., M.D.

Jackson, Richard J., M.D.
James, William
Jenkins, Lesley M.
Johnson, Deane
Jones, Clara J.
Jones, John W.
Jones, T. Stephen, M.D.
Jones, Warren R.
Jordan, Wilbert C., M.D.

Karzen, Jerome B.
Kaufman, Shirley
Kay, Dale E.
Keenlyside, Richard A., MBBS
Kelly, John
Kimmel, Thomas R.
King, Leland
Kingma, Frederick S.
Kissee, Ben
Kloth, Theodore I., M.D.
Koplan, Jeffrey P., M.D.

LaForce, F. Marc, M.D.
Landrigan, Phillip J., M.D.
Lane, J. Michael, M.D.
Langmuir, Alexander D., M.D.
Lantz, Samuel A.
LaPointe, Mark D.
Lary, Darrel L., M.D.
Larson, Edward
Lather, George
Leggin, Phillip
Lenz, Catherine E. Vaughn
Leonard, Thomas A.
Lessin, Phillip
Leutzinger, Craig
Lewis, James O.
Lichfield, Paul Lantz
Lichfield, Paul R.
Lincoln, Burton J.
Loggins, Mary S.
Loher, Bernard J.
Long, Gary W., M.D.
Lorenz, Rodney A., M.D.
Lourie, Bernard, M.D.
Lyle, Mary Ann
Lythcott, George I., M.D.

McBean, A. Marshall, M.D.
McCannon, Patrick
McEnaney, John P.
Mack, Thomas M., M.D.
Malberg, Donald R.
Marino, Frank A.
Martin, William E.
Marty, Michael J.
Masso, Anthony R.
Meehan, Leo J.
Melchinger, David B., M.D.
Melewicz, Frank M., M.D.
Meschievitz, Carlton, M.D.
Millar, J. Donald, M.D.
Miller, David C., M.D.
Miller, Donna L.
Miller, Joe
Miller, Richard
Mitchell, William H.
Mize, James W.
Monath, Thomas P., M.D.
Moore, Donald J., M.D.
Moore, Joseph N.
Morgan, Kenneth H.
Morris, Leo, Ph.D.
Moser, Claude R., Jr.
Mosley, James W., M.D.
Murphy, Kevin B.
Musante, Edward
Music, Stanley I., M.D.

Nakano, James H., Ph.D.
Neff, John M., M.D.
Nelson, John W., Jr.
Nelson, William Q.
Newberry, David M.
Newport, Frank E.
Noble, John, Jr., M.D.
Noonan, Allan S., M.D.

O'Connor, Richard
Olsen, Dennis G.
Orenstein, Walter, M.D.

Page, Malcolm I., M.D.
Paz, Elizabeth
Perry, Samuel R.
Peters, Bruce F., M.D.
Phillips, Shirley J.
Pifer, John M., M.D.
Pope, Malcolm I., M.D.
Pope, Randall S.
Post, Clarence J.
Pratt, David, M.D.
Pust, Ronald E., M.D.

Quinn, Michael J.

Raines, David
Ramirez, Robert
Reid, Gordon, M.D.
Reiman, Sol
Rich, James A.
Richardson, John H., M.D.
Robbins, Gordon E.
Roberto, Ronald R., M.D.
Romm, Fredric J., M.D.
Roots, Logan H., M.D.
Rosenberg, Mark L., M.D.
Rosenbloom, Arlan L., M.D.
Rosenblum, Bernard, M.D.
Rothstein, Nathaniel
Roy, Jeannel A.
Roy, Muriel T.
Ruben, Frederick L., M.D.

Scally, Francis J.
Scardaci, Anthony M.
Schade, Charles, M.D.
Sencer, David J., M.D.
Shoemaker, William D., Jr.
Silvernail, Carl
Smith, Edward W.P., M.D.
Smith, James
Solter, Steve, M.D.
Sparks, Larry
Stapp, Joy H.
Stetler, Harrison C., M.D.
Stiso, Frank
Stroh, George

Tapia, Robert
Teller, Benjamin E., M.D.
Thieme, Martha L.
Thomas, Elaine A.
Thompson, David M., M.D.
Thornton, James N.
Tierkel, Ernest, D.V.M.
Trotter, William Yates, M.D.
Tulloch, Roger

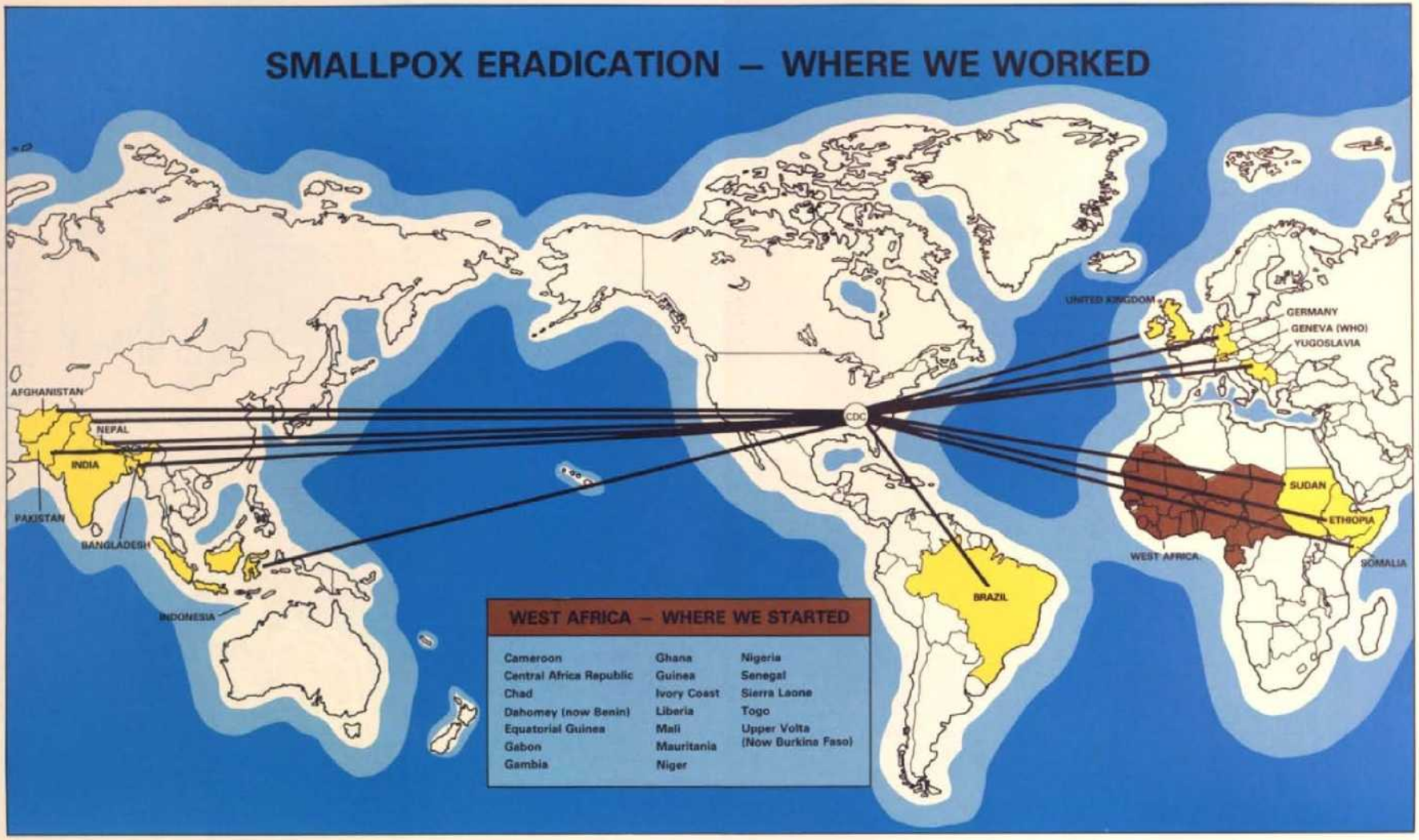
Usher, Glenn, M.D.

Van Buskirk, Arthur
Vanderhook, Ray, M.D.
Van Patten, Harold
Vastine, David, M.D.
Veazey, James M., M.D.

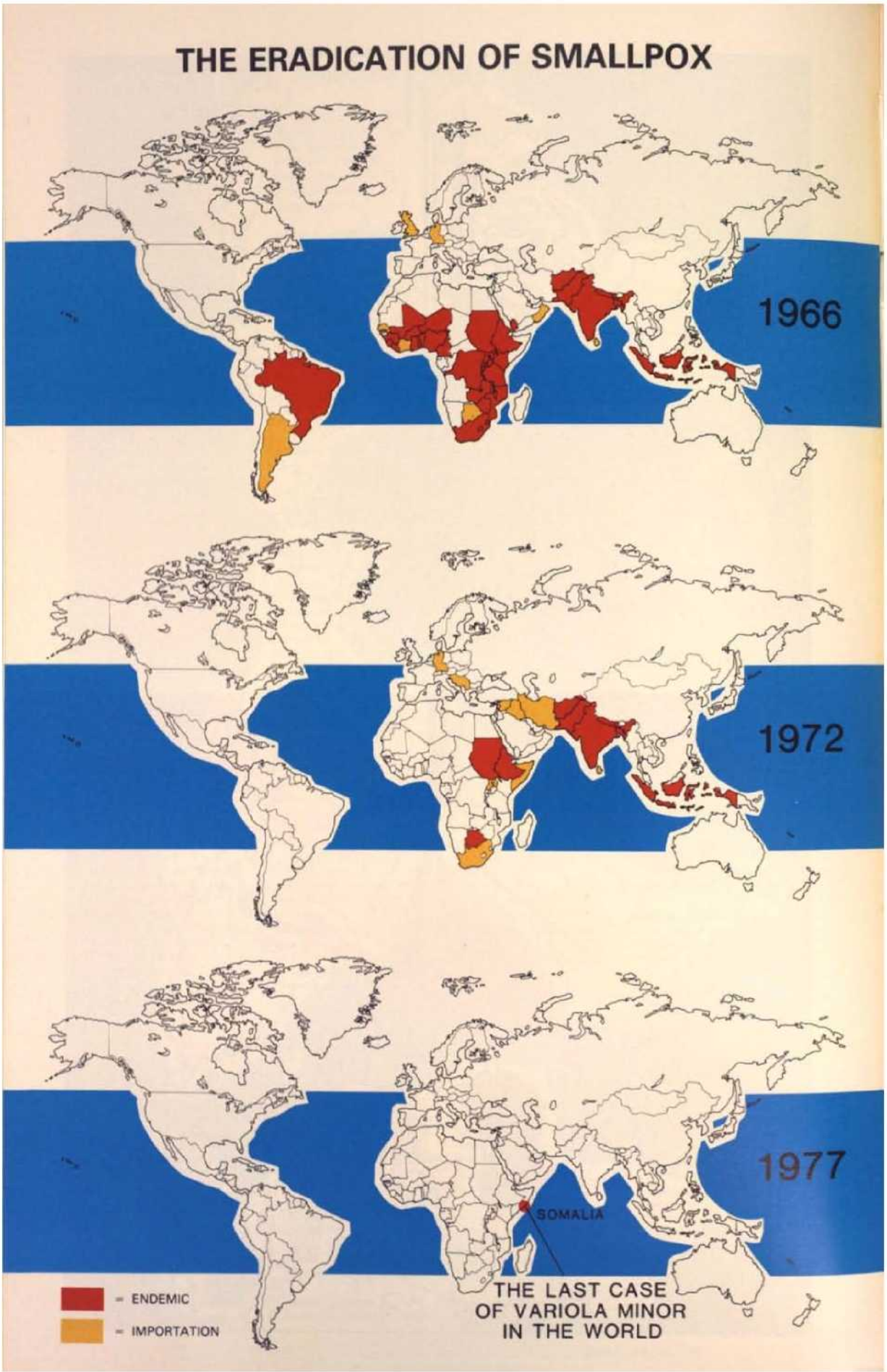
Wade, Lloyd W.
Waldman, Ronald, M.D.
Wanner, Rudolf C., M.D.
Watkins, Charles H.
Watson, William C., Jr.
Wehrle, Paul H., M.D.
Weisfeld, Jason S., M.D.
Weniger, Bruce G., M.D.
West, Gary
West, James W.
Westmoreland, Hilda
Wheeler, Jerry
Whipple, David
White, William J., Jr.
Wilder, Michael, M.D.
Williams, Gene
Wilson, John E.
Wilson, Mary A.

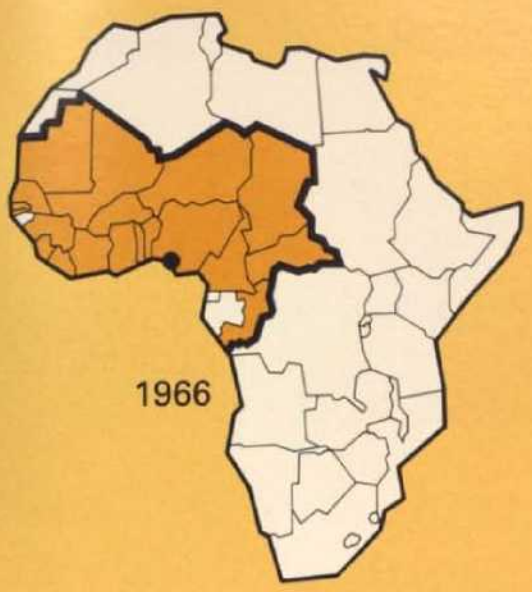
Zyla, Laurence D.

Dated: July 20, 1987


SMALLPOX ERADICATION – WHERE WE WORKED
AFGHANISTAN
NEPAL
INDIA
PAKISTAN
BANGLADESH
INDONESIA
CDC
UNITED KINGDOM
GERMANY
GENEVA (WHO)
YUGOSLAVIA
SUDAN
ETHIOPIA
SOMALIA
WEST AFRICA
BRAZIL
WEST AFRICA – WHERE WE STARTED
Cameroon
Central Africa Republic
Chad
Dahomey (now Benin)
Equatorial Guinea
Gabon
Gambia
Ghana
Guinea
Ivory Coast
Liberia
Mali
Mauritania
Niger
Nigeria
Senegal
Sierra Leone
Togo
Upper Volta
(Now Burkina Faso)

THE ERADICATION OF SMALLPOX





Sequential Map Showing Decline of Smallpox

AREAS OF
WEST AND CENTRAL AFRICA









RESOLUTION OF THE WORLD HEALTH ASSEMBLY
RESOLUTION DE L'ASSEMBLEE MONDIALE DE LA SANTE
РЕЗОЛЮЦИЯ ВСЕМИРНОЙ АССАМБЛЕИ ЗДРАВООХРАНЕНИЯ
RESOLUCION DE LA ASAMBLEA MUNDIAL DE LA SALUD

DECLARATION OF GLOBAL ERADICATION OF SMALLPOX

The Thirty-third World Health Assembly, on this the eighth day of May 1980;

Having considered the development and results of the global programme on smallpox eradication initiated by WHO in 1958 and intensified since 1967;

1. DECLARES SOLEMNLY THAT THE WORLD AND ALL ITS PEOPLES HAVE WON FREEDOM FROM SMALLPOX, WHICH WAS A MOST DEVASTATING DISEASE SWEEPING IN EPIDEMIC FORM THROUGH MANY COUNTRIES SINCE EARLIEST TIMES, LEAVING DEATH, BLINDNESS AND DISFIGUREMENT IN ITS WAKE AND WHICH ONLY A DECADE AGO WAS RAMPANT IN AFRICA, ASIA AND SOUTH AMERICA;

2. EXPRESSES ITS DEEP GRATITUDE TO ALL NATIONS AND INDIVIDUALS WHO CONTRIBUTED TO THE SUCCESS OF THIS NOBLE AND HISTORIC ENDEAVOUR;

3. CALLS THIS UNPRECEDENTED ACHIEVEMENT IN THE HISTORY OF PUBLIC HEALTH TO THE ATTENTION OF ALL NATIONS, WHICH BY THEIR COLLECTIVE ACTION HAVE FREED MANKIND OF THIS ANCIENT SCOURGE AND, IN SO DOING, HAVE DEMONSTRATED HOW NATIONS WORKING TOGETHER IN A COMMON CAUSE MAY FURTHER HUMAN PROGRESS.





PHOTO: TARANTOLA

Last case of naturally occurring variola major in the world: Rahima Banu of Kuralia village, Bhola Island in Barisal District of Bangladesh. Onset of rash was October 16, 1975.



PHOTO: WHO

Smallpox victim from Zaire.



PHOTO: JASON WEISFELD

Last case of naturally occurring smallpox: Ali Maow Maalin of Merka, Somalia. Onset of rash was October 26, 1977.



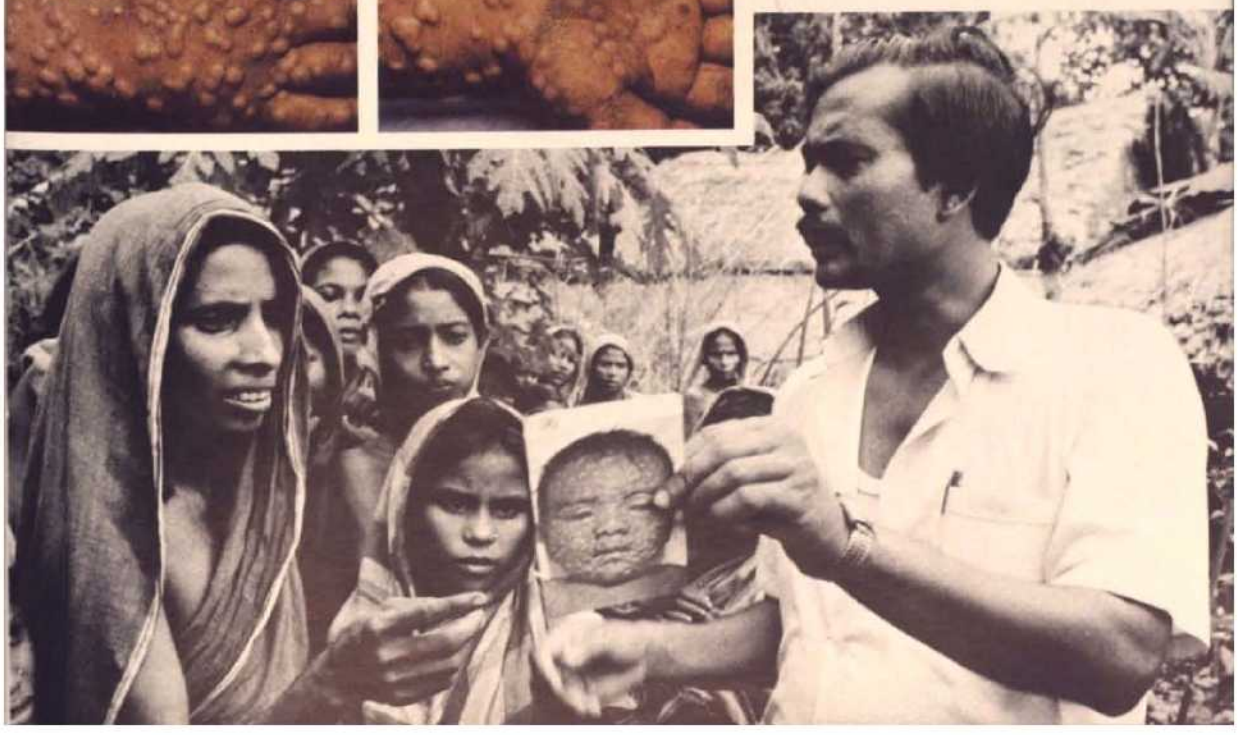
PROGRAM OPERATIONS



Left - *"Recognition card" developed by the World Health Organization to facilitate active surveillance for cases of smallpox.*

Below - *House-to-house search for smallpox, Bangladesh. Mr. Shahabuddin uses a recognition card.*

PHOTOS: WHO



Wall poster publicizing 250 taka reward for reporting Smallpox - Bangladesh, 1975.



PHOTO: WHO



PHOTO: D. HOPKINS

A potential vaccinee gets the word in Sierra Leone.

...ese
...ortant part
...people
...ox vaccinations
...Asia.

POSTERS: WHO

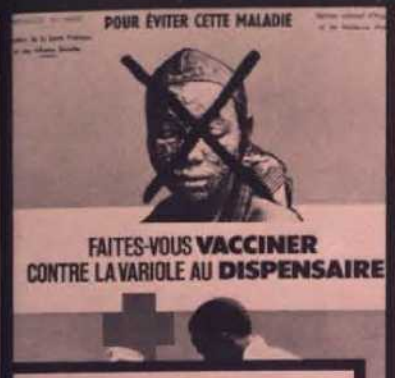




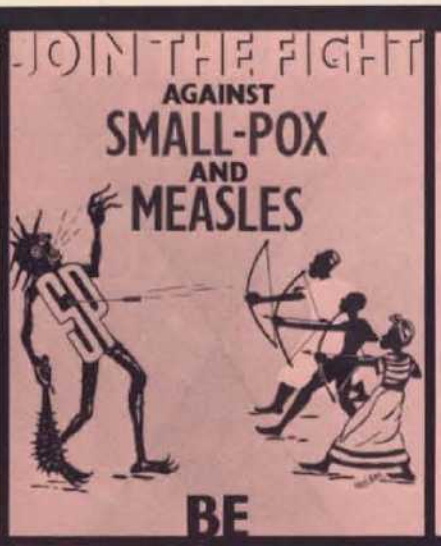






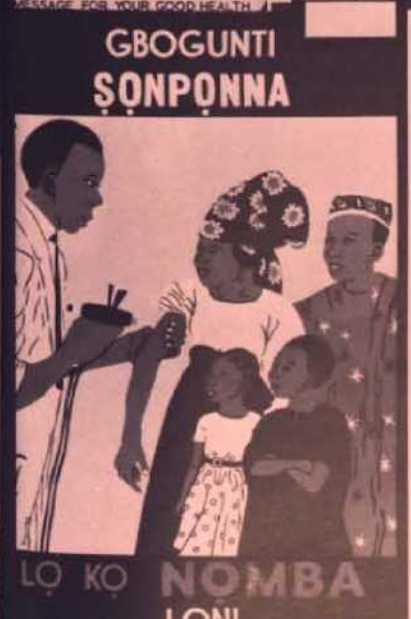


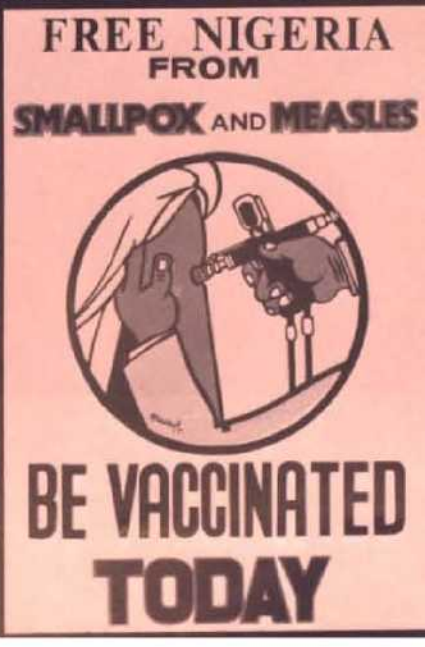






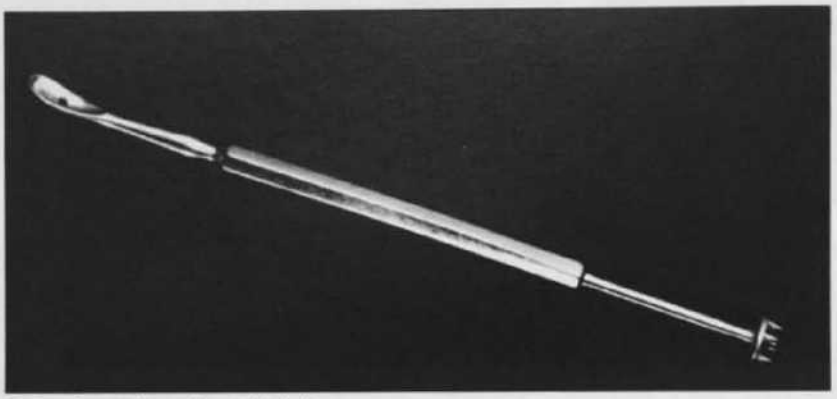




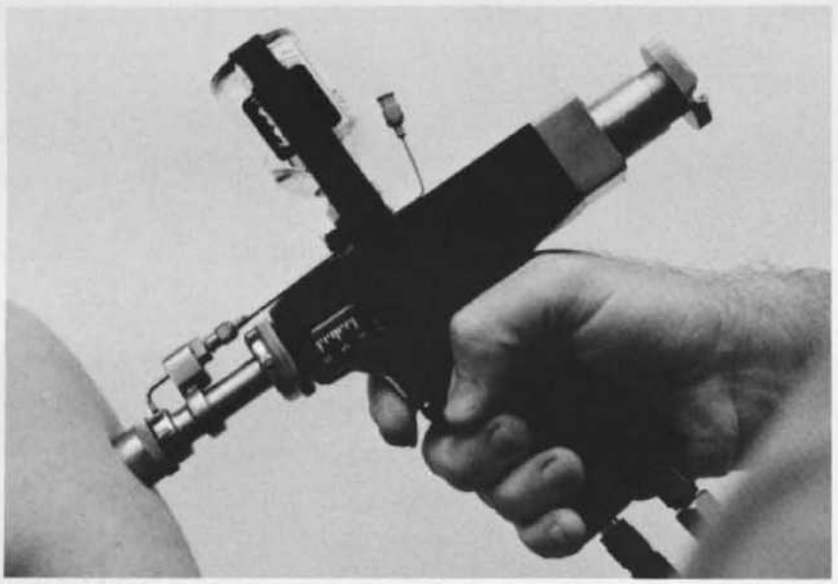








Rotary lancet *formerly used in India.*



Jet injector *helped make African program succeed.*



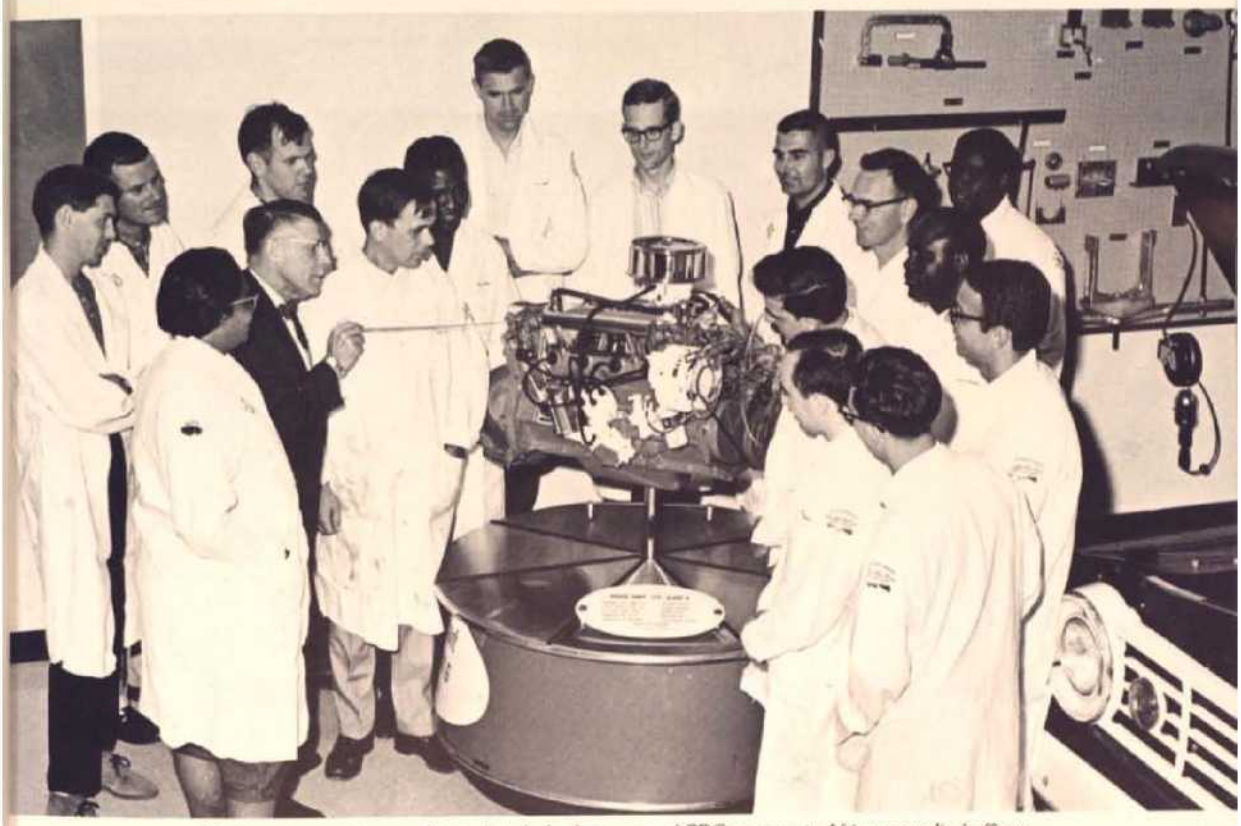
Bifurcated needle *in use.*



At Headquarters in Dacca, Bangladesh, Dr. Stanley O. Foster communicates by radio with field staff.



Brazilian girl being vaccinated by William W. Dyal with the "handgun," an early model, spring-operated jet injector (Amapá, 1965).



Basic engine repair was subject of study for first group of CDCers to go to Africa as medical officers and operations officers.



Child being vaccinated with jet injector in Nigeria, 1968.



Taureg girl in Mali pauses for vaccination against smallpox.



PHOTO: JAY FRIEDMAN



PHOTO: J. MICHAEL LANE, M.D.

Above
Jubilant vaccinee receives his certificate of vaccination, Mali, 1967.

Left
A Nepalese smallpox patient collecting smallpox scabs from his foot. Mr. Jay Friedman holds a small cup in which the specimens will be sent to the laboratory for diagnosis.

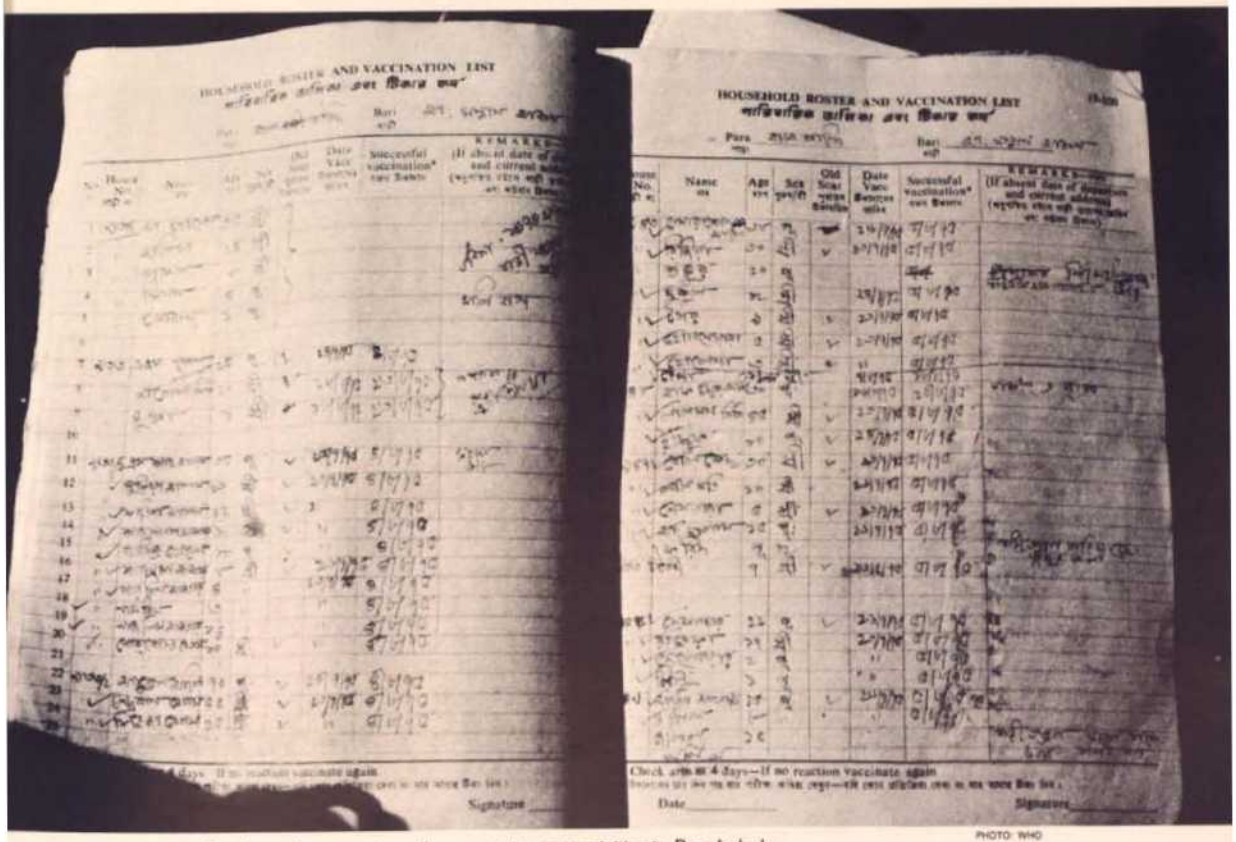


PHOTO: WHO

Book used to record smallpox containment activities in Bangladesh.



PHOTO: STANLEY FOSTER, M.D.

Vaccination lines at Yako, Upper Volta.





PHOTO: ROBERT J. BALDWIN

After waiting in long lines, each vaccinee received a certificate of vaccination.



PHOTO: WHO

Outbreak-containment vaccination of contacts in Bangladesh. Azizur Rahman on right.

TRANSPORTATION



Active seatches for smallpox in Bangladesh

PHOTO: WHO



On occasion, helicopters were used to reach remote locations, especially late in the eradication program.



Nonmechanical transportation used by operations officer Anthony R. Masso during a smallpox outbreak in Niger.



Dr. Jeffrey P. Koplan and counterpart travel from village to village searching for smallpox in Bangladesh.



The sun and the Dodge sink slowly into the Gambia River. This accident occurred at a ferry crossing.

PHOTOS: W.L. DES PREZ



Motor bikes and trucks provided by U.S. Agency for International Development were the principal mechanical means of transportation for the vaccination and surveillance teams in West and Central Africa. Mali.

Dr. D. A. Henderson led the WHO Smallpox Eradication Program from 1966 to 1976 while on loan from CDC.



PHOTOS: TROY L. HALL



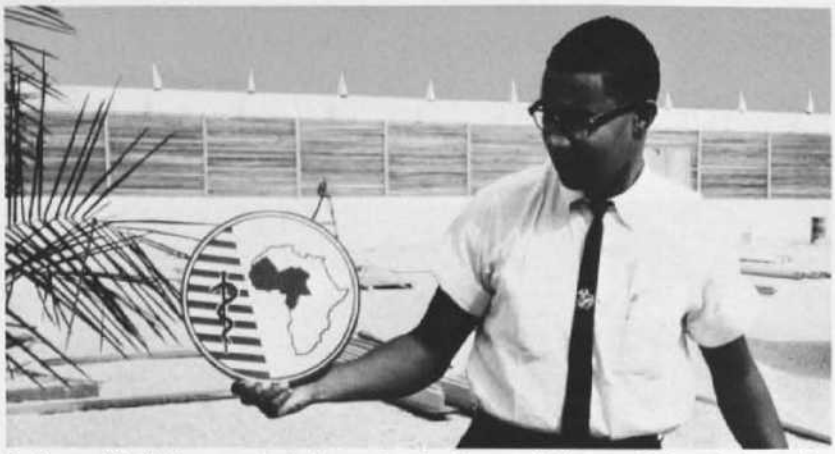
Three former directors of CDC's smallpox eradication efforts (L to R): Dr. J. Donald Millar (Chief, Smallpox Eradication Program, 1966-1970); Dr. William H. Foege (Chief, Smallpox Eradication Program, 1970-1973); Dr. J. Michael Lane (Chief, Smallpox Eradication Program, 1973-1981).



Dr. John Hannah, Administrator of AID, addresses group at ceremony celebrating the 100-millionth smallpox vaccination in the West and Central African campaign.



Dr. David J. Sencer, Director of CDC from 1965 to 1977, whose vision and leadership guided CDC's contributions throughout the global Smallpox Eradication Program.



Dr. Bernard D. Challenor, medical officer assigned to Togo and Dahomey, displays the logo of the CDC/AID West and Central African Smallpox Eradication/Measles Control Program.



PHOTO: TROY HALL

Celebrating the announcement on July 6, 1975, of eradication of smallpox in India (L to R: Dr. J. D. Millar, Mr. James W. Hicks, Dr. W. H. Foege, and Mr. Billy G. Griggs). In their midst is a clay figure of Shitala Mata, Indian goddess of smallpox.

Public Health Service Surgeon General Dr. William Stewart (EIS alumnus), dancing with Paramount Chief during ceremony in Ghana commemorating the 25-millionth smallpox vaccination in the West and Central Africa Program, January 15, 1968. Dr. George Lythcott, Director of the Regional Office in Lagos, standing behind the Surgeon General.

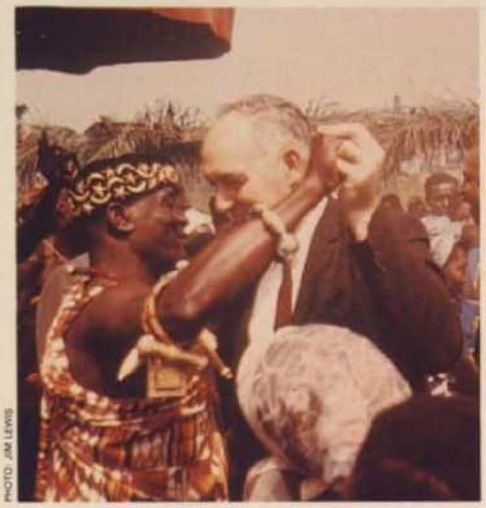


PHOTO: JIM LEWIS



Visit to Mali by PHS Surgeon General following ceremony in Ghana commemorating 25-millionth smallpox vaccination in the West and Central African Program. L to R: Mr. Jay Friedman, Dr. David Sencer, Surgeon General William H. Stewart, Dr. Pascal J. Imperato, Dr. J. D. Millar, Dr. George Lythcott, and Dr. Ben Blood of the Office of International Health.



Dr. D. A. Henderson addresses the annual regional meeting of the West and Central African program held in the Parliament Building, Lagos, Nigeria,in May 1969.



Dr. James H. Nakano working in a glovebox of the smallpox virus repository at CDC.

PHOTO: WHO



Dr. T. Stephen Jones and colleagues reviewing strategies for smallpox control, Syhlet, Bangladesh.

Man on left was the index case in smallpox epidemic in Kosovo, Yugoslavia, March/April 1972.



PHOTO: J. MICHAEL LANE



Dr. J. Michael Lane holds forth to an outbreak investigation team in Niger, 1967.



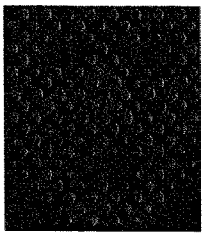
Proud father with infant who received the 100-millionth smallpox vaccination in the West and Central African campaign in Boubon, Niger, in December 1969. In background (L to R): Dr. J. D. Millar and Mr. Gordon E. Robbins.



Smallpox Eradication Program: *NCDC/WHO Orientation and Training Course, Atlanta, 1968*
Lower Row (left to right): *J. D. Millar (SEP/Atl.); D. Eddins (SEP/Atl.); J. M. Lane (SEP/Atl.); A. Kargbo-Reffell (Sierra Leone); M. Jenkins (SEP/Senegal); J. Donoho (SEP/Nigeria); M. Awadh (WHO/Zambia); G. Glokpor (Togo); T. Nchinda (Cameroon); F. Adibzadeh (WHO/Pakistan); Mrs. J. Bunn; J. Bunn (SEP/Atl.); E. Antezana (PAHO/Colombia); D. Vastine (SEP/Atl. - Course Coordinator).* **Upper Row:** *L. Roots (SEP/Niger); F. Ruben (SEP/Atl.); D. A. Henderson (WHO/Geneva); B. Griggs (SEP/Atl.); T. Mack (SEP/Atl.); K. Sanneh (The Gambia); W. Foege (SEP/Atl.); R. Barui (SEATO/Pakistan); K. Markvart (WHO/Pakistan); J. Hayward (FQP/Atl.); C. K. Rao (India); P. Bond (SEP/Nigeria); S. Jobe (The Gambia); J. Adetosoye (W. Nigeria); J. West (SEP Reg. Office, Lagos); D. Newberry (SEP/Ghana); R. Lyonnet (WHO/Tanzania); H. Godfrey (SEP/I.C.); R. Evans (SEP/Nigeria); R. Arnold (SEP/Nigeria); E. Coffi (I.C.); A. Samostreljskij (WHO/Somalia).*



Headquarters and Regional Office staff: *first OCEAC subregional meeting, Yaounde, Cameroon, 1967.*



4

DOMESTIC POLICIES FOR SMALLPOX CONTROL

Throughout the course of the campaign in West and Central Africa and in the years immediately following its triumphant conclusion, the Centers for Disease Control (CDC) played a leading role in the formulation of new policies for smallpox control in the United States based on increased knowledge of the disease and its changing status around the world. This same period saw the development of a different role for CDC in support of the World Health Organization's (WHO's) program for global eradication.

TRANSITIONS

As Donald Millar describes it: "In April 1970, only three weeks away from the last case of smallpox in West Africa, duty knocked unexpectedly on my door in the person of my boss, Dr. David J. Sencer." Sencer denies that he knocked. But they agree on the outcome. Sencer was asking Millar, who had been involved in CDC smallpox activities virtually from the first day and who had directed the Smallpox Eradication Program during its march through Africa, to "take the lessons you've learned in Africa and apply them in the United States." Millar shortly became Director of the Bureau of State Services, CDC's primary instrument for developing and enhancing disease prevention programs in partnership with state and local health departments. Succeeding Millar at the head of

the Smallpox Program was Dr. William H. Foege, principal author of the Eradication Escalation (E^2) strategy.

Following the achievement of zero-pox in West and Central Africa in 1970 and the painstaking searches to make sure that it had in fact been achieved, a maintenance phase was prescribed. This phase involved vaccination of the newborn cohorts and persons who had been missed originally and continued intensive surveillance. The shift in program needs, coupled with increasing reluctance on the part of the U.S. Agency for International Development (AID) to sustain its support beyond the five-year period originally agreed upon, resulted in a gradual withdrawal of the CDC forces in Africa. The staff at the Regional Office in Lagos was substantially reduced. Personnel in the field were increasingly given multi-country instead of single-country responsibility. Those who returned to the states, flushed with victory in what had been for many the most exciting duty tour of their careers, found, like Ulysses's warriors, that the reentry was tough and frustrating. Sencer has observed that bringing the people back from Africa and placing them on their return was much more difficult than recruiting them and sending them over.

CDC's relationships with AID, which had always been complicated, became even more so. As has been noted earlier in this narrative, AID had always placed higher priority on the measles component of the program. Even now, many of its officials seemed unwilling to acknowledge the magnitude of the achievement of smallpox eradication, although this accomplishment would have redounded greatly to AID's credit. The problems between the agencies took a turn for the worse in August 1970 when a highly placed AID official in Washington stated in a memo to Foege that "the measles program is a complete bust."

By any rational standard this was an unfair assessment. Much was in fact achieved in measles control, and many lives were saved in Africa as a consequence. In addition, valuable information was obtained about the epidemiology of measles in Africa and the problems attendant upon its control, most of which served to confirm CDC's refusal from the outset to conduct the program under the banner of "measles eradication." CDC studies revealed that fully 50 percent of measles cases occurred in children less than fifteen months of age. In heavily populated areas morbidity could be decreased by about half for one year following a mass vaccination campaign and for up to two years in sparsely populated sections. But the barriers to true eradication were very high, as CDC had suspected from the outset. Measles in Africa was much more highly communicable than smallpox; the heat-sensitive vaccines used at this time required a level of sustained refrigeration virtually unattainable in tropical areas; and the natural maternal immunity conferred to infants, which lasted six months or more, rendered vaccination useless in most of the very young.

Despite these formidable obstacles, CDC personnel and their African counterparts in one country, The Gambia, actually succeeded in interrupting measles

transmission for two years. To this day, this accomplishment has been duplicated in only one other country of either the developed or developing world, Czechoslovakia. In The Gambia it was achieved by a well-organized campaign based on the scrupulous application of a computer model developed by Dr. George McDonald, who had been Millar's mentor at the London School of Hygiene and Tropical Medicine. This model called essentially for a mass vaccination campaign yearly.

Valuable services had also been performed by CDC field personnel during the smallpox eradication/measles control program in dealing with other major diseases. In late 1969 outbreaks of yellow fever occurred in five countries—Ghana, Upper Volta, Mali, Nigeria, and Togo—the most widespread occurrence of this disease in West Africa in thirty years. In Mali the Minister of Health ordered the smallpox/measles teams diverted to the western part of the country to help contain the disease by conducting mass vaccinations against yellow fever. In Upper Volta the American Ambassador asked CDC to help contain yellow fever after it had been imported from Ghana; CDC's Thomas Leonard received a State Department Commendation Medal for his work in coordinating the containment activities.

Cholera, which had been absent from West Africa since 1894, was introduced into Guinea in August 1970. The disease spread to thirteen West African countries. Case fatality rates were initially very high since the disease was virtually unknown in the region. Cholera vaccine, though not considered an effective means of outbreak control, was offered and avidly sought, in some places in circumstances approaching panic. CDC was actively involved in cholera control on a broad front, both through the African smallpox/measles teams in the field and with medical officers who provided technical information and organizational assistance on rehydration treatment. These efforts were deeply appreciated by the individuals and countries concerned.

In September 1970, months after zero-pox had been declared in the region, a case of smallpox was reported from a remote village in Liberia. This alarming report triggered a massive surveillance sweep and vaccination campaign in the area. Drs. Edward W. Brink and Stan Foster were called in to assist the Liberia team of Messrs. Dennis G. Olsen and C. Randy Moser. Four cases of a rash disease were found, three in the first village and the fourth, with no traceable connection, in another. Subsequently, one additional case was found in Sierra Leone and another in Nigeria. But intensive searches failed to turn up a possible source case, which, if the disease were smallpox, had to exist somewhere. No further cases appeared. Finally, in December 1970, the CDC laboratory determined that the virus involved in these outbreaks was not smallpox but monkeypox.

Monkeypox in humans was a new epidemiological and public health problem. CDC's only previous reference to it had been in connection with an infection in a

monkey handler at the Detroit Zoo. Now, with the African outbreak, there was serious concern that confusion of monkeypox with smallpox might invalidate or discredit the eradication effort. The disease has been under careful surveillance ever since. Through the decade of the 1970s, some eighty-five cases of monkeypox in humans were identified in sporadic outbreaks, most of them in Zaire. Thorough study has shown that the disease, though clinically similar to smallpox, is not readily spread from person to person and does not mutate into smallpox. Thus, its existence does not compromise the validity of smallpox eradication.

The last Regional Conference of the West African Smallpox Eradication Program was held in Accra, Ghana, in 1971. CDC field personnel presented plans for ongoing activity in Africa, making use of the new infrastructures laboriously developed in the smallpox/measles program, for immunization programs against other diseases and for other public health purposes. Africans present at the meeting urged that support for health be extended beyond the original five-year agreement.

It was evident, however, that AID had already made the decision not to provide support for such programs. The agency's priorities were shifting from Africa to Southeast Asia, and within the reduced African program, assistance for health was a vulnerable target. Foege was officially notified that the African program must be phased out by December 31, 1971.

CDC Director Sencer decided to retain a presence and involvement in West African health affairs by assigning a senior epidemiologist, using CDC's own authority and funds, to the *Organization de Coordination et de Coopération pour la Lutte contre Grandes Endemies* (OCCGE) and another to the *Organization de Coordination pour la Lutte contre Endemies d'Afrique Central* (OCEAC). This course of action was made possible by some recent shifts of responsibility back home. Indeed, for the next two years, many CDC smallpox activities occurred within the United States.

SMALLPOX POLICY IN THE UNITED STATES

Foreign quarantine was among the first health responsibilities assigned to the U.S. Federal Government, dating back to the early nineteenth century. The quarantine boat with its yellow flag, bobbing up and down on the waters of the harbor, was a familiar and not always welcome sight to crews and passengers at the end of an ocean crossing. Quarantine inspection and, when deemed necessary, detention and isolation were the barriers a nation erected against the importation of the great epidemic diseases.

For most of its long history, the Foreign Quarantine Program had been lodged administratively in the Public Health Service's (PHS's) Bureau of Medical Services. In 1965 a PHS reorganization shifted foreign quarantine responsibilities to CDC,

as part of that agency's evolution as the PHS's primary arm for disease prevention. Over the next few years, the traditional quarantine service, little changed since the 1800s, was transformed. It became a system of "protection without walls" that was adapted to meet the needs of a world of high-volume, high-speed travel. In the reform process the number of "quarantinable" diseases was trimmed from twenty-two to six—specifically smallpox, plague, cholera, yellow fever, typhus, and louse-borne relapsing fever. The field staff was cut from 630 to 35, freeing human resources that could be used in other ways. Among many, the positions assigned to OCCGE and OCEAC came from this pool.

Above all, the new quarantine responsibilities and procedures gave CDC a solid mandate of its own to become more deeply involved in international health activities, as a means of carrying out its primary mission of protecting the health of Americans. The new system of protection depended on three basic factors: the maintenance of a strong system of epidemiologic surveillance within the United States; continuous flow of accurate and up-to-date information on the occurrence of diseases around the world; and, ultimately, the reduction of the threat of importation by the control, reduction, or in the case of smallpox, eradication of the disease where it is still endemic.

Dr. Sencer's determination to keep the CDC investment in global smallpox activity alive and his subsequent response to WHO's requests for assistance in Asia, described in the next chapter, were justified domestically. This justification was based on the premise that it would be both more effective and far more economical to assist in the accomplishment of global eradication than to maintain in perpetuity its defenses of widespread vaccination and outbreak containment in the United States. It was estimated in 1970 on the basis of 1968 data, that the United States was spending $150 million per year to protect its citizens against smallpox. At that rate the *total* cost of the multi-year CDC/AID commitment for smallpox eradication would be recouped every 2-1/2 months.

"Routine" Vaccination

In the 1960s smallpox vaccination was generally considered to be a routine part of pediatric practice in the United States and, in a sense, as one of the pillars of public health. Most children were vaccinated in infancy, and nearly all by the time they entered school. In most states, in fact, vaccination was a legal requirement for entering school.

It had not always been thus. Throughout the nineteenth and first quarter of the twentieth centuries, vaccination legislation had swung back and forth on alternate tides of fear of the disease and insistence on freedom of choice. Massachusetts had passed the first mandatory school vaccination law in 1855. New York soon followed, as did other states. But in 1909 California actually repealed its law requiring compulsory vaccination for schoolchildren. In 1922 the U.S. Supreme Court was called upon to rule that states did, in fact, have the right to

require vaccination for school admission. By the 1930s only nine states and the District of Columbia had compulsory-vaccination laws, six states provided for local option, twenty-nine had no laws at all, and four (North Dakota, Minnesota, Utah, and Arizona) had laws explicitly prohibiting compulsory vaccination. It is worth noting that between 1919 and 1928 the average annual incidence of smallpox per 100,000 population was 6.6 in the ten states with compulsory-vaccination laws and 115.2 in the four that prohibited compulsory vaccination.

Despite these controversies, however, vaccination in early childhood had become a standard part of the medical and public health practice of American physicians by the turn of the century. And the disease was declining. In 1927, for the first time, no outbreak of variola major was recorded in the United States, although variola minor, which had not been encountered in this country before 1896, was occurring sporadically. Occasional reports of outbreaks continued through the 1930s and early 1940s.

In the post-World War II era, smallpox in the United States was entirely limited to outbreaks resulting from importations. An American soldier returning from Japan in 1945 initiated an outbreak in Seattle that eventually totaled sixty-five cases with twenty deaths. In 1947 a man infected in Mexico brought the disease to New York, and by the time it was correctly diagnosed, secondary cases began appearing in persons who had been in contact with him in the hospital. This triggered a near-panic during which over 6 million New Yorkers were vaccinated. Finally, in 1949 an importation, presumably from Mexico, caused the last outbreak in the United States, in the Rio Grande Valley in Texas. This outbreak involved eight cases with one death, the last known fatality from smallpox in this country.

Meanwhile, complications resulting from vaccination, though extremely few in relation to the number immunized, continued to occur and take an annual toll. As has been mentioned earlier, a distinguished pediatrician, Dr. C. Henry Kempe, began in the early 1960s an impassioned campaign to eliminate the routine vaccination of children against smallpox. Dr. Kempe was an eminent authority; he had worked with smallpox for years in Madras, India, and now his pediatric department in a Denver hospital was the national referral center for vaccination complications. He reported to a meeting of the American Pediatric Society in 1965 that since 1948, 200-300 children had died from complications of smallpox vaccination in the United States, while there had been only the single death from the disease itself.

At that time CDC's recently established Smallpox Surveillance Unit began a systematic study of Dr. Kempe's hypothesis, led initially by Dr. John M. Neff and later spearheaded by Dr. J. Michael Lane. At this time CDC's position was that although Dr. Kempe's arguments were persuasive, the data on which they were based were not sufficiently solid to serve as the foundation for a major reversal of vaccination policy.

As has been noted, the controversy between Dr. Kempe and CDC came to a head in 1965 in connection with the handling of the presumptive case of smallpox imported from Ghana to Washington, D.C., which later turned out to have been misdiagnosed. Kempe felt that the extensive publicity generated by that "non-case" served to perpetuate a fear of smallpox and, therefore, to make the continuation of universal childhood immunization unassailable. Even so, he was supportive of the surveillance and other public health measures CDC had taken in connection with the Washington *cause celebre* and was from the outset a strong supporter of U.S. participation in global eradication.

Through the middle and late 1960s, while the campaigns in Africa were being waged, the CDC Smallpox Program in Atlanta was gathering data to provide an objective basis for a national immunization policy, which was becoming the subject of growing debate in the medical and public health communities. Among the factors to be considered were the true nature, extent, and distribution of vaccination complications; the relative likelihood of importation; the nature and extent of epidemics following importations into Europe and the United States; and the country's capability to deal with an imported case should one occur.

Using multiple and diverse sources, Neff, Lane, and their colleagues carried out intensive studies of vaccination complications in the U.S. population. Their data confirmed Kempe's basic thesis. Out of some 5-6 million primary vaccinations performed in the United States each year, five to ten recipients died from complications. The risk was especially high for infants, amounting to a rate of approximately five deaths per million in the population under one year of age. This fact, which became quickly evident, resulted in the recommendation as early as 1967 that primary vaccination in the United States be deferred until after the first year of life.

Other studies indicated that Kempe may actually have underestimated the total number of complications, since only the most serious cases tended to come to his attention. It was established that over 2,000 hospital days per year were necessary to treat vaccination complications.

One of the arguments invoked by those favoring continued routine vaccination of children was the need to maintain a high level of immunity in the general population. Millar himself had cited this argument in the earlier days of the debate. Studies were now showing, however, that the immunity level of the general U.S. population never was very high—probably not above 40 percent—because of the relatively low frequency of revaccinations following the primary vaccination in early childhood.

Meanwhile, of course, the likelihood of importation was decreasing rapidly as more and more countries became smallpox-free. The explosive growth of air travel, which brought every part of the world within a day of our doorstep, was more than counterbalanced by the diminishing reservoir of smallpox in the world. By 1971 only eight countries in the world still had endemic smallpox.

Even in these countries the rates of incidence were diminishing as eradication programs progressed. Moreover, smallpox was increasingly becoming a disease found only in isolated rural areas or among the urban poor. Its victims were thus extremely unlikely to travel to the United States, and the chances that an international traveler to a country with endemic smallpox might experience the kind of face-to-face contact required for smallpox transmission were very remote. The historical record demonstrated the unlikelihood of importation to the United States: after 1949, although the disease was still endemic in Brazil and throughout Asia, Africa, and the Middle East, not a single importation had occurred here, even though several had occurred in Europe.

Nevertheless, one *might* occur. The possibility could not be dismissed so long as smallpox existed anywhere in the world. Many, including medical practitioners, had fears of an epidemic's sweeping rapidly through an unprotected population. But knowledge of smallpox epidemiology gained during the eradication programs made it clear that such fears were unrealistic. The disease was clearly less infectious than, for example, measles, chickenpox, or influenza. It spread slowly, through direct contact with an overtly ill patient. Thus, an outbreak could be quickly controlled, as we have seen, by containment—isolation, contact tracing, and vaccination of those in the immediate environment of the patient.

Recent experience with importations into Europe served to demonstrate the success of these techniques. During the 1950s, when there had been twenty-three importations, an average of twenty-six cases occurred as a result of each. Between 1966 and 1970, when ten importations were reported, the average number of cases per importation had been reduced to ten, and most of these were the result of a single outbreak of variola minor in England. One-third of the importations resulted in no indigenous cases at all.

As evidence accumulated in support of a change in the time-honored smallpox vaccination policy, CDC faced the task of gaining acceptance for the change on the part of the nation's public health authorities and private physicians. This was no easy chore and could not be accomplished overnight, since routine vaccination of children was a foundation stone of public health practice. The "safe" thing to do was to make no change as long as any risk of importation remained, however small, and the public health fraternity is no less prone to this kind of conservatism than any other. Accordingly, the Smallpox Program was engaged, beginning in the late 1960s, in a process of gradually converting state health officers, pediatric societies, and others to what seemed to some a revolutionary notion.

Finally, in October 1971 the Advisory Committee on Immunization Practice of the PHS issued guidelines recommending the cessation of routine smallpox vaccination in the United States. As summarized by Lane and Foege, the decision was based on five lines of evidence:

> First is the rapidly dwindling reservoir of smallpox. Second is the low risk of importation. Third is the low risk of the spread of the disease after a theoreti-

> cal importation. Fourth is the relatively low state of immunity brought about by our old policy. Fifth is the slight but significant risk of primary vaccination.

At that stage of the worldwide eradication effort, of course, the PHS recommendations, like those of WHO, called for continued vaccination of international travelers, especially those traveling to countries where the disease was still present, and the inspection of vaccination certificates of foreign nationals entering the country. They also stressed again the importance of vaccinating medical and hospital workers since, as we have noted before, smallpox in developed countries had become primarily a hospital-acquired disease.

Dissemination of new policies is not instantaneous, even when the leadership has been persuaded, and their adoption is far slower. This is especially true when the new policies require abandonment of career-long beliefs and practices. Lane estimates that during the mid-1970s there was an annual 50 percent reduction in childhood smallpox vaccinations. It was not until the end of the decade that the practice was virtually eliminated. Routine vaccination against smallpox, which had won acceptance only after a long struggle, died hard. But die it finally did, after the disease was gone.

Trouble in Europe

Two particularly important outbreaks occurred in Europe in the early 1970s. Both were the result of importations. The first, in the town of Meschede near Düsseldorf in the Federal Republic of Germany, began in January 1970 when a twenty-year-old West German male returned home from Pakistan, where he was reported to have wandered for some days and perhaps slept in the streets of Karachi. He arrived in Germany with a valid vaccination certificate dated the previous year, but it became evident that he had never been successfully vaccinated. On January 10 he was admitted to a private room in an isolation ward of Meschede Hospital with a febrile illness first diagnosed as typhoid fever. Despite a seemingly well-designed isolation facility and careful adherence to procedures, seventeen additional cases developed between January 22 and January 31, well within the incubation period for contact cases, and two more in mid-February. All were associated with the Meschede Hospital, and none of the smallpox patients, so far as could be determined, had had direct contact with the index case. Four of the total of twenty cases resulted in deaths: one nurse, two patients, and a patient contact died. The last three who died had relatively mild smallpox cases but were already seriously ill.

Dr. Henry M. Gelfand, whom we have met before in the early days of the CDC smallpox activity and in the negotiations for and management of the West African campaign, was at that time stationed in London with CDC's foreign quarantine program. Studies of the Meschede outbreak in which Gelfand and Dr. Paul H. Wehrle, a U.S. epidemiologist working with WHO, collaborated with West German officials indicated that the only possible means whereby the dis-

ease could have been transmitted throughout the well-maintained three-story isolation wing was via the air circulation system. The experience sounded a warning for handling of future imported cases. It also served to reinforce the already well-recognized urgency for adequate protection on the part of hospital workers.

Shortly after the PHS issued its revised policy on routine childhood immunizations, a much larger and more sobering episode occurred in Yugoslavia, a country that had been smallpox-free for forty years. A thirty-five-year-old Yugoslavian male, returning from a pilgrimage to Mecca to his home in Kosovo Province along the Albanian border, initiated an outbreak that was the largest Europe had experienced in many years. Happily, it also turned out to be the last of any size.

Mike Lane recalls: "We had just stopped routine vaccination, and here were 174 cases from an importation. Everyone was thinking 'Can it happen here?' " Acting quickly and appropriately on its quarantine authority, CDC sent a team of seven to Yugoslavia, at that government's invitation, with Lane as the chief of party. They took twenty-four jet injectors and 3 million units of vaccine. Several European countries contributed large amounts of vaccine as well.

The majority of the 1.1 million people in Kosovo Province were of Albanian origin, and that region was the least developed economically in the country. Because of Yugoslavia's multiethnic and multilingual makeup and its decentralized administrative procedures, problems of communication and logistics were particularly challenging. Vaccine inventories were hard to maintain, and vaccination schedules difficult to meet. The Yugoslavian Army was well organized and committed to help, but the national policy of sending recruits to serve in areas outside their native province reduced the army's effectiveness in dealing with the local people.

Active surveillance was carried out in the infected villages, where house-to-house searches were undertaken. But contact tracing was difficult, and the number of susceptible persons could not be easily determined because many had been vaccinated with an outdated vaccine.

The Yugoslavian outbreak persisted for three generations of cases, of which the largest number, 133, were in the second. The final toll was 174 cases with thirty-four deaths. The spread was facilitated by the fact that the index case, which was very mild, had gone undetected, and other very mild cases infected substantial numbers of people.

The CDC team felt that their potential contribution to control of the outbreak was not fully realized because Yugoslavian health officials tended to view them chiefly as vaccinators and ped-o-jet experts. Nevertheless, the U.S. Ambassador to Yugoslavia wrote at the end of the episode that "the CDC team can claim considerable credit for the fact that the outbreak was quickly contained and

brought under control." He also noted that in many parts of Yugoslavia "the possibility of being vaccinated by the 'American pistols' became a major drawing card, inducing people previously unvaccinated or those whose earlier vaccinations did not take to undergo vaccination by 'jet.' "

While the Yugoslavian outbreak was going on, CDC's foreign quarantine program placed under disease surveillance all travelers from Yugoslavia who did not have a valid smallpox vaccination certificate or who had been vaccinated within the last fourteen days. EIS officers were stationed at John F. Kennedy (JFK) Airport in New York and O'Hare in Chicago. The presence in Yugoslavia of a CDC team, whose daily telephone calls pinpointed the precise location where cases were occurring, enabled the surveillance effort to focus on those travelers whose itineraries placed them at greatest risk. Other contingency plans included the selection of a suitable isolation ward in New York for use if a suspected importation arrived. The choice fell on an underused area of the PHS hospital on Staten Island, but it was never needed. No suspect case showed up.

The Yugoslavian outbreak had served as yet another reminder of the importance of protecting hospital and medical staff and had demonstrated the potential danger of spread of the disease from mild cases that might be difficult to detect. After some months of activity and concern on both sides of the Atlantic, the books were closed on the episode with the new vaccination policy unshaken.

Vigilance and Readiness

The new, streamlined system that had replaced the traditional quarantine approach to disease protection was in place and functioning well by the summer of 1970. In one typical instance, a young American woman arrived at JFK Airport at 8:30 on a Thursday evening, on a flight from Copenhagen. She was feeling ill, and a customs inspector who talked with her noted signs of a rash around her mouth. Her itinerary showed that two days before she had been in Pakistan, where smallpox was still endemic. A physician at the airport could not rule out smallpox by visual examination, and she and her traveling companion were taken to the Staten Island Hospital for observation.

Meanwhile, the machinery was moving. An EIS officer carried clinical specimens from New York to CDC's laboratory in Atlanta for testing. By morning seventy-two of the young woman's eighty-three fellow passengers from Copenhagen had been identified, and their U.S. destinations noted. Inquiries had been sent to Copenhagen to trace the other eleven. Intervening flights she had taken between Karachi and Copenhagen were identified. Telegrams of notification were prepared for the foreign governments involved, and the notification system for health officers of the states where her fellow passengers were going was ready to be activated. At Staten Island on Friday morning, the young woman was showing classical smallpox symptoms—headache, fever, rash on the hands and feet. Then the CDC laboratory provided the story with a quick and happy ending.

She was suffering not from smallpox but from herpes simplex. In less than twenty-four hours she was on her way home, and her fellow passengers were going about their business unaware of the public health attention they had all enjoyed.

Strengthening and assuring the effectiveness of this system of protection without walls was a high priority for the CDC Smallpox Program in the early 1970s. They did it through a process that Foege describes as "vintage CDC: taking science to the states." Digesting and adapting the experiences gained in Africa and the rapidly accumulating knowledge on smallpox epidemiology from around the world, they developed for the state health departments what was called the *CASE Manual*. The acronym stood for "Comprehensive Action in a Smallpox Emergency."

The *CASE Manual* consisted of a notebook that contained, in its front pocket, a two-page foldout depicting graphically what needed to be done in case of a smallpox importation. In the pocket inside the rear cover was a PERT chart detailing who should do what to whom, in what sequence, to stop an outbreak. Each page of the notebook expanded on a box in the chart. Such essential tasks as isolation techniques, contact vaccination procedures, investigation and search methods, and obtaining of laboratory diagnosis were spelled out.

Development and use of the manual not only brought the states "up to speed" but forced CDC itself to think through how an outbreak would be contained. This effort also became the basis for outbreak control plans for other diseases that might be imported, such as Lassa fever.

Through the early 1970s the surveillance system was becoming more and more efficient. It was possible for the program to obtain a diagnosis from the CDC laboratory in a remarkably short time. The system operated twenty-four hours a day, with specimens not infrequently arriving after midnight. When a person with suspected smallpox was detained at JFK, specimens would be taken and split in two, and one-half retained. The other half would be dispatched to Atlanta by the fastest available means. If necessary it would be hand-carried to CDC by a public health advisor, an EIS officer, or someone else who could be pressed into service. Special kits for this transmittal process were developed and used. It was not unusual for a phone call releasing the person from quarantine to come back to JFK from CDC in four hours.

Evolution of the CDC Smallpox Laboratory

The swift and reliable diagnostic service on which this system was based depended, above all, on laboratory services of the highest quality. By the late 1960s the CDC smallpox lab had come a long way from the fledgling unit whose false-positive finding on the suspected importation from Ghana to Washington,

D.C., in 1965 had brought a shower of notoriety. It had, in fact, become the premier smallpox lab in the world.

When the West African program was in its preparatory phase in 1965, Dr. Henry Gelfand recruited a young scientist then working with polioviruses, Dr. James H. Nakano, to begin formation of a laboratory to support the smallpox program. An important management decision was made at the outset: the Smallpox Eradication Program would get full support from the smallpox laboratory, but organizationally the lab would remain as part of the Virology Section of what was then the CDC Laboratory Branch. This early example of "matrix management" gave the program what it needed while assuring that the laboratory would be able to draw on the full scientific and technical resources of the Center.

Dr. Telford Work, Chief of the Virology Section at the time, had obtained CDC's first electron microscope in 1964. Thereafter, electron microscopy became the primary method for rapid diagnosis of smallpox, surpassing other methods in speed and reliability. Nakano and a young medical officer with laboratory experience, Dr. John Noble, Jr., were sent in early 1966 on a whirlwind tour of European facilities in Great Britain, the Netherlands, Germany, and Denmark to gather the information necessary for establishing a national reference diagnostic laboratory for smallpox at CDC.

A first task on their return was to design and build a smallpox lab that would not allow a laboratory-associated case of the disease to occur. The resulting facility, completed in 1967, and the personnel procedures attendant upon it were widely regarded to provide the safest such lab environment in the world. Later refinements were added in 1972, and a totally new "hot-lab" facility supplanted it in 1982, but the laboratory designed and presided over by Dr. Nakano served its purpose without mishap through the busy years of the late 1960s and 1970s.

In addition to the continuing task of case diagnosis and confirmation, working on samples from sixteen African countries with endemic smallpox and from many others around the world, CDC's smallpox laboratory was involved in many related scientific problems. Its work was instrumental in delineating the strengths and weaknesses of various laboratory diagnostic methods; in demonstrating that no reservoir of smallpox could be maintained in wild animals; in differentiating among various pox diseases including, significantly, monkeypox; and in testing the possible survival of the smallpox virus in materials used for variolation. Papers and textbook chapters written by Nakano and his associates between 1968 and 1985 constitute a key scientific resource in this field.

In the spring of 1968, the CDC laboratory officially became a part of WHO's global smallpox eradication effort as a WHO Regional Reference Center for Smallpox. Its status was upgraded in 1972 to that of a WHO International Reference Center, in recognition of its worldwide activities, and in 1974 it was named a WHO Collaborating Center for Smallpox and Other Poxvirus Infections, a title it retains. As of 1987 it is one of only two such Collaborating Centers in the

world, the other being located in the Research Institute for Viral Preparations in Moscow. In this capacity CDC is responsible for the storage and maintenance of smallpox virus strains transferred from other countries and organizations, including Japan, the United Kingdom, the Netherlands, the U.S. Army, and the American Type Culture Collection. The Moscow laboratory maintains its own repository. These two facilities contain all the smallpox virus extant in the world.

Prior to 1974 the CDC smallpox laboratory received an average of about 300 virological specimens per year. Then as the achievement of worldwide eradication drew near, the pressure increased. As a country approached interruption of transmission, it faced the need to be absolutely certain of diagnoses, and thus specimens from an increasing number of doubtful or suspect cases were submitted for examination. Dr. Nakano, whose work in smallpox had begun in 1966, personally worked on the material from the last case of naturally occurring smallpox, which occurred in Somalia in October 1977. Then in 1978, as WHO proceeded with its country-by-country certification process, the CDC smallpox lab received and processed a record total of more than 4,000 specimens.

A NEW INTERNATIONAL ROLE

As has been noted earlier, the success of the smallpox eradication campaign in West and Central Africa proved beyond reasonable doubt that global eradication was feasible in a finite length of time. No other part of the world posed a greater challenge. Yet the combination of rudimentary or nonexistent infrastructures, transportation and communication difficulties, political and cultural complexities, and widespread occurrence of the disease had been overcome.

It is not surprising, therefore, that D. A. Henderson at WHO called upon his CDC comrades-in-arms to help WHO build support and enthusiasm in those countries where the disease was still endemic. As a result Foege, Millar, Lane, and others became, to use Foege's word, "evangelists." They not only "rode the circuit" of WHO-sponsored regional and intercountry meetings to tell the Africa story, but also on occasion spent substantial time on working missions to teach the technology learned in Africa and assist countries in other ways. Meanwhile, succeeding World Health Assemblies, drawing on the CDC experience, were urging countries to strengthen their surveillance, case investigation, active containment measures for outbreaks, and assessment activities.

While the Africa campaign was going on, a CDC epidemiologist-statistician, Dr. Leo Morris, had been seconded to WHO for assignment to Brazil, the last stronghold of smallpox in the Americas. There for more than three years, he played a key role in helping provide continuity and accountability for that country's eradication effort. After 1971, CDC personnel in growing numbers were sent to work in national programs in nearly all the remaining countries with endemic smallpox, under WHO auspices. The final chapter of this narrative describes this different but vital CDC role in the triumphant final phase of the global eradication story.

05

SMALLPOX CONQUERED

THE WHO INTENSIFIED PROGRAM

The Twentieth World Health Assembly in 1967 completed the process of committing the World Health Organization (WHO) to the goal of global eradication, following up on an earlier resolution in 1959 and another in 1966 that formalized a regular budget for smallpox eradication. The 1967 resolution requested WHO "to elaborate and implement the detailed plan, including the coordination of all international, bilateral and national efforts" for an Intensified Smallpox Eradication Program.

At that time, which coincided with the launching of the Centers for Disease Control/U.S. Agency for International Development (CDC/AID) program in West and Central Africa, a world map of smallpox occurrence showed five major areas of the world in which the disease was endemic: South America, represented by Brazil; West and Central Africa; eastern and southern Africa; a solid block of countries across southern Asia stretching from Afghanistan to Burma; and the great archipelago of Indonesia. A total of thirty-one countries were identified as having endemic smallpox; of these, thirteen, including six in West Africa, were reporting rates of greater than five cases per 100,000 population. The five epidemiological zones noted above were significant because, due to

geographic separation and travel patterns, it was considered unlikely that reinfection by importation would occur once eradication was achieved in a given zone.

The true extent of the disease was difficult to estimate until the late stages of the campaign when national and international surveillance was fully developed.

In 1967, the year the Intensified Program began, a total of 131,793 cases were reported, the highest number in almost a decade. Only a small amount of the increase could be attributed to improved reporting. But the number, sobering in itself, was known to represent only a small fraction of the true total. Early field observations had suggested that perhaps one case in twenty was being reported. Later experience in many countries indicated that the true figure was probably closer to one in 100. Total cases worldwide were unquestionably in the range of 10-15 million in 1967. Implementing a global program was a great deal more difficult than enacting a resolution. Even though it was passed unanimously by an assembly representing almost all the ministries of health of the world, and could therefore be considered morally binding, the resolution carried no guarantees of active support. Universal characteristics of the countries in which the disease remained endemic were a multiplicity of health problems and extremely limited resources.

WHO itself was, by global standards, a relatively small organization with a total professional and secretarial staff worldwide of only 3,300. The number assigned to smallpox at no time exceeded 150, including consultants. Moreover, from its founding WHO had viewed its role vis-a-vis the member states as one of responding to their requests for assistance, based on self-determined priorities, rather than of imposing of a program from without. In this response the WHO regional offices played a major role. In fact, as late as 1966 Dr. Marcelino Candau, then Director-General, had cautioned his regional directors against appearing to impose smallpox eradication on their respective constituencies. Two regions, the Americas and the Eastern Mediterranean, incorporated eradication in their regional plan that year. Africa and Southeast Asia did not.

As noted in Africa, the urgency accorded to smallpox eradication by national health authorities varied widely. In several West African countries, it was initially undertaken as a "rider" to the more popular measles control effort. In Brazil, where the only strain of smallpox was variola minor, with a very low case fatality rate, the "big three" diseases to which major attention was given were schistosomiasis, Chagas' disease, and malaria.

In addition, of course, honest doubt remained among many responsible health authorities at national, regional, and global levels as to whether eradication was, in fact, achievable at all. The success story of the West African campaign was a powerful force for allaying these doubts, which is why D. A. Henderson and the CDC "evangelists" recounted it again and again at intercountry meetings. But despite this evidence that it could be done and the certainty that nothing less than true worldwide eradication would be satisfactory, resources were difficult to

come by. The annual item for smallpox in the WHO regular budget never rose significantly above the level of $2-$4 million (U.S.) initially earmarked in 1966. Pursuit of funding from outside sources yielded relatively little until the late stages of the campaign in Asia.

WHO STRATEGY

By the time the Intensified Program got under way, the strategic plan for eradication was based on two elements: mass vaccination campaigns, using vaccine of assured quality and accompanied by assessment of coverage and take rates, and the development of a surveillance system for the detection of cases and containment of outbreaks. These principles were elaborated in the WHO *Handbook for Smallpox Eradication in Endemic Areas*, which was adapted from the CDC manual developed in 1966.

The concept of mass vaccination was familiar to public health authorities and readily accepted, though it was not always successfully implemented. Assessment, surveillance, and containment had not been commonly practiced. Their importance was not widely recognized, and they proved difficult to incorporate in many countries whose resources were severely strained just to support mass vaccination.

For some years it had been assumed that, when the proportion of susceptible persons in the population had been reduced sufficiently, transmission would cease. Vaccination of 80 percent of the population within a four- to five-year period was believed to be the requisite for this to occur. The figure 80 percent, however, was based less on hard scientific data than on a sense that this would represent an attainable level for a competent program. Then in 1964 a WHO Smallpox Expert Committee declared 80 percent to be insufficient and recommended a goal of 100 percent vaccination coverage. The recommendation was based on data from India showing that smallpox persisted in some areas where the number of vaccinations performed exceeded 80 percent of the total population. Later field studies by Dr. Henry Gelfand indicated that the total number of vaccinations administered was a very unreliable index to actual population coverage, because of the use of subpotent vaccines and frequent revaccination of the most easily accessible groups, such as schoolchildren. In other words, the total numbers of vaccinations reported included numerous revaccinations of the same individuals and many vaccinations of people who were never successfully immunized at all. The effective output of a mass immunization campaign could only be determined accurately through careful assessment of coverage and take rates, a process that, unfortunately, was considered by many countries to be a luxury their programs could ill afford.

So too with surveillance, which also tended to get short shrift in resource allocations. The WHO *Handbook* stressed the importance of surveillance in connection with the ultimate goal of eradication:

> The success of the programme, therefore, is appraised ultimately by the occurrence or absence of endemic smallpox and the principal assessment technique, accordingly, is surveillance. . . . However extensive a country's vaccination campaign, however accurately assessed, a country with an inadequate system for surveillance cannot determine whether eradication has been achieved.

Viewed thus, surveillance could be seen as an important activity only in the later stages, as eradication drew near. Its value as an offensive weapon for accelerating the interruption of transmission was more fully appreciated later.

As has been shown, one technological development, the jet injector adapted for field conditions as the ped-o-jet, had greatly enhanced the chances of success in West and Central Africa. In 1968 another such development, the bifurcated needle, became available as a result of research at a major U.S. pharmaceutical company.

The bifurcated needle was employed in the multiple-puncture vaccination technique. When dipped in vaccine, the needle collected the correct amount of liquid for a vaccination between its two points. It was easy to use—in only ten to fifteen minutes a local villager could be trained to reconstitute vaccine and perform successful vaccinations. It was inexpensive, costing only about five U.S. dollars per thousand. Moreover, the needles could be reused repeatedly after sterilization by simple boiling. By measuring the exact amount of vaccine needed for successful vaccination, they conserved vaccine supplies and reduced wastage. Use of the bifurcated needle eliminated the persistent problems of maintenance and repair of the jets. Finally, while the jet injector had been effective in permitting quick vaccination of large numbers of people standing in line at an assembly point—the procedure generally used in Africa—the bifurcated needle was especially adaptable to the house-to-house procedures found to be necessary in most of Asia. Being easily portable, the bifurcated needle enabled large numbers of vaccinators to set forth by bicycle or on foot.

For all these reasons the bifurcated needle supplanted the jet injector as the instrument of choice in almost all programs conducted after 1970 and was in every sense instrumental in their ultimate success. It was perhaps the most tangible product, but by no means the only significant outcome, of research conducted during the course of the Intensified Program. At the outset, many had believed that research should not be a key element of the strategy—essentially, that everything needed for eradication was already known, waiting to be applied. WHO, although it had only minuscule resources of its own for this purpose, included research in its plan and encouraged the development and sharing of new knowledge while the program was in progress.

Many appropriate topics for ongoing research were identified in clinical, epidemiological, technological, and laboratory areas. As we have seen, epidemi-

ological data collected during the campaigns challenged the traditional wisdom about the disease and led to substantial changes in the tactics of eradication. The CDC laboratory, and others in several countries under governmental, academic, or private sector auspices, made important improvements in diagnostic techniques. They also examined in depth the question of a potential, natural, nonhuman reservoir for the smallpox virus and made important contributions to knowledge concerning other poxvirus diseases in man and animals. The willingness of scientists to share this information widely and rapidly, often before professional papers could be formally produced and published, permitted the programs to benefit immediately from new discoveries and make operational changes as indicated.

CHRONOLOGY OF CONQUEST

As a backdrop against which to project the role played by CDC personnel in the final stages of global eradication, working with national counterparts under WHO auspices, it may be useful to trace briefly the progress of the worldwide struggle during the years leading up to the achievement of zero-pox in 1977.

In 1967, the year that marked the beginning of both the WHO Intensified Program and the CDC/AID African campaign, thirty-one countries were considered smallpox endemic. These included one in the Americas (Brazil); seven in Asia (Afghanistan, Bangladesh, India, Indonesia, Nepal, Pakistan, and Yemen); eleven in West and Central Africa (Cameroon, Dahomey, Ghana, Guinea, Liberia, Mali, Niger, Nigeria, Sierra Leone, Togo, and Upper Volta); and twelve in eastern and southern Africa (Burundi, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, South Africa, Tanzania, Uganda, Zaire, Zambia, and Zimbabwe).

By the end of 1967, fourteen of these thirty-one countries had special programs under way—eight in the area of the CDC/AID program in West and Central Africa. Brazil had launched its national program late in 1966 after many delays. Zaire (then the Democratic Republic of the Congo) began its program late in 1967, as did Indonesia. Three WHO-supported programs were under way in Afghanistan, Nepal, and Zambia. Other countries were planning major efforts for 1968 and 1969. However, India, which was reporting more than half the world's cases, was considering termination of its five-year-old national mass vaccination campaign.

At the beginning of 1968, the total number of countries with endemic smallpox remained at thirty-one. Ghana had interrupted transmission, but Sudan had become infected following importations from Ethiopia. By the end of the year, six more of the West African countries were smallpox-free. Elsewhere in Africa, Uganda and Zambia stopped transmission. In Indonesia the province of East Java, with over 25 million inhabitants, became free of the disease. Other important developments included an intercountry seminar in Zaire to stress the concept of surveillance and the initiation in May of regular biweekly reports on the

program through the WHO *Weekly Epidemiological Record*, distributed throughout the world.

By the end of 1969, the number of countries reporting endemic cases had dropped to eighteen, as all but Nigeria of the West and Central African countries achieved zero-pox along with Kenya, Mozambique, and Yemen. Reported cases throughout the world had declined to 54,215, well below half the 1967 total, despite more complete reporting in many countries. Formidable problems remained, however, in Zaire, Sudan, and Ethiopia; in the giant Asian countries of Indonesia and India; and in West and East Pakistan. Also in 1969, the WHO Executive Board formally recommended that every country investigate every outbreak and apply vigorous containment measures.

The year 1970 was marked by interruption of transmission in six more countries. These included Nigeria, which left the entire region of West and Central Africa smallpox-free, the first of the five endemic zones to achieve that status. Also included, very surprisingly, was East Pakistan, soon to become Bangladesh and soon also, unfortunately, to be devastatingly reinfected. Brazil in 1970 appeared to be on the brink of success. Indonesia estimated that 85 percent of its people lived in smallpox-free areas. Of the twelve remaining countries with endemic smallpox, four seemed farthest from the goal—Sudan and Ethiopia in Africa and India and West Pakistan in Asia. Also in 1970, though not recognized until later, smallpox temporarily became reestablished in Iran. At a seminar for the South East Asia Region in New Delhi, veterans of the West African and Indonesian campaigns described in detail their successes with the strategy of surveillance and containment.

Two years later, by the end of 1972, only six countries had endemic smallpox. One, Botswana, which had reentered the list with widespread reinfection in 1970, was down to its last twenty-seven cases. Another, Nepal, traced virtually all its remaining 277 cases to importations from India. That left four with formidable problems: Ethiopia, India, Pakistan, and now-independent Bangladesh, where the disease had been reintroduced on a huge scale by 10 million refugees streaming back into the country from infected camps in India.

During these two transitional years, containment of the last cases in Brazil in April 1971 left the entire Western Hemisphere smallpox-free. Afghanistan and Indonesia had achieved zero-pox through heroic effort, as had Sudan, which interrupted transmission very quickly after its civil war ended. In western Asia, Iran, Iraq, and Syria all had reentered the endemic list and then successfully removed themselves from it—but not before an exported case from Iraq had triggered Europe's last large outbreak, as already described, in Yugoslavia.

Thus, as 1973 began, the stage was set for the final push, a further intensification of the Intensified Program. Evidence was clear that a major push was needed. In the first six months of 1973, nearly 85,000 cases were reported worldwide,

49,000 of them in India alone, far above the totals of the immediately preceding years. There was cause for guarded optimism, however. Some of the increased numbers were attributable to improved surveillance, and the remaining cases were largely concentrated in relatively small geographic areas. According to one estimate, the remaining areas with endemic smallpox by early 1974 were no larger in aggregate than the state of Texas.

Global eradication at last was within reach. Grasping it, as will be seen in the country-by-country narratives that follow, required the overcoming of natural disasters and civil strife in Asia and of open warfare in Africa. Success came hard, but it came. Pakistan reported its last case in late 1974; Nepal and then India in the spring of 1975; and Bangladesh, in spite of a succession of catastrophes, in October of that year, accounting for the last naturally occurring case of variola major. Ethiopia finally won its long struggle against smallpox in August 1976.

For seven weeks no cases were reported anywhere in the world. Then Somalia, which had been reporting importations from Ethiopia since 1972, acknowledged existence of the disease in its capital city. After more than a year, and more than 3,000 documented cases, the last naturally occurring case emerged in Somalia on October 26, 1977. With the achievement of zero-pox, the global eradication campaign had reached absolute success. As Mohan Singh has written, "Behold, perfection may be found in the attainment of nothingness."

CDC AND THE GLOBAL PROGRAM

It has already been stated in this narrative that the CDC role in global smallpox eradication, after the successful conclusion of the campaigns that left twenty nations of West and Central Africa smallpox-free, was not so much institutional as individual. This statement is true in the sense that CDC as an agency was not running the show but rather providing personnel to work in national campaigns under WHO auspices. In a broader sense, however, CDC made and sustained a depth and degree of commitment without which the ultimate goal would surely have been delayed and might never have been attained.

This was in every sense an institutional commitment. One individual was largely responsible for it: Dr. David J. Sencer, Director of CDC from the inception of the African program almost to the day of final worldwide victory. It was Sencer who brought the fledgling CDC Smallpox Unit into his immediate office to assure its bureaucratic stature at the outset. It was Sencer who drew a box labeled "Bureau of Smallpox Eradication" on the chart of a reorganized CDC in 1972, giving it equal status with the largest components of the agency. Above all, it was he who interpreted CDC's growing role in protecting the health of the American people to include the detection and elimination of potentially threatening diseases at their source, and who found the elasticity in both the limited legislative authorities and the still more limited resources at his disposal to enable the job to be done. Bill Foege, who helped spearhead the program in India and later was to

succeed Sencer as Director of CDC, has said of his predecessor's leadership: "Dave never refused me anything I asked for. I found myself trying hard not to ask, but later I became shameless. I went on asking and he went on responding."

CDC's function of providing needed expertise to WHO in support of national smallpox programs began in Brazil in 1967, as the CDC/AID effort in West and Central Africa was gaining momentum. It continued in Asia; peaked in the two crucial countries of India and Bangladesh, where more than 100 CDC employees made vital contributions; and ended in East Africa, where a CDC epidemiologist helped investigate the last outbreak. Indeed, CDC's commitment continued well beyond the last case. Several CDC experts, including Sencer himself, served on the blue-ribbon panels established by WHO to certify that countries were smallpox-free, and the CDC smallpox laboratory carried heavy responsibilities in the certification process.

Latin America

Dr. Leo Morris, a statistician-epidemiologist, was assigned to the Pan American Health Organization (PAHO), WHO's Regional Office for the Americas, and sent to Brazil in 1967 as that country's long-delayed national campaign was getting under way. Morris had worked on the team with Millar, Griggs, and others that set the African program in motion. Before that, he had accompanied Millar to Amapá, in northern Brazil, and taken part in the program described in chapter 2, which was the proving ground for the jet injectors under field conditions. His interest in a Brazilian assignment met a critical Brazilian need.

PAHO, which as the Pan American Sanitary Bureau long predated WHO and which subsequently became its Regional Office for the Americas in 1948, was the first international organization to declare eradication of smallpox as a regional goal. This declaration occurred in a resolution of the Thirteenth Pan American Sanitary Conference in 1950, at the instigation of PAHO's Director, Dr. Fred L. Soper of the United States.

When WHO's Intensified Global Smallpox Eradication Program was announced officially in 1967, South America seemed to present the best prospects for eradication among the continents where the disease was still endemic. By 1959 smallpox transmission had been interrupted in all but five countries of South America—Brazil, Colombia, Ecuador, Bolivia, and Argentina. Of these, Colombia and Ecuador already had systematic mass vaccination programs; Bolivia had just completed an efficient two-year campaign and reported only seven cases in 1959; and Argentina's thirty-six cases were concentrated in areas adjacent to Brazil. Ecuador had recorded its last case in 1963, Colombia in 1965, and Bolivia in 1966. Peru, which had successfully interrupted transmission in the 1950s, had a serious relapse with over 800 cases reported in 1963, generated in the Amazon jungle along the Brazilian border. But this epidemic was quickly contained by an intensive campaign after a few cases reached the capital at

Lima, and Peru once again became smallpox-free in 1966. Argentina reported fifty-four cases between 1967 and 1971, but relatively little was known about them except that they were occurring close to Brazil.

Indeed, it could be said that in Latin America, Brazil *was* the problem. This huge, sprawling nation of about 85 million touched the border of all but two South American countries. It alone had not mounted a national program. By 1967 it accounted for 4,514 of the 4,544 cases of smallpox reported for the entire continent.

Of the remaining countries worldwide with endemic smallpox, Brazil was one of the most developed. Yet it contained areas within its borders that ranged from the most primitive to the most highly sophisticated. Structured as a federal republic, each of its twenty-two states had primary legal responsibility for the health of its citizens, as is the case in the United States as well. The Smallpox Eradication Program, however, was envisioned from the outset as a centrally directed national program. The plan, proclaimed in August 1966, was intended "to intensify and coordinate public and private activities, nationwide, to prevent and combat smallpox . . . toward the goal of eradication of this disease." The strategy was strictly one of mass vaccination, which was to proceed state by state, following what proved to be an unrealistically optimistic schedule. Surveillance was given little importance and was not intended to begin until the vaccination program in each state was complete.

When Leo Morris arrived at the headquarters of the national campaign in Rio de Janeiro in March 1967 to begin his PAHO assignment, the program had been in progress four months. It had been launched in three of the least economically developed states, in the northeastern part of the country, where smallpox incidence was thought to be highest. Although not moving as rapidly as had been hoped, the vaccinators reported nearly half a million vaccinations performed in the first few months.

Morris found on his arrival that a national reporting system was virtually nonexistent. Helping to create one was his most immediate task. As he traveled around to several of the states, he found that some had reasonably good reporting systems of their own but had no idea whom to notify at the national level.

In July 1967 an incident occurred that Morris considers to have been the first significant turning point in Brazil's program. The town of Branquinhas, in Alagoas State, was supposed to have completed its systematic mass vaccination program three months earlier. The records showed that 6,558 vaccinations had been done in the *municipio*, which had a total population of 6,317. Yet now twenty-one cases of smallpox were being reported in the town. An investigation by national staff quickly found not twenty-one but fifty-one cases.

Four possible explanations were examined. The diagnosis of the cases could be wrong, but it was quickly evident that the disease was indeed smallpox. The

cases might be occurring among a group who had migrated into Branquinhas after the campaign was completed, but there had been no such migration. The vaccine might have been impotent, or the techniques incorrect; but take rates among those who had been vaccinated in the community were satisfactory. This left only one likely cause: vaccination records had been falsified and planning and supervision were poor. Case-by-case investigation revealed that only two of the fifty-one persons contracting the disease had been vaccinated at all.

This episode, coupled at about the same time with the appearance of cases of smallpox in Brasília, the country's recently constructed capital city, helped turn the Brazilian campaign around. A new director was named, the internationally respected Dr. Oswaldo da Silva. The importance of creating independent assessment teams was recognized, and these evaluators began working early in 1968 in teams of four, visiting vaccinated areas seven to ten days after completion of the mass vaccination campaign. These survey teams, trained in a program that Morris helped develop and carry out, visited county seats and sample rural areas, assessing take rates and overall program coverage.

Meanwhile, Morris had helped develop a national smallpox reporting system. Beginning in May 1967 a weekly surveillance report, called the *Boletim Semanal da Campanha de Erradicacao da Variola*, was published and distributed to over 2,000 senior public health officials and program staff throughout the country. The *Boletim*, patterned after CDC's *Morbidity and Mortality Weekly Report (MMWR)*, described progress in the program and reported on the results of field investigations. The unpretentious mimeographed report served many purposes, not the least of which was to convey a sense of coherence and momentum to the widely scattered participants. The *Boletim* remained a lively force throughout the campaign and later evolved into Brazil's equivalent of the *MMWR*, reporting on a variety of diseases and programs nationwide.

Retaining its predominant emphasis on mass vaccination, the program gathered some momentum under Dr. da Silva's leadership in 1968. Some 12 million vaccinations were performed, more than twice the previous year's total though well below da Silva's goal of 5 million per quarter. The number of reported cases in 1968 was slightly higher than in 1967, but the increase was clearly related to better reporting.

Late in 1968 came the second turning point. Dr. Nelson Morais, an epidemiologist, was appointed to the top post of General Secretary of the Ministry of Health. Morais agreed to develop a surveillance program. Accordingly, in January 1969, a special training program in surveillance and the epidemiology of smallpox was conducted in São Paulo. Leo Morris, in conjunction with staff of the smallpox program and the Adolfo Lutz Institute, developed and presented the program to fifteen medical officers with important smallpox responsibilities plus three young epidemiologists.

The latter, recent graduates of the School of Public Health in Rio de Janeiro, were assigned to three populous states where the vaccination campaign had not yet reached. They worked with extremely limited resources, due to general cutbacks in program funding and continued reluctance to divert resources away from mass vaccination, and their jobs were terminated in less than a year by yet another change of leadership at the top. But their work was outstanding in demonstrating the potential of the surveillance-containment strategy. Two of them, Drs. Nilton Arnt and Ciro de Quadros, were later recruited by WHO and performed excellent service in Asia and East Africa. Their work has been characterized as "the beginning of the end" of smallpox in Brazil.

Dr. de Quadros was assigned to the large, populous southern state of Paraná. Finding a strong health infrastructure and a dynamic and supportive young state health officer, he immediately sent a telex to every health facility in the state urging rapid reporting of cases. As responses came in he "hit the road" with his lone vehicle, a driver, jet guns, and a small supply of vaccine. On the scene he performed case tracing and limited containment vaccination. During each investigation he involved the local medical personnel and supplied them with aerogram forms for reporting. He took care to hold a local press conference at the end of each investigation. He inaugurated his own state monthly bulletin and sent complete reports each week to Leo Morris for the national *Boletim*.

By September 1969, de Quadros had investigated some fifteen outbreaks, with more than 1,000 cases. He had also visited nearly every health facility in the state and had enlisted the local mayor as reporting officer where no facilities existed. He performed, in total, no more than 35,000 vaccinations. Yet when the national campaign workers marched across the state of Paraná in the fall giving 6-7 million vaccinations, they found no cases at all. Transmission had been interrupted before they arrived.

If this was the beginning of the end, the end was a long time coming. Brazil's national campaign survived many vicissitudes. During its short five-year lifespan it served under five different program directors and three different ministers of health. Resources ebbed and flowed with political tides. Finally, when reports for 1969 indicated 7,407 cases as compared with 4,372 in 1968, duly recorded and widely disseminated in the *Boletim* developed by Morris, the problem reached the attention of top governmental levels. With some additional help from WHO, more than 30 million vaccinations were done in 1970.

Dr. Leo Morris returned to CDC during that year, but his counterparts carried on the systems he had helped set in motion. In November 1970 it appeared that Brazil had achieved eradication. But three months later two clusters of cases were discovered by search teams in the city of Rio de Janeiro, not far from the headquarters of the national program. The last case in Brazil, and in the Americas, was located in Rio on April 19, 1971.

Indonesia, Afghanistan, and Nepal

As the countdown of countries still reporting endemic smallpox moved below ten, all now located in Asia or eastern Africa, national campaigns were mounted with continuous encouragement and support from WHO. Of these, CDC staff played a major role in two, those in India and Bangladesh, each of which will be described in some detail. Brief mention needs to be made also, however, of the assistance rendered by CDC personnel in several of the others.

Indonesia had become smallpox-free before World War II while still under Dutch colonial administration. The disease was reintroduced during the war and widely reseeded throughout most of the huge, populous archipelago. The national eradication program, initiated in 1967 and operated with relatively little outside support on a decentralized basis, had great success in eliminating the disease from some areas of the country, including areas of very high population density. But great difficulties remained. CDC's Dr. Bernard Lourie, who had worked in Chad, visited the island of Sumatra and found "much smallpox and little surveillance."

In 1969 WHO's South East Asia Regional Office (SEARO) requested that Dr. J. Michael Lane evaluate the Indonesian program. Lane, whom we have met several times before in this narrative, was at that time one of the three subregional "desk officers" in Atlanta for the African campaign. He arrived in Indonesia as an evaluator with a second agenda, to promote the strategy of surveillance and containment.

He found in densely populated West Java a strong power structure, with good communication into every village, which had never been used for disease reporting purposes. Once each village was being asked regularly for information on smallpox cases, outbreaks were quickly located, and containment measures could be applied.

On a second trip in 1970 in the company of fellow-consultant Dr. Paul Wehrle, a CDC alumnus, Lane introduced surveillance and containment to the South Celebes area, where smallpox was still endemic. Again the Indonesian program staff were quick to take advantage of the strategy. Soon it had been adopted throughout the country. So enthusiastic was Indonesia about its results in hastening eradication that Dr. P. A. Koswara, an Indonesian delegate to a regional meeting at SEARO late in 1970, proposed that mass vaccination campaigns be eliminated and replaced by surveillance and containment throughout the region.

Indonesia's success in achieving eradication was a great boost to program morale in Asia, coming at a time when the programs in the other big countries of the subcontinent were floundering. Like Brazil, Indonesia contributed importantly to global success by exporting a number of excellent smallpox personnel to serve with WHO in other national campaigns.

Afghanistan had been expected to be one of the very toughest countries in which to achieve eradication. Vast areas, sparse settlement, rugged terrain, primitive transportation and communication, poorly developed health infrastructure, many nomadic peoples—all those factors seemed to conspire against success. To add one more complication, it was known that variolation was widely practiced, and popular resistance to vaccination was anticipated.

Afghanistan's national program overcame all these obstacles in a remarkably short time. It began in 1967, primarily using the mass vaccination approach, with the assistance of volunteers from the U.S. Peace Corps. In 1969 a retired Indian army officer, Dr. A. G. Rangaraj, assumed leadership of the program and introduced surveillance and containment as the principal strategy. Rangaraj ran an efficient, well-organized program. His well-trained surveillance teams were tenacious in investigating cases and rumors of cases.

By 1972, when CDC's Andrew Agle arrived as a WHO staff member, no more endemic cases could be found in Afghanistan. For some time, however, there was considerable fear, and occasional actual occurrences, of imported cases from across the border with still endemically infected Pakistan.

Agle had served in the West African program in Nigeria, Togo, and later in Upper Volta, where he, like CDC operations officers in other countries, had developed proposals for continuing U.S. support of disease control in West Africa. When these were not adopted by AID at the Accra meeting already chronicled, Agle returned to the United States for a year of advanced schooling. Eager to return to work in international health, he accepted a WHO post in 1972, becoming an early CDC staffer, in the tradition of D.A. Henderson and Leo Morris, to undertake WHO employment in the Smallpox Eradication Program.

Having arrived soon after the last endemic cases were recorded, Agle was assigned by Dr. Rangaraj to a post in the city of Kandahar, in southern Afghanistan, where he and his national counterpart supervised surveillance teams searching for imported cases among the nomadic tribes that crossed and recrossed the frontier with Pakistan. Much of the time, by his own account, he was "underemployed and bored."

One day, however, the telephone rang—a rare occurrence in itself. A member of the search team was calling from a remote outpost. They had located a case of smallpox in a twelve-year-old boy traveling with a small group of Kuchi tribesmen. The location of the nomads' camp could only be given by geographic coordinates, but Agle engaged in terrestrial navigation across the rugged wastelands and located the place. On arrival he found the boy with smallpox, a female relative, and the surveillance team member. The remainder of the Kuchi group, complete with baggage and camels, had somehow managed to steal away during the previous night while the search team slept. Agle took the boy and his chaperon

back to Kandahar, only to find that the hospitals there refused to admit him. Improvising on the spot, Agle made the boy and the woman as comfortable as possible in the smallpox program office for the duration of his isolation period.

The case, one of only four importations detected during Agle's 1-1/2-year tour of duty, was traced back to a source in Pakistan. With the general situation so well in hand in Afghanistan thanks to Dr. Rangaraj's program, WHO transferred Agle to Bangladesh in 1974, where he worked with many CDC colleagues in that country's push for eradication.

Nepal, a small country whose formidable topography stretches from steaming jungles along the Indian border to the tops of the world's highest mountains, had an excellent smallpox program that combined mass vaccination with surveillance and containment. Until WHO provided funds for the program to rent airplanes and helicopters, investigating an outbreak often required many days' trekking to an isolated village where, not infrequently, no cases would be found.

Jay Friedman, another CDC veteran of the campaign in West Africa, accepted a WHO post in 1972 as smallpox officer in Nepal. He found a well-organized system with a smallpox office and surveillance team in each of the country's seventy-five districts, making regular monthly visits to every village. A suspected outbreak was investigated by a senior medical officer or a WHO smallpox officer. On one such occasion, Friedman and his helicopter were hopelessly lost while searching for a tiny mountain settlement. When they put down on a hillside to ask directions, a young man volunteered to come along and show them the way. He guided them unerringly to the correct village, said farewell, and started for home on foot. Friedman was told that he faced no less than a five-day trek. Not all the heroes of global smallpox eradication were formally enrolled in the campaign.

There was little smallpox in Nepal in 1972, thanks to the success of the national program. But in 1973 and 1974, when neighboring Bihar State in India was experiencing devastating epidemics, many cases were exported to Nepal, and the disease moved back and forth across the common border. Nepalese teams frequently crossed into India to locate index cases and report them to Indian authorities. An informal system of cross-notification was devised by Friedman, Lane, and Rangaraj that bypassed the cumbersome official reporting process via Katmandu and New Delhi. Inevitably, Nepal's ultimate success in achieving zero-pox was interwoven with India's, and the last case of smallpox in Nepal was reported on April 6, 1975, just a month before India became smallpox-free.

India

Eradication of smallpox from India required operations on a scale that has probably never been approached in the annals of public health. At its peak the program engaged an army of more than 100,000 health workers each year, who

carried out nearly 10 million village visits during the three-year period 1973-1975. It consumed nearly 7 million bifurcated needles from 1970 through 1976 and printed and distributed over 26 million forms.

The backbone of this enormous work force was made up of Indian nationals, of whom some 33,000 constituted regular staff members, augmented at peak periods by over 100,000 additional workers. Working closely with them in a number of professional, technical, and administrative capacities were 232 international health workers from thirty different countries on six continents. Of these, sixty-two were officially listed as CDC representatives in WHO's volume, *The Eradication of Smallpox from India*. This number does not include some, like Dr. William Foege and Mr. Anthony Scardaci, who served as full-time WHO staff, nor several other U.S. participants who were CDC alumni and veterans of the African campaign, like Drs. Henry Gelfand, Joel Breman, and Ron Roberto.

Fittingly, however, the CDC list does include, in its proper alphabetical sequence, one "Dr. D. J. Sencer," whose creative administration as CDC Director made the entire CDC investment possible. As has been noted, he used "foreign-quarantine" positions, funds, and authority to rotate almost all of the CDC contingent through ninety-day assignments, that being the statutory limit for such overseas tours. Appropriately, Sencer was a member of WHO's international panel that in 1977 officially certified India to be smallpox-free.

Several different versions exist as to the precise circumstances that brought Dr. William Foege to India in the summer of 1973. In one story the assignment was triggered at a meeting at SEARO headquarters in New Delhi to which D. A. Henderson had invited him in his role of evangelist to help persuade the Indian government not to reduce its commitment to smallpox eradication, which was then being seriously considered. According to this version, Foege urged them to proceed at full speed toward a target date of 1975, and they agreed to do so if Foege himself would come to help. This account is somewhat apocryphal, since Foege had asked to be assigned there early in 1973. But it is clear that D. A. Henderson wanted him there, India was enthusiastic, Sencer was willing, and Foege himself was eager to tackle it. Certainly, his assignment was the beginning of CDC's major involvement in the Indian program. As Sencer has said in retrospect, "Once you've committed Bill Foege, you're committed."

It was not the first venture of CDC personnel in India in connection with smallpox. Several, including Drs. Ralph Henderson, J. Lyle Conrad, and Henry Gelfand, had visited India earlier as consultants. In 1972 Dr. John Pifer, who had served with distinction in Nigeria, accepted a WHO post as epidemiologist in Bihar, an enormous Indian state with a population more than half as large as that of the entire West African region and with many times more smallpox. For a number of reasons, including the sheer size of the problem, the grinding poverty, and the bureaucratic complexity of the situation, Pifer had asked to be relieved after six months. Foege acknowledges that some friends advised him against the India

assignment ("You don't need a failure like that on your record") and others urged him not to go without very specific resource commitments.

Two things were abundantly clear. Global eradication could not succeed without India, and India wanted and needed help. Their national eradication program, inaugurated in 1963 using a mass vaccination strategy, had succeeded in eliminating smallpox from most of southern India. But in 1971 the number of reported cases increased by 31 percent over 1970, and in 1972 by another 69 percent over 1971. Most of the cases had occurred in four big, populous northern states—Madhya Pradesh, Uttar Pradesh, Bihar, and West Bengal. In 1973, outbreaks were occurring across northern India. More than 87,000 cases were reported during the year, more than 80 percent of them in Uttar Pradesh, Bihar, and West Bengal, and the actual total was undoubtedly several times higher.

There were numerous contributory causes. The most colorful was resistance to vaccination stemming from widespread worship of the smallpox goddess, Shitala Mata. Many shrines had been erected to her across northern India. She was portrayed as a large-eyed deity who traveled about sowing the deadly grains from which pustules were said to spring. The victim's survival depended upon whether Shitala Mata used cleansing water or an ineffectual dry broom, both of which she carried, to clean up the grains. Vaccination constituted tampering with her divine will and therefore was thought to risk incurring her wrath.

Other, and perhaps more substantive, factors contributing to the magnitude of the problem were frequent use of outdated vaccine, concealment of outbreaks, inadequacy of resources at the state level in India's federal system, and above all the overwhelming density of the population and the extreme crowding that made every case a potential source of multiple infections.

When Foege arrived in New Delhi in the summer of 1973, the Indian National Smallpox Eradication Program was under the direction of the highly competent Dr. M.I.D. Sharma, Director of the National Institute of Communicable Diseases. WHO's smallpox program at SEARO was headed by an outstanding French physician-administrator, Dr. Nicole Grasset. The three quickly formed an effective working partnership based on profound mutual admiration, friendship, and respect. So close did the team become that decisions were never made unilaterally.

The most important decision made conjointly in the summer of 1973 was to reorient the national program, now called the Intensified Program by the Indian government, strongly toward a surveillance and containment strategy. This conversion was accepted by the top health officials of India, Dr. P. Diesh, Director-General of Health Services, and Dr. Karan Singh, Minister of Health. But it was evident that surveillance and containment, Indian style, would need to be very different from the tactics pursued successfully in West Africa, Brazil, and elsewhere. Accordingly, the India/WHO team drafted an audacious plan based on village-by-village searches. Launched in the autumn of 1973 in the four big states with

endemic smallpox and subsequently carried to the rest of the country, the scheme for an active search probably constituted the largest single public health operation in history.

To convey some appreciation of the scope of this endeavor, approximately 1.3 million village visits were made in organized "search weeks" from October to December 1973. These village visits continued at the rate of 352,000 per month in 1974 and 340,000 per month in 1975, totaling 4.2 and 4.1 million village visits, respectively, for these two years. In the latter part of the campaign, when house-to-house tactics had been adopted, 100 million houses were being visited during the six-day search week each month.

Such a system requires planning at every level and extensive training, not just to set it in motion but to review and modify it in progress. Beginning in September 1973, meetings were organized at state level in the states carrying out the search. Similar meetings were conducted at district level, and briefing and training sessions were held in the thousands of primary health centers. Monthly state review meetings, including epidemiologists and divisional, state, and central governmental and WHO officials, became a regular feature of the system. These meetings served multiple purposes, not the least of which was morale boosting. They were generally held in sizable cities, where field staff could look forward to cold drinks, better food, and other amenities as well as collegial exchanges.

The very first sweep, in October 1973, turned up 10,000 new cases. This startling figure gave a clear indication of how much smallpox there was and also suggested that this was perhaps the most thorough surveillance ever carried out anywhere. But changes constantly needed to be made. The system was built around carefully developed forms, filled out with almost religious zeal by the search teams, sent up through the layers of the system, and reviewed and totaled up at every layer. In India it can be said truly that function follows forms.

These early sweeps also revealed, not surprisingly, that the surveillance capability far exceeded the capacity to contain the outbreaks detected. At the outset, wherever a case was discovered the team was expected to vaccinate the immediate family and five adjacent households. As the workers become more experienced, they were gradually able to give better coverage to each outbreak. In the later stages, where resources permitted, containment teams were deployed distinct from the surveillance teams and sought to vaccinate entire affected villages using census data and careful enumeration of the population.

Late in 1973 additional financial resources began to come into the program. A grant of $7 million from the Swedish International Development Agency was made directly to SEARO. It was especially helpful because it was noncategorical; the money could be used for any purpose, with no strings attached and minimal accounting requirements. This kind of funding gave the program much-needed flexibility as it entered its most critical stage.

One indirect result of this increase in resources was Foege's request to Sencer for more administrative support, to help make sure that the funds were efficiently put to work. He first asked for Billy Griggs, administrative architect of most of the African campaign and now, in early 1974, Program Management Officer for the Bureau of Smallpox Eradication at CDC. But the decision was made to keep Griggs in Atlanta to preside over and arrange for the build-up of CDC personnel in Asia that was plainly on the way. Instead, Sencer's own deputy, William C. Watson, Jr., volunteered for a three-month tour, and his performance paved the way for sending numerous other experienced administrative officers to India.

At first it was not easy for nonphysicians to gain acceptance in the highly degree-conscious Indian setting. One of the early ones, Harry R. Godfrey, found himself frequently asked for clinical consultation by an Indian physician, whereupon he would "mumble something about the need for lab confirmation and head for the exit." But gradually, as had been the case in Africa, the varied contributions of the public health advisors came to be recognized and appreciated.

Indian officials had some reluctance about accepting international physicians as well, in part because there was a surplus of underemployed Indian doctors. Foege used a long train ride to persuade one of the top officials in the Ministry of Health and Family Welfare that the practice of teaming foreign epidemiologists with Indian counterparts would enhance the program's chance of success. Once the doors were thus opened, not only CDC but other U.S. and international personnel became engaged in the program in increasing numbers under the auspices of WHO, to excellent effect. In the fall of 1973, for example, a team of consulting epidemiologists included Dr. Isao Arita of Japan, a WHO staff member; Dr. I. Selivanov of the USSR; and Dr. Donald Hopkins of CDC.

This had not been the only occasion when Foege found the trains of India to be a useful venue for doing business. In an office it was sometimes difficult to get past the amenities. But on a long train trip there was ample time to reach agreements. The six-foot seven-inch Foege became a familiar figure to the trainmen across the northern part of the country, and his cordial cultivation of their friendship paid unexpected dividends—space magically found to accommodate a bulky quantity of vaccine, or a seat on a crowded train made available for an Indian official who was a friend of the "tall American."

Despite the influx of new resources and the success of the village-by-village searches in bringing smallpox to light, the first months of 1974 were dark and uncertain times. Monthly meetings were burdensome as field staff, in the time-honored way of field staff everywhere, unloaded their frustrations on the New Delhi people. There was plenty to be frustrated about. As surveillance became more sophisticated, it was evident that many cases were still going undetected. And containment capacity was not up to dealing with all the cases that were being reported.

In the spring of 1974, India, with much fanfare, exploded its first nuclear device. Journalists gathered to observe that event from all over the world. They took note of the irony implicit in a country with enough science to explode a bomb but still suffering from smallpox. Fortunately, officials at the very highest levels of the Indian government also took note of the contradiction and criticism, and the eradication program gained additional attention and support.

Meanwhile, however, an explosive epidemic was occurring in the state of Bihar that dwarfed in size any other outbreak experienced since the global eradication program began. At its peak, during one week in May 1974, 11,000 cases were detected—more in a week in a single state than the number that had been reported in all of West Africa in an entire year. At this critical time the chief health officer of Bihar threatened to abandon the surveillance and containment strategy and return to mass vaccination. Foege and others from New Delhi confronted the issue at a state meeting on a Monday in May. While the issue was hanging in the balance, an Indian physician expressed metaphorical support for surveillance and containment: "If someone's house caught on fire, we would pour water on *his* house, not others." The decision was made to pursue the strategy for one more month.

Throughout the spring, while smallpox rates were climbing, there had been widespread civil unrest in much of India. Railroad workers were on strike, and without the railroads critical supplies could not be shipped from Delhi to Bihar. Other unions were ready to strike as well. There were student riots and calls for nonviolent resistance. Foege recalls that within the program itself half of the vaccinators were going on strike and the other half were considering it. Even physicians were threatening to go out. Resources were least available at the moment of most crucial need.

Fortunately, within a few weeks the strikes were settled. Civil strife subsided. The program was able to go back to work at top capacity. And with the advent of the monsoons, smallpox outbreaks began to subside as well.

Now the disease was on the run. The massive search activities continued to turn up large numbers of cases, but to an increasing degree they were occurring within a shrinking geographic perimeter. By fall Foege was able to predict publicly, in response to a question, that smallpox would be eradicated from India in 1975. Some of his colleagues were surprised to learn that this was his real opinion and not simply a political reply.

As the countdown continued, good results began to come from the technique of offering a modest financial reward to the member of the public and/or the health worker who first reported a new outbreak. Foege had suggested instituting the reward system soon after he first arrived, as a means of overcoming resistance to case reporting. Fortunately, he had been talked out of it by his Indian colleagues; installing it too soon, in 1973, would have broken the bank. But now, in the later

stages, an increasing proportion of first reports came from the public. In 1975, 11 percent of outbreaks were detected through reports from the general public, compared with 2.6 percent in 1973. In areas without endemic disease, reports from the public accounted for 36 percent of all detected outbreaks in 1975.

Throughout the latter half of 1974 and into 1975, CDC epidemiologists and public health advisors in growing numbers were working with their Indian counterparts and other international staff to help achieve "Target Zero," the objective now proclaimed for the Indian program. For nearly all of them, it was an intense experience—three months of seven-day work weeks, fifteen hours a day, as part of a huge team working toward a monumental achievement. Dr. David Sencer has observed: "The hidden value of the smallpox program was the change it made in people's lives."

On May 17, 1975, the 226th anniversary of the birth of Edward Jenner, the last known indigenous smallpox outbreak in India occurred in Pachera village, Katihar District, state of Bihar. One week later India's last known smallpox patient was identified, a thirty-year-old woman who had become infected in Bangladesh. Thanks to rapid and effective containment, no secondary cases occurred. On July 5, 1975, India was proclaimed a nonendemic country. Fewer than fourteen months had elapsed since the week in which 11,000 cases had been reported in Bihar.

Bangladesh

The scene of the final battle for smallpox eradication in Asia, and the last refuge of endemic variola major in the world, was the densely populated, newly independent country of Bangladesh, bordering and almost completely surrounded by India. Few if any countries in the annals of smallpox have had such precipitous ups and downs as Bangladesh.

As East Pakistan, joined politically to but separated geographically from the larger bloc of Pakistan in the West, it had experienced a massive epidemic of smallpox in the late 1950s, recording some 86,000 deaths in a three-year period. Beginning in 1961 an effective smallpox eradication program was undertaken in the region, initially based on a plan involving mass vaccination of the entire population within a two-year period. Reported cases dropped sharply to an all-time low of 69 in 1964, but then rose again to a new peak of more than 9,000 in 1968. Recognizing that eradication was not being achieved by mass vaccination alone, the program added a modest surveillance component. Once again the number of cases declined, with fewer than 1,500 reported in 1970, these being confined to only four districts; no cases were found in the last five months of that year. Then for 1971 the country reported no smallpox cases at all.

But 1971 was the year of Bangladesh's struggle for independence, a goal whose attainment was finally proclaimed on December 16. Smallpox vaccination and

surveillance continued through the civil strife, but whether or not the country was totally smallpox-free during that period will never be known with certainty.

Unfortunately, the question quickly became academic. During the war that led to Bangladesh's independence, millions of people—perhaps as many as 10 million—had streamed across the borders into India from East Pakistan. There, they were crowded together in refugee camps, the largest of which, near Calcutta, held upwards of 300,000 people. With the proclamation of independence, these people started for home. And smallpox, as it had done so often in its long history, traveled with them. Back in Atlanta, a CDC staff member recognized smallpox in close-ups during television news coverage of these migrations. The reseeding was rapid and widespread, as persons with active cases, others in incubation stages, and unvaccinated contacts traveled together in trucks, trains, and buses and on foot.

Dr. Stan Foster arrived in the capital city of Dacca in the spring of 1972, seconded by CDC to serve with WHO in Bangladesh. He found smallpox "all over the place," but since the war had disrupted administrative systems including disease reporting, the size of the epidemic was unclear. A sample survey in May of one heavily infected *thana*, a local administrative subdivision, estimated 2,298 cases in a population of 250,000—almost one case per 100 people. Fewer than one-tenth of these cases had been reported.

Part of the reporting problem was traceable to a long-standing system whereby the discovery of cases was considered to represent a failure of vaccination and the responsible health worker who reported it was punished for it. Foster helped to make sure that this system was changed. Incentives and ultimately rewards for reporting, for both health workers and the public, were initiated.

In addition, at the instigation of Foster and his counterparts, three systems of surveillance were instituted: market surveillance, infected-village surveillance, and house-to-house surveillance. In June 1972, ten four-man surveillance teams began the active search of marketplaces, using the WHO "recognition card" showing a photograph of a smallpox patient. The searchers found that young boys were the best reporters. As the method proved successful and more resources became available, the number of surveillance teams in Bangladesh increased to fifty-five by 1974. This idea was picked up and used in India as well.

The year 1973 marked the peak of the resurgence of smallpox in Bangladesh, with more than 32,000 cases reported. But both the national and the international staffs were being strengthened. Andrew Agle, reassigned from Afghanistan, joined Foster in the WHO office in 1974 as administrative officer. CDC epidemiologist Dr. Stanley I. Music was among the first of the international personnel, whose numbers grew from fewer than five through most of 1973 to a high point of sixty-five working in Bangladesh in mid-1975.

As these added resources took hold, operating within a new, unified health structure, and surveillance and containment efforts became more effective, hopes for quick eradication rose. The seasonal rise in outbreaks in the spring of 1974, though substantial, was far lower than that of 1973. By October 1974 the number of infected villages had been reduced to ninety-one. Nearly all of these villages were localized in two subdistricts. Interruption of transmission was predicted by December.

But it was not to be. In October the two remaining areas with endemic smallpox were struck by devastating floods, the worst to strike this lowland country in fifty years. Entire villages were destroyed, crops were ruined, and famine developed. People streamed from the desolated countryside into the already-crowded urban areas where nighttime population densities were already as high as 500,000 per square mile. Inevitably, smallpox spread again. To make matters worse, many displaced people who subsequently became ill tried to return to their home villages for care, thus spreading the disease even further. To this set of tragic circumstances, yet one more was added: a major urban slum clearance project had the effect of rendering still larger numbers homeless and transient at the same critical time. By April 1975 the number of infected villages had risen to 1,280. Foster recalls these as grim times. But the country and the program rose to the occasion.

The President of Bangladesh declared a national emergency. Additional national and international resources were mobilized, including more than sixty epidemiologists from twenty-two countries. Roughly half the international contingent were CDC personnel, including both epidemiologists and operations officers. House-to-house searches were intensified. House guards were employed to enforce isolation of the sick. Rewards for reporting cases were increased and so widely publicized that of the last 119 outbreaks in Bangladesh, 46 percent were identified by members of the public.

As a consequence of this major mobilization, combined with the anticipated seasonal decline, cases and outbreaks decreased dramatically beginning in May 1975. By July there were fewer than 150 infected villages in the entire country. What was thought at the time to be the last case occurred in Chittagong District in September. Two months of continuous searching yielded no new ones.

Then on November 14, the day on which a congratulatory cable arrived from WHO headquarters in Geneva, another cable reported an active case of smallpox in the village of Kuralia on Bhola Island in the mouth of the Ganges River. The epidemiology team that headed south from Dacca to investigate hoped they would find a misdiagnosis. But when they reached the infected house after a twenty-four-hour trip by boat, jeep, and on foot, they found a 2-1/2-year-old girl with unmistakable smallpox. Containment had already been initiated. Intensive surveillance throughout the area turned up no further cases. The little girl, Rahima Banu, had suffered and survived the last case of variola major to occur naturally in the world.

There is an appropriate footnote to the Bangladesh story. As has been noted, WHO appointed an international commission for each country to certify that it was indeed smallpox-free. The blue-ribbon panel for Bangladesh met in the country December 1-14, 1977. Its unanimously elected chairman was Dr. Alexander D. Langmuir, who in 1961 in Atlanta had asked his young aide-de-camp Millar to keep an eye on smallpox.

The Horn of Africa

By 1973 Sudan was smallpox-free. The last known case had occurred in early December 1972. Health workers from Sudan had done vaccinations for years before WHO sent in a representative of the Intensified Global Eradication Program in 1971. The nation's civil war had lasted until March 1, 1972. Roads were still mined and transport was difficult when Dr. Donald P. Francis of CDC arrived in Khartoum in early spring of 1973 to work on postvaccination surveillance under the auspices of WHO. He was followed into Sudan by Mr. David C. Bassett of CDC, who arrived later in the spring of 1973 and was stationed at Juba, where he planned and conducted surveillance in southern Sudan.

"We had a strong foundation from which to work," said Francis. "Omar el Haj Suliman was a Sudanese who had done brilliant work in smallpox before we got there. WHO snapped him up and sent him to Pakistan to work on eradication there. Our job was surveillance—to be sure there was no more smallpox in Sudan."

Bassett, as WHO advisor to the Sudan smallpox program, helped with the planning of a series of three- to four-week surveillance campaigns. As he has noted, "I participated in the first one personally and then turned the others over to my Sudanese counterparts."

Three special challenges awaited the smallpox fighters in Sudan: First, the rural border and the isolation of much of southern Sudan complicated searches for evidence of smallpox. Limited access made checking difficult. Sudanese health workers found old cases, in an extremely remote mountainous area some sixty miles off the main road. But there were no new cases as surveillance continued. Second, immigrants who worked for a period of time in Sudan and then continued migration to Jedda and Mecca made surveillance difficult. Third, though military hostilities had ended in 1972, the aftermath of battle complicated transportation and communication. These and other difficulties were overcome.

By November 1975 the countdown of endemic countries stood at one: Ethiopia, at the eastern extremity of the African continent. Its neighbor, Somalia, was added later. The two countries shared the classic characteristics of the smallpox-endemic—underdevelopment, rugged terrain, civil strife, nomadic populations. Variolation was known to be widely practiced in Ethiopia. Moreover, among

many serious problems, variola minor with its 1 percent mortality rate, the only type of smallpox extant in Ethiopia, was not given high priority.

For these and other reasons, Ethiopia was among the last to organize a national eradication program. It did so in 1971 at the urging and with the assistance of WHO and initially with substantial manpower support from the U.S. Peace Corps to assist the Ethiopian sanitarians. In the first year the number of reported cases shot upward from 722 in 1970 to 26,329 in 1971. Despite increasing civil strife, the program managed to reduce the number of cases substantially in each succeeding year, pursuing a strategy of surveillance and containment from the outset under extremely difficult geographical conditions.

Beginning in 1974 the country was undergoing a revolutionary process that ultimately resulted, in 1976, in the overthrow of the traditional monarchy and the establishment of the People's Democratic Republic of Ethiopia. U.S. influence declined. The Peace Corps volunteers were withdrawn from the program in 1975. WHO increased its support, reaching a peak of twenty-five foreign epidemiologists and advisors in 1976.

But in comparison with its role in many other countries, CDC's involvement in Ethiopia was relatively small. Dr. Donald Hopkins helped conduct some training activities at the outset of the Ethiopia campaign alongside Dr. Isao Arita of WHO headquarters and Dr. Ciro de Quadros, the Brazilian epidemiologist assigned to the program by WHO. Harry Godfrey and David C. Bassett were among those carrying out surveillance in rural areas. In addition, when it became evident that helicopters were essential to eradication operations in the many roadless, nearly inaccessible areas of the country, Dr. Sencer made some CDC funds available to help keep them flying.

Considering the obstacles to be overcome, eradication was achieved quickly in Ethiopia. By the beginning of 1976, outbreaks were confined to two areas—rugged country near the gorge of the Blue Nile in the north and the Ogaden Desert in the south, where warfare was continuing. The last northern outbreak was contained in July, and the country's last recorded case occurred in the Ogaden with an onset date of August 8.

Ethiopia and Somalia have a long history of hostility, much of it stemming from conflicting territorial claims in the Ogaden, where skirmishes have been commonplace. Nomadic tribes crossing and recrossing this open border undoubtedly passed smallpox between the two countries. Somalia had reported only imported cases for several years up to and including 1976. In August of that year, as the last cases were being recorded in the Ethiopian portion of the Ogaden, a severe drought caused nomadic tribes to migrate from that area into Somalia, and they may have carried the disease with them. In any event five cases were reported in September in the Somalian capital of Mogadishu, more than a month after the last cases reported in Ethiopia, thus forcefully delaying

celebration of worldwide eradication. By January 1977 a total of thirty-nine cases had been detected in Somalia.

Meanwhile, in December 1976 five cases of smallpox were reported in Kenya near the Somalian border, evidently reintroduced from Somalia. WHO convened a coordination meeting in Nairobi in March 1977 attended by epidemiologists from Somalia, Kenya, Ethiopia, and Sudan.

By April it was clear that smallpox outbreaks were occurring widely in the southern half of Somalia. National and international resources were mobilized. A WHO team of epidemiologists arrived in May. At the World Health Assembly in Geneva, Drs. Don Hopkins, George Lythcott, Bill Foege, and Isao Arita of WHO helped to negotiate permission with the Somalian delegation for U.S. epidemiologists to work in the country, under WHO auspices, at a time when political relations between the United States and Somalia were very cool.

By the end of June, twenty-three WHO epidemiologists and 3,000 Somalian health personnel were hard at work, dealing with outbreaks that recorded more than 3,000 cases before the last one was snuffed out. The ubiquitous Stan Foster arrived that month. While observing transmission of the disease among nomads, he suggested that isolation of cases could be made more acceptable and therefore more effective by making use of the thorn barriers generally used to fence in animals, thereby enabling the infected individual to remain with his family and friends. Dr. Jason S. Weisfeld, who had seen smallpox service in India and Bangladesh, also arrived in June and was a member of the team that investigated the world's last outbreak that October. Diagnosis of the final case, which occurred in the town of Merka on October 26, was confirmed in the laboratory of Dr. Jim Nakano in Atlanta. Just as important, the CDC laboratory in the following months was able to confirm that all subsequent suspect cases were false alarms.

Nearly two centuries after Jenner's discovery of smallpox vaccination, but just over a decade since initiation of WHO's Intensified Global Eradication Program and the CDC/AID campaign in West and Central Africa, the ancient enemy was finally gone from the world.

Epilogue

In the market-surveillance strategy employed in Bangladesh and India, smallpox workers found ten-year-old youngsters to be among the best reporters. Shown a "recognition card" with a photograph of a smallpox victim, they would circulate, after the way of children everywhere, and bring back reports that often led to an undiscovered outbreak.

The ten-year-olds of today were born into a smallpox-free world. Since 1977 nearly a billion children have been born for whom the recognition card would be a bizarre curiosity. For them and for all who come after, the great legacy of the global Smallpox Eradication Program is freedom from a threat of death or disfigurement that they will never know. Those who later learn of the disease will perceive a distant menace, misted by time, scarcely real and not truly menacing at all.

This is no small legacy. Not only have countless millions of lives been prolonged, but many millions more have been enriched in quality through being spared smallpox's disabling consequences. Cynics may point out that some were spared smallpox only to become subject to hunger, want, and other killing and disabling conditions. To the degree that this is true, it should in no way diminish pride in the achievement. Rather, it should quicken our interest in other quests.

Public health authorities today list at least four infectious and parasitic diseases as appropriate targets for eradication. Two of these, yaws and dracunculiasis (guinea worm disease), are diseases of tropical regions and are associated with unsanitary water supplies and living conditions. The other two, poliomyelitis and measles, are among the immunizable diseases of children that are the priority concern of the World Health Organization's Expanded Program on Immunization.

Of the four, dracunculiasis would seem the most immediately amenable to eradication. India has demonstrated how a dracunculiasis campaign can be

carried out. The disease shares with smallpox the attribute of being readily identified by health workers and the public alike and therefore easily measured and traceable. The Centers for Disease Control (CDC) has been among the organizations playing a leading role in stimulating the necessary international accords to give priority to its eradication.

International symposia have been convened in recent years by the Fogarty International Center of the National Institutes of Health to examine the potential for eradication of measles, poliomyelitis, and yaws. The Pan American Health Organization has set 1990 as a target year for eliminating the transmission of poliomyelitis, a disease that has all but totally disappeared in the United States (two cases reported in all of 1986), from the Western Hemisphere. Measles, which for a number of valid technical reasons was not considered a candidate for eradication at the time of the West and Central African Smallpox Eradication/ Measles Control Program, is now considered eradicable by many authorities. Dr. William Foege forecasts that it could be done by the year 2005, with enormous saving of lives and prevention of residual disability from this still-underestimated disease of childhood.

Experts agree there is a way. Is there a will? In some quarters the goal of eradication seems again to be out of favor. As the smallpox eradication story clearly shows, the factors most critical to success in such an enterprise are belief that it can be done and commitment to do it.

Fear of failure, stemming from the unsuccessful malaria eradication effort many years ago, is one negative element. For some, the triumph of smallpox eradication is set aside as a special case, applicable only to diseases with exactly the same characteristics as smallpox—of which, of course, there are none. But, as we have seen, the success with smallpox was achieved through intensive study and field experience; these served as the basis for flexible strategies tailored both to the disease and to the different circumstances in which it was found. The model presented by smallpox eradication is not a blueprint but a set of attitudes, disciplines, and approaches.

A second element militating against eradication campaigns is a belief that commitment of the resources needed to eradicate a single disease will diminish the worldwide effort to make primary health care universally accessible. This need not be true. A goal of eradication requires the strengthening of primary care. Indeed, it can be convincingly argued that a specific achievable target of eradication can furnish a measurable objective that generates momentum from which broader programs of services can be developed. Excitement mobilizes support. Success leads to success.

The global Smallpox Eradication Program left a rich scientific and technical endowment. Significant advances were made in epidemiology that are widely applicable. Laboratory science was also greatly advanced across a broad range

of viral diseases. The logistics of public health in the developing world is another area in which great gains were made—in particular by illustrating the vital contribution of nonmedical personnel in orchestrating major campaigns.

Many veterans of the smallpox eradication campaigns comment on the spirit of camaraderie that remains. This spirit has practical benefit. More than once a knotty and seemingly insoluble international tangle has been miraculously resolved when former smallpox comrades-in-arms sat down together and worked them through. This has happened even more often domestically, as the smallpox alumni have moved into leadership positions, not only at CDC itself but in the state and local health departments, schools of public health, and elsewhere.

Dr. David Sencer has been quoted earlier in this narrative to the effect that an abiding value of the Smallpox Eradication Program was the difference it made in people's lives. He was referring specifically to the CDC personnel and their families. His statement is clearly true in a broader context as well. Smallpox workers in every country share in one of the rarest of human experiences—that of having participated in an endeavor of enormous importance that achieved absolute success.

Both Sencer and Foege have pointed out that smallpox eradication is a constant source of refreshment for the public health movement. More broadly still, it can serve as a constant source of refreshment for all who believe that people of every country and culture can work effectively together to advance the human condition.

Bibliography

by CDC Authors or Co-Authors

GENERAL

Arita, I., and J. G. Breman, 1979. "Evaluation of Smallpox Vaccination Policy," *Bull WHO*, 57:1-9 (also published in French as "Evaluation de la Politique de Vaccination Antivariolique," same volume, 195-205).

Arita, I, and D. A. Henderson, 1968. "Smallpox and Monkeypox in Non-Human Primates," *Bull WHO*, 39:277-283.

Arita, I., and D. A. Henderson, 1969. "Freeze Dried Vaccine for the Smallpox Eradication Programme," *Proceedings of Symposium on Smallpox*, Yugoslav Academy of Arts and Sciences, Zagreb, pp. 39-50.

Arita, I., and D. A. Henderson, 1969. "Smallpox and Monkeypox in Primates," *Primates in Medicine*, 3:122-123.

Breman, J. G., 1976. "Measles Vaccination and Control: Practical Considerations for Tropical Countries," *Children in the Tropics* (English and French), 104:11-17.

Breman, J. G., 1978. "Bilan et Enseignements de la Campagne d'Eradication Mondiale de la Variole," *Médecine et Maladies Infectieuses*, 11:550-558.

Breman, J. G., 1984. *"Poxviruses," in Tropical and Geographical Medicine*, edited by K. S. Warren, and A. A. F. Mahmoud, McGraw Hill Co., New York, pp. 594-602.

Breman, J. G., 1984. "Viral Infections with Cutaneous Lesions and Poxviruses," *Hunter's Tropical Medicine*, 6th edition, edited by G. T. Strickland, W. B. Saunders Co., Philadelphia, pp. 110-120.

Breman, J. G., and I. Arita, 1978. "Poxvirus Infections in Humans Following Abandoment of Smallpox Vaccination," in Proceedings of the 3rd Munich Symposium on Microbiology, *Natural History of Newly Emerging and Re-emerging Viral Zoonoses," Munich*, pp. 137-159.

Breman, J. G., and I. Arita, 1980. "The Confirmation and Maintenance of Smallpox Eradication," *N Engl J Med*, 303:1263-1273.

Breman, J. G., E. Coffi, K. R. Bomba-Ire, S. O. Foster, and K. L. Herrman, 1975. "Evaluation of a Measles-Smallpox Program by a Sero-Epidemiologic Method," *Am J Epidemiol*, 102:564-571.

Breman, J. G., Kalisa-Ruti, M. V. Steniowski, E. Zanotto, A. I. Gromyko, and I. Arita, 1980. "Human Monkeypox, 1970-79," *Bull WHO*, 58:165-182.

Breman, J. G., J. H. Nakano, E. Coffi, H. Godfrey, and J. C. Gautun, 1977. "Human Poxvirus Disease after Smallpox Eradication," *Am J Trop Med Hyg*, 26:273-281.

Breman, J. G., G. Perraud, and K. P. Compaore, 1975. "Evaluation de la Campagne Contre la Variole à Bobo-Dioulasso," *Médecine d'Afrique Noire*, 22:705-712.

Brilliant, L. B., J. H. Nakano, T. Kitamura, L. N. Hodakevic, and P. B. Bharucha, 1981. "Occupationally-Acquired Smallpox in an IgM-Deficient Health Worker," *Bull WHO*, 59:99-106.

Budd, M. A., R. G. Scholtens, R. F. McGehee, Jr., and P. Gardner, 1967. "An Evaluation of Measles and Smallpox Vaccines Simultaneously Administered," *Am J Public Health*, 57:80-86.

CDC, 1978. "Smallpox Surveillance - Worldwide," *MMWR*, 27:8.

CDC, 1980. "Advisory Memo No. 59: Global Eradication of Smallpox," 1980. Centers for Disease Control, Atlanta.

CDC, 1980. "Smallpox Vaccine," *MMWR*, 29:417.

CDC, 1982. "Smallpox Vaccination," *MMWR*, 31:159.

CDC, 1983. "Orthopox Surveillance: Post-Smallpox Eradication Policy," *MMWR*, 32:640.

CDC, 1983. "Post Smallpox Eradication Surveillance," *MMWR*, 32:490.

CDC, 1983. "Smallpox Vaccine Available for Protection of At-Risk Laboratory Workers," *MMWR*, 32:543.

CDC, 1984. "Smallpox: Post-Eradication Policy—Destruction of Variola Virus Stocks," *MMWR*, 33:24.

CDC, 1986. "Orthopoxvirus Infections," *MMWR*, 35:667.

Delon, P. J., and J. G. Breman, 1979. "Problèmes Lies à la Période Terminale de l'Eradication de la Variole," *La Médecine Practicienne*, 749:91-102.

Esposito, J. J., and J. C. Knight, 1985. "Orthopoxvirus DNA: A Comparison of Restriction Profiles and Maps," *Virology*, 143:230-251.

Esposito, J. J., J. F. Obijeski, and J. H. Nakano, 1977. "Serological Relatedness of Monkeypox, Variola, and Vaccinia Viruses," *J Med Virol*, 1:35-47.

Esposito, J. J., J. F. Obijeski, and J. H. Nakano, 1978. "Orthopoxvirus DNA: Strain Differentiation by Electrophoresis of Restriction Endonuclease Fragmented Virion DNA," *Virology*, 89:53-66.

Esposito, J. J., J. F. Obijeski, and J. H. Nakano, 1978. "Orthopoxvirus DNA: Strain Differentiation by Electrophoresis of Restriction Endonuclease Fragmented Virion DNA," *Virology*, 89:53-66.

Fenner, F., D. A. Henderson, I. Arita, Z. Jezek, and I. D. Ladnyi. *Smallpox and Its Eradication*, to be published, 1987.

Foege, W. H., 1979. "Should The Smallpox Virus Be Allowed To Survive?" *N Engl J Med*, 300:670-671.

Foege, W. H., S. O. Foster, and J. A. Goldstein, 1971. "Current Status of Global Smallpox Eradication," *Am J Epidemiol*, 93:223-233.

Foege, W. H., J. D. Millar, and J. M. Lane, 1971. "Selective Epidemiologic Control in Smallpox Eradication," *Am J Epidemiol*, 94:311-315.

Foster, S. O., 1978. "Participation of the Public in Global Smallpox Eradication," *Public Health Rep*, 93:147-149.

Foster, S. O., E. W. Brink, D. L. Hutchins, J. M. Pifer, B. Lourie, C. R. Moser, E. C. Cummings, O. E. K. Kuteyi, R. E. Eke, J. B. Titus, E. A. Smith, J. W. Hicks, and W. H. Foege, 1972. "Human Monkeypox," *Bull WHO*, 46:569-576.

Goldstein, J. A., J. M. Neff, J. M. Lane, and J. P. Koplan, 1975. "Smallpox Vaccination Reactions, Prophylaxis, and Therapy of Complications," *Pediatrics*, 55:342-347.

Heiner, G. W., N. Fatima, P. K. Russia, A. T. Haase, N. Ahmed, N. Mohammed, D. B. Thomas, T. M. Mack, M. M. Khan, G. L. Knatterud, R. L. Anthony, and F. R. McCrumb, 1971. "Field Trials of Methisazone in Smallpox Prophylaxis," *Am J Epidemiol*, 94:435-449.

Henderson, D. A., 1967. "Smallpox Eradication and Measles-Control Programs in West and Central Africa - Theoretical and Practical Approaches and Problems," *Industry and Tropical Health VI*, Harvard School of Public Health, Boston, pp. 112-120.

Henderson, D. A., 1969. "La Evaluacion en los Programas de Vacunacion," *Bol Of Sanit Panam*, 66:426-434.

Henderson, D. A., 1969. "The Status of the Global Smallpox Eradication Programme in September, 1969," *Proceedings of Symposium on Smallpox*, Yugoslav Academy of Arts and Sciences, Zagreb, pp. 23-35.

Henderson, D. A., 1970. "Control and Eradication of Smallpox," *Trop Doct*, 1:33-35.

Henderson, D. A., 1970. "Smallpox Surveillance in the Strategy of Global Eradication," *Health Centre Journal*, 12:59-66.

Henderson, D. A., 1971. "Smallpox: The Problem," *International Conference on the Application of Vaccines against Viral, Rickettsial and Bacterial Diseases of Man*, PAHO, Washington, pp. 139-143.

Henderson, D. A. 1972. "Epidemiology in the Global Eradication of Smallpox," *Int J Epidemiol*, 1:25-30.

Henderson, D. A., 1973. "Eradication of Smallpox: The Critical Year Ahead," *Proc R Soc Lond (Biol)*, 66:493-500.

Henderson, D. A., 1973. "La Variole," *Médecine et Hygiene*, 31:709-719.

Henderson, D. A., 1973. "Monkeypox and Its Relevance to Smallpox Eradication," *WHO Chron*, 27:145-148.

Henderson, D. A., 1974. "Genesis, Strategy and Progress of the Global Smallpox Eradication Program," *J Commun Dis*, 6:155-159.

Henderson, D. A., 1975. "Current Status of Smallpox in the World," *J Commun Dis*, 7:165-170.

Henderson, D. A., 1975. "Global Smallpox Eradication Programme," *Swasth Hind*, 19:116-118.

Henderson, D. A., 1975. "Smallpox Eradication - The Final Battle (Jenner Lecture)," *J Clin Pathol*, 28:843-849.

Henderson, D. A., 1976. "Surveillance of Smallpox," *Int J Epidemiol*, 5:19-28.

Henderson, D. A., 1976. "The Eradication of Smallpox," *Sci Am*, 235:25-33.

Henderson, D. A., 1977. "Smallpox Eradication," Proc R Soc Lond (Biol), 199:83-97.

Henderson, D. A., 1978. "Smallpox - Death of a Disease," *National Geographic*, December 1978, pp. 796-805.

Henderson, D. A., 1979. "Smallpox: Eradication of a Killer," *Encyclopedia Britannica, Medical and Health Annual*, pp. 125-144.

Henderson, D. A., 1979. "The Saga of Smallpox Eradication: An End and a Beginning," *Can J Public Health*, 70:21-27.

Henderson, D. A., 1980. "History of Smallpox Eradication," *Times, Places, and Persons* (Supplement to the *Bulletin of the History of Medicine*), edited by A. M. Lilienfeld, Johns Hopkins Press, Baltimore, pp. 99-108.

Henderson, D. A., 1980. "Landmarks in American Epidemiology: Smallpox Eradication," *Public Health Rep*, 95:422-426.

Henderson, D. A., 1980. "Smallpox After Eradication: Storing the Virus," *Encyclopedia Britannica, Medical and Health Annual*, pp. 254-256.

Henderson, D. A., 1982. "Letter to the Editor: Global Measles Eradication," *Lancet*, 2:208.

Henderson, D. A., 1982. "The Deliberate Extinction of a Species (Harben Lecture)," *American Philosophical Society*, 126:461-471.

Henderson, D. A., 1984. "Lessons from The Smallpox Eradication Experience" in *Medicine, Science, and Society*, edited by K. J. Issalbacher, John Wiley and Sons, New York, pp. 715-726.

Henderson, D. A., 1985. "Smallpox," *Epidemiology and the Community Control of Disease in Warm Climate Countries*, edited by D. Robinson, Churchill Livingstone, Edinburgh, pp. 249-261.

Henderson, D. A., 1985. "Smallpox," *Maxcy-Rosenau Preventive Medicine and Public Health*, 12th edition, edited by J. M. Last, Appleton-Century-Crofts, New York, pp. 129-138.

Henderson, D. A., 1985. "Variola and Vaccinia," *Cecil Textbook of Medicine*, 17th Edition, edited by J. B. Wyngaarden, L. H. Smith, W. B. Saunders, Philadelphia, pp. 1724-1728.

Hopkins, D. R. 1976. "After Smallpox Eradication: Yaws?" *Am J Trop Med Hyg*, 25:860-865.

Hopkins, D. R. 1977. "Benjamin Waterhouse (1754-1846), the 'Jenner of America,'" *Am J Trop Med Hyg*, 26:1060-1064.

Hopkins, D. R., 1983. *Princes and Peasants: Smallpox in History*, University of Chicago Press, Chicago, 380 pp.

Hopkins, D. R., 1985. "Beyond Smallpox Eradication," *Assignment Children*, edited by P. E. Mandl, UNICEF, Geneva, 69/72, pp. 235-241.

Hopkins, D. R., A. R. Hinman, J. P. Koplan, and J. M. Lane, 1982. "The Case for Global Measles Eradication," *Lancet*, 1:1396-1398.

Ifekwunigwe, A. E., N. X. Grasset, R. I. Glass, and S. O. Foster, 1980. "Immune Response to Measles and Smallpox Vaccinations in Malnourished Children," *Am J Clin Nutr*, 33:621-624.

Johnson, R. H., J. R. Krupp, A. R. Hoffman, J. P. Koplan, J. H. Nakano and T. C. Merigan, 1976. "Nosocomial Vaccinia Infection," *West J Med*, 125:266-270.

Johnson, R. H., J. R. Krupp, A. R. Hoffman, J. P. Koplan, J. H. Nakano and T. C. Merigan, 1976. "Transmission of Vaccinia Infection in a Hospital," *Clin Res* 24:113A.

Koplan, J. P., 1975. "Treatment of Smallpox and Vaccinia," *Current Therapy*, edited by H. Conn, W. B. Saunders, Philadelphia, PA, pp. 62-66.

Koplan, J. P., and S. O. Foster, 1979. "Smallpox: Clinical Types, Causes of Death, and Treatment," *J Infect Dis*, 140:440-441.

Koplan, J. P., J. Goldstein, and S. O. Foster, 1972. "Congenital Vaccinia: Some Doubts," *Pediatrics*, 50:971.

Koplan, J. P., and K. I. Marton, 1975. "Smallpox Vaccination Revisited: Some Observations on the Biology of Vaccinia," *Am J Trop Med*, 24:656-663.

Koplan, J. P., K. A. Monsur, S. O. Foster, F. Huq, M. M. Rahaman, S. Huq, R. A. Buchanan, and N. A. Ward, 1975. "Treatment of Variola Major with Adenine Arabinoside," *J Infect Dis*, 131:34-39.

Ladnyi, I.,and J. G. Breman, 1978. "Smallpox Eradication: Progress and Problems," *Dev Biol Stand*, 41:281-290.

Lane, J. M., T. M. Mack, and J. D. Millar, 1970. "Take Rates by Double Versus Single Insertions of Smallpox Vaccine in Revaccinees," *Public Health Rep*, 85:928-932.

Long, Gary W., J. Noble, Jr., F. A. Murphy, K. L. Herrmann, and B. Lourie, 1970. "Experience with Electron Microscopy in the Differential Diagnosis of Smallpox," *Appl Microbiol* 20:497-504.

Mack, T. M., and J. Noble, 1970. "Natural Transmission of Smallpox from Man to Performing Monkeys," *Lancet* 1:752-754.

Mack, T. M., J. Noble, and D. B. Thomas, 1972. "A Prospective Study of Serum Antibody and Protection Against Smallpox," *Am J Trop Med Hyg*, 21: 214-218.

Millar, J. D., 1965. "Smallpox: A Continuing Threat," *Hospitals* 39:57-59.

Millar, J. D., 1966. "Problems of Mass Vaccination Programs," *Proceedings of the PAHO/WHO International Conference on Vaccines Against Viral and Rickettsial Diseases in Man*, Washington, D.C., pp. 460-465.

Millar, J. D., 1967. "Smallpox Alert (Editorial)," *Ann Intern Med*, 66:1289-1290.

Millar, J. D., 1983. *Smallpox, Vaccinia and Cowpox, Infectious Diseases*, 3rd Edition. Harper and Row Publishers, New York, pp. 867-875.

Millar, J. D., 1985. *Vaccine Viruses as Vectors for Vaccine Antigens: Proceedings of the Workshop on Vaccinia Viruses as Vectors for Vaccine Antigens, held November 13-14, 1984, in Chevy Chase, Maryland*, USA, edited by G. V. Quinnan, Jr., Elseveir Science Publishing Co., Inc., New York, 258 pp.

Millar, J. D., and R. R. Roberto, 1964. "Vacunacion Intradermica Contra la Viruela por Inyeccion a Presion," *Bol Of Sanit Panam*, 57:537-547.

Millar, J. D., R. R. Roberto, H. Wulff, H. A. Wenner, and D. A. Henderson, 1969. "Smallpox Vaccination by Intradermal Jet Injection. 1. Introduction, Background, and Results of Pilot Studies," *Bull WHO*, 41:749-760.

Miller, G., J. Gale, V. Villarejos, W. James, C. G. Arteaga, H. Casey, and D. A. Henderson, 1967. "Edmonston B and Further Attenuated Measles Vaccine - A Placebo Controlled Double Blind Comparison," *Am J Public Health*, 57:1333-1340.

Nakano, J. H., 1973. "Evaluation of Virological Laboratory Methods for Smallpox Diagnosis," *Bull WHO* 48:529-534.

Nakano, J. H., 1980. "Smallpox, Monkeypox, Vaccinia, and Whitepox Viruses," *Manual of Clinical Microbiology*, 3rd Edition, edited by E. H. Lennett and J. P. Truant, Washington, D.C., American Society for Microbiol, 1044 pp.

Nakano, J. H., 1982. "Human Poxvirus Diseases and Laboratory Diagnosis," edited by L. M. De La Maza, E. M. Peterson, *Med. Virol*, Elsevier Science Publishing Company, New York, 407 pp.

Neff, J. M., J. D. Millar, R. R. Roberto, and H. Wulff, 1969. "Smallpox Vaccination by Intradermal Jet Injection. 3. Evaluation in a Well-Vaccinated Population," *Bull WHO*, 41:771-778.

Noble, J., Jr., 1970. "A Study of New and Old World Monkeys to Determine the Likelihood of a Simian Reservoir of Smallpox," *Bull WHO*, 42:509-514.

Noble, J., Jr., and M. S. Loggins, 1970. "Accuracy of Smallpox Diagnosis by Immunofluorescence with a Purified Conjugate," *Appl Microbiol*, 19: 855-861.

Noble, J., Jr., and J. A. Rich, 1969. "Transmission of Smallpox by Contact and by Aerosol Routes in *Macaca irus*," *Bull WHO*, 40:279-286.

Roberto, R. R., 1965. "Smallpox Vaccination by Intracutaneous Jet Injection," Dissertation Submitted for the Academic Post Graduate Diploma in Tropical Public Health, London School of Hygiene and Tropical Medicine University of London, (Copy in CDC Library).

Roberto, R. R., H. Wulff, and J. D Millar, 1969. "Smallpox Vaccination by Jet Injection - II. Cutaneous and Serological Responses to Primary Vaccination in Children," *Bull WHO*, 41:761-769.

Ruben, F. L., and J. M. Lane, 1970. "Ocular Vaccinia: an Epidemiologic Analysis of 348 Cases," *Arch Ophthamol*, 84:45-48.

Tarantola, D. J. M., F. Hug, J. H. Nakano, and S. O. Foster, 1981. "Immunofluorescence Staining for Detection of Variola Virus," *J Clin Microbiol*, 13:723-725.

Walls, H. H., D. Wziegler, and J. H. Nakano, 1981. "Characterization of Antibodies to Orthopoxviruses in Human Sera by Radio Immunoassay," *Bull WHO*, 59:253-262.

Wulff, H., T. D. Y. Chin, and H. A. Wenner, 1969. "Serologic Responses of Children After Primary Vaccination and Revaccination Against Smallpox," *Am J Epidemiol*, 90:312-318.

Ziegler, D. W., H. D. Hutchinson, J. P. Koplan, and J. H. Nakano, 1975. "Detection by Radioimmunoassay of Antibodies in Human Smallpox Patients and Vaccinees," *J Clin Microbiol*, 1:311-317.

AFRICA

Arita, I., and D. A. Henderson, 1976. "Monkeypox and Whitepox Viruses in West and Central Africa," *Bull WHO*, 53:347-353.

Breman, J. G., 1971. "Smallpox Epidemiology and Eradication in Guinea, West Africa," Dissertation, Ross Institute, London School of Hygiene and Tropical Medicine, University of London, 115 pp.

Breman, J. G., A. B. Alecaut, and J. M. Lane, 1977. "Smallpox in the Republic of Guinea, West Africa - I. History and Epidemiology," *Am J Trop Med Hyg*. 26:756-764.

Breman, J. G., A. B. Alecaut, D. R. Malberg, R. S. Charter, and J. M. Lane, 1977. "Smallpox in the Republic of Guinea, West Africa - II. Eradication Using Mobile Teams," *Am J Trop Med Hyg*, 26:765-774.

Breman, J. G., J. Bernadou, and J. H. Nakano, 1977. "Poxvirus in West African Non-Human Primates: Serologic Survey Results," *Bull WHO*, 55:605-612.

Breman, J. G., and R. Helmholz, 1969. "Les Problemes Techniques Poses par la Vaccination Antirougeoleuse de Masse en Afrique Tropicale, Dakar, 15 janvier 1969," *Médecine d'Afrique Noire*, (special issue), 55-56.

Deria, A., Z. Jezek, K. Markvart, P. Carrasco, and J. Weisfeld, 1980. "The World's Last Endemic Case of Smallpox: Surveillance and Containment Measures," *Bull WHO*, 58:279-283.

Foege, W. H., J. D. Millar, and D. A. Henderson, 1975. "Smallpox Eradication in West and Central Africa," *Bull WHO* 52:209-222.

Fofana, B., P. J. Imperato, and J. Nedvidek, 1971. "The Transmission Pattern of Smallpox in Eastern Mali," *Acta Trop (Basel)*, 28:175-179.

Foster, S. O., and A. Deria, 1983. "Smallpox Eradication in Somali Nomadic Encampments, the Search for a Culturally Acceptable Method of Case Detection, Case Isolation, and Outbreak Control," *Med Anthropol*, 7:19-25.

Foster, S. O., A. G. H. El Sid, and A. Deria, 1978. "Spread of Smallpox Among a Somalia Nomadic Group," *Lancet*, 2:831-833.

Foster, S. O., and E. A. Smith, 1970. "Smallpox Eradication in Nigeria," (W. Africa) *Bull Int Epidemiol Assoc*, 20:30-41.

Foster, S. O., and E. A. Smith, 1970. "The Epidemiology of Smallpox in Nigeria," *J Nigeria Med Assoc* 7:41-45.

Gelfand, H. M., and D. A. Henderson, 1966. "A Program for Smallpox Eradication and Measles Control Throughout West Africa," *J Int Health*, 2:24-33.

Gelfand, H. M., and D. A. Henderson, 1966. "Mass Prevention Medicine: Program for Smallpox Eradication and Measles Control Throughout West Africa," *J Int Health*, 2:24-33.

Henderson, D. A., 1971. "Smallpox Vaccination," *Proceedings of the Seminar on Vaccination in Africa*, Centre International de l'Enfance, Paris, pp. 44-46.

Henderson, R. H., 1973. "Assessment of Vaccination Coverage, Vaccination Scar Rates, and Smallpox Scarring in Five Areas of West Africa," *Bull WHO*, 48:183-194.

Henderson, R. H., and M. Yekpe, 1969. "Smallpox in Dahomey," *Am J Epidemiol*, 90:423-428.

Hopkins, D. R., J. M. Lane, E. C. Cummings, and J. D. Millar, 1971. "Smallpox in Sierra Leone. I. Epidemiology," *Am J Trop Med Hyg*, 20:689-696.

Hopkins, D. R., J. M. Lane, E. C. Cummings, J. N. Thornton, and J. D. Millar, 1971. "Smallpox in Sierra Leone. II. The 1968-69 Eradication Program," *Am J Trop Med Hyg*, 20:697-704.

Hopkins, D. R., J. M. Lane, E. C. Cummings, and J. D. Millar, 1971. "Two Funeral-Associated Smallpox Outbreaks in Sierra Leone," *Am J Epidemiol*, 94: 341-347.

Imperato, P. J., 1968. "The Practice of Variolation Among the Songhoi of Mali," *Trans R Soc Trop Med Hyg*, 62:868-873.

Imperato, P. J., 1969. "Anaphylaxie Fatale a la Suite de la Vaccination Contre la Rougeole Chez un Enfant Malien," *Afrique Medicale*, 69:301-303.

Imperato, P. J., 1969. "The Use of Markets as Vaccination Sites in the Mali Republic," *J Trop Med Hyg*, 72:8-13.

Imperato, P. J., 1969. "Traditional Attitudes Towards Measles in Mali," *Trans R Soc Trop Med Hyg*, 63:768-780.

Imperato, P. J., 1970. "The Transmission Pattern of Smallpox in a West African School Population," *J Trop Ped Child Health*, 16:202-209.

Imperato, P. J., 1974. "Nomads of the West African Sahel and the Delivery of Health Services to Them," *Soc Sci Med*, 8:443-457.

Imperato, P. J., 1974. "Observations on Variolation Practices in Mali," *Trop Geogr Med*, 26:429-440.

Imperato, P. J., 1975. *A Wind in Africa, A Story of Modern Medicine in Mali*, Warren H. Green & Co., St. Louis, 363 pp.

Imperato, P. J., 1975. "The Dubious Gamble Against Smallpox," *Natural History*, 84:8-18.

Imperato, P. J., 1977. *African Fold Medicine: Practices and Beliefs of the Bambara and Other Peoples*. York Press, Baltimore, 251 pp.

Imperato, P. J., 1978. "Traditional Medical Beliefs in Africa and Their Influence on the Success of Public Health Programs," *Courrier*, 28:339-344.

Imperato, P. J., B. Fofana, and O. Sow, 1975. "Strategie et Tactique pour la Vaccination des Populations du Delta L'Interieur du Niger," *Afrique Medicale*, 14:309-316.

Imperato, P. J., O. Sow and B. Fofana, 1972. "La Variole en Republique du Mali," *Afrique Medicale*, 105:983-994.

Imperato, P. J., O. Sow and B. Fofana, 1972. "The Epidemiology of Smallpox in the Republic of Mali," *Trans R Soc Trop Med Hyg*, 66:76-182.

Imperato, P. J., O. Sow and B. Fofana, 1973. "Mass Campaigns and Their Comparative Operational Costs for Nomadic and Sedentary Populations in the Republic of Mali," *Trop Geogr Med*, 25:516-522.

Imperato, P. J., O. Sow and B. Fofana, 1973. "The Persistence of Smallpox in Remote Unvaccinated Villages During Eradication Program Activities," *Acta Trop (Basel)*, 30:261-268.

Imperato, P. J., and D. Traore, 1968. "Traditional Beliefs About Smallpox and Its Treatment Among the Bambara of Mali," *J Trop Med Hyg*, 71:224-228.

Imperato, P. J., and D. Traore, 1969. "Traditional Beliefs About Measles Among the Bambara of Mali," *Trop Geogr Med*, 18:62-67.

Imperato, P. J., and D. Traore, 1979. "Traditional Beliefs About Smallpox and Its Treatment in the Republic of Mali," *African Therapeutic Systems*, edited by Z. A. Ademuwagun, J. A. A. Ayoade, I. E. Harrison, and D. M. Warren, Crossroads Press - African Studies Association, Waltham, Massachusetts, pp. 15-18.

Imperato, P. J., and D. Traore, 1979. "Traditional Beliefs About Measles and Its Treatment Among The Bambara of Mali," *African Therapeutic Systems*, edited by Z. A. Ademuwagun, J. A. A. Ayoade, I. E. Harrison and D. M. Warren, Crossroads Press - African Studies Association, Waltham, Massachusetts, pp. 19-21.

Jean-Joseph, P., P. J. Imperato, O. Sow, R. H., Henderson, H. L. Casey, and J. Noble, 1969. "Comparison of Edmonston-B and Schwartz Measles Vaccine in Malian Children," *Lancet*, 1:665-667.

Jean-Joseph, P., S. Sow, H. L. Casey, P. J. Imperato, and R. H. Henderson, 1969. "A Comparison of Edmonston-B and Schwarz Measles Vaccine in Malian Children," *Lancet*, 1:665-667.

Millar, J. D., 1970. "Theoretical and Practical Problems in Measles Control," *Proceedings of the Seminar on Smallpox Eradication and Measles Control in Western and Central Africa*, Lagos, Nigeria, May 13-20, 1969," *SEP Report*, Vol. IV, No. 2:165-176.

Millar, J. D., and W. H. Foege, 1969. "Status of Eradication of Smallpox (and Control of Measles) in West and Central Africa," *J Infect Dis*, 120:725-732.

Saliou, P., and J. G. Breman, 1976. "Une Mallette pour la Surveillance Epidemiologique de la Variole, du Cholera et de la Fievre Jaune," Note de Presentation, *Bull Soc Pathol Exot Filiales*, 69:398-411.

Saliou, P., and J. G. Breman, 1977. "La Surveillance Epidemiologique des Maladies Transmissibles dans les Pays Tropicaux: Les Principes en Son Application Pratique pour Trois Maladies Soumises au Reglement Sanitaire International (Cholera, Fievre Jaune et Variole)," *Médecine d'Afrique Noire*, 24:93-107.

Saliou, P., J. L. Rey, J. G. Breman, and P. Stoekel, 1977. "Une Annee d'Utilisation en Haute Volta d'une Mallette pour la Surveillance du Cholera, de la Fievre Jaune et de la Variole," *Bull Soc Pathol Exot Filiales*, 70:544-552.

ASIA

Foster, S. O., 1977. "Smallpox Eradication, Lessons Learned in Bangladesh," *WHO Chron*, 31:245-247.

Foster, S. O., N. A. Ward, A. K. Joarder, N. Arnt, D. Tarantola, M. Rahman, and K. Hughes, 1980. "Smallpox Surveillance in Bangladesh: I-Development of Surveillance Containment Strategy," *Int J Epidemiol*, 9:329-334.

Gelfand, H. M., 1966. "A Critical Examination of the Indian Smallpox Eradication Program," *Am J Public Health*, 56:1634-1651.

Hughes, K., S. O. Foster, D. Tarantola, H. Mehta, J. L. Tulloch, and A. K. Joarder, 1980. "Smallpox Surveillance in Bangladesh: II-Smallpox Facial Scar Survey Assessment of Surveillance Effectiveness," *Int J Epidemiol*, 9:335-725.

Koplan, J. P., M. Azizullah, and S. O. Foster, 1978. "Urban Hospital and Rural Village Smallpox in Bangladesh," *Trop Geogr Med*, 30:355-358.

Mack, T. M., D. B. Thomas and M. M. Khan, 1970. "Variola Major in West Pakistan," *J Infect Dis*, 122:479-499.

Mack, T. M., D. B. Thomas, A. Ali, and M. M. Khan, 1972. "Epidemiology of Smallpox in West Pakistan - I. Acquired Immunity and the Distribution of Disease," *Am J Epidemiol*, 95:157-168.

Mack, T. M., D. B. Thomas, and M. M. Khan, 1972. "Epidemiology of Smallpox in West Pakistan - II. Determinants of Intravillage Spread Other than Acquired Immunity," *Am J Epidemiol*, 95:169-177.

Sommer, A., and S. O. Foster, 1974. "The 1972 Smallpox Outbreak in Khulna Municipality, Bangladesh. I. Methodology and Epidemiologic Findings," *Am J Epidemiol*, 99:291-302.

Sommer, A., 1974. "The 1972 Smallpox Outbreak in Khulna Municipality, Bangladesh. II. Effectiveness of Surveillance and Containment in Urban Epidemic Control," *Am J Epidemiol*, 99:303-313.

Thomas, D. B., W. M. McCormack, I. Arita, M. M. Khan, S. Islan, and T. M. Mack, 1971. "Endemic Smallpox in Rural East Pakistan — I: Methodology, Clinical and Epidemiologic Characteristics of Cases, and Intervillage Transmission," *Am J Epidemiol*, 93:361-372.

Thomas, D. B., I. Arita, W. M. McCormack, M. M. Khan, S. Islam, and T. M. Mack, 1971. "Endemic Smallpox in Rural East Pakistan — II: Intravillage Transmission and Infectiousness," *Am J Epidemiol*, 93:373-383.

Thomas, D. B., T. M. Mack, A. Ali, and M. M. Khan, 1972. "Epidemiology of Smallpox in West Pakistan — III. Outbreak Detection and Interlocality Transmission," *Am J Epidemiol*, 95:178-189.

BRAZIL

Arnt, N., and L. Morris, 1972. "Smallpox Outbreaks in Two Brazilian Villages: Epidemiologic Characteristics," *Am J Epidemiol*, 95:363-370.

Costa, E. de Azeredo, and L. Morris, 1975. "Smallpox Epidemic in a Brazilian Community," *Am J Epidemiol*, 101:552-561.

Millar, J. D., L. Morris, A. Macedo Filho, T. M. Mack, W. Dyal, and A. A. Medeiros, 1971. "The Introduction of Jet Injection Mass Vaccination into the National Smallpox Eradication Program of Brazil," *Trop Geogr Med*, 23:89-101.

Morris, L., H. Cappello, R. Soares, J. Ponce de Leon, and W. Lester, 1971. "Smallpox Occurrence in the Municipio of Sao Paulo, Brazil, 1945-69," *HSMHA Health Rep*, 86:87-91.

Morris, L., O. Jose, and A. V. Martinez, 1970. "Epidemiologic Investigation of a Smallpox Outbreak in a Town (of Brazil) Reported to Be '100% Vaccinated,'" *Am J Epidemiol*, 92:294-300.

Noble, J., Jr., G. W. Long, E. Kirchner, and J. Sesso, 1970. "A Clinical and Laboratory Study of Smallpox in Brazil. Accuracy of the Laboratory Diagnosis of Smallpox in Patients with Brazilian Variola Minor Infection," *Am J Trop Med*, 19:1020-1028.

Suzart de Carvalho Filho, E., L. Morris, A. Lavigne de Lemos, J. Ponce de Leon, A. Escobar, and O. Jose da Silva, 1970. "Smallpox Eradication in Brazil, 1967-69," *Bull WHO*, 43:797-808.

EUROPE

Gelfand, H. M., and J. Posch, 1971. "The Recent Outbreak of Smallpox in Meschede, West Germany," *Am J Epidemiol*, 93:234-237.

Gordon, H., and J. T. Lewis, 1969. "Smallpox in Wandsworth (E) 1967," *Public Health*, 83:97-106.

Mack, T. M., 1972. "Smallpox in Europe, 1950-1971," *J Infect Dis*, 125:161-169.

Wehrle, P. F., J. Posch, K. H. Richter, D. A. Henderson, 1970. "An Airborne Outbreak of Smallpox in a German Hospital and Its Significance with Respect to Other Recent Outbreaks in Europe," *Bull WHO*, 43:669-679.

UNITED STATES

CDC, 1980. "Fatal Reaction to Smallpox Vaccination - California," *MMWR*, 29:117.

CDC, 1984. "Contact Spread of Vaccinia from a Recently Vaccinated Marine—Louisiana," *MMWR*, 33:37.

Clark, P. S., and J. M. Lane, 1971. "Complications of Smallpox Vaccination, 1968. Results of a Statewide Survey in Alaska," *Calif Med*, 115:7-10.

Foege, W. H., and J. M. Lane, 1972. "End of Routine Smallpox Vaccination in Childhood," *Ann Intern Med*, 76:324.

Koplan, J. P., and J. W. Hicks, 1974. "Smallpox and Vaccinia in the United States - 1972," *J Infect Dis*, 129:224 226.

Lane, J. M., 1969. "Vaccination and Henoch-Schoenlein Purpura," *N Engl J Med*, 280:781.

Lane, J. M., 1977. "Smallpox Vaccination," *JAMA*, 237:2419-2420.

Lane, J. M., 1977. "When Friends or Patients Ask About... Smallpox Vaccination," *JAMA*, 237:2419-2420.

Lane, J. M., and W. H. Foege, 1971. "New Guidelines for Smallpox Vaccination," *Pediatrics Digest*, 13:24-29.

Lane, J. M., and J. D. Millar, 1969. "Routine Childhood Vaccination Against Smallpox Reconsidered," *N Engl J Med*, 281:1220-1224.

Lane, J. M., F. L. Ruben, E. Abrutyn, and J. D. Millar, 1970. "Deaths Attributable to Smallpox Vaccination, 1959 to 1966 and 1968," *JAMA*, 212: 441-444.

Lane, J. M., and J. D. Millar, 1971. "Risks of Smallpox Vaccination Complications in the United States," *Am J Epidemiol*, 93:238-240.

Lane, J. M., J. D. Millar, and J. M. Neff, 1971. "Smallpox and Smallpox Vaccination Policy," *Annu Rev Med* 22:251-272.

Lane, J. M, F. L. Ruben, J. M. Neff, and J. D. Millar, 1969. "Complications of Smallpox Vaccination, 1968," *N Engl J Med*, 281:1201-1208.

Lane, J. M., F. L. Ruben, J. M. Neff, and J. D. Millar, 1970. "Complications of Smallpox Vaccination, 1968: Results of Ten Statewide Surveys," *J Infect Dis*, 122:303-309.

Mellin, H., J. M. Neff, H. Garber, and J. M. Lane, 1970. "Complications of Smallpox Vaccination, Maryland 1968," *Johns Hopkins Medical Journal* 126:160-168.

Neff, J. M., 1971. "The Case for Abolishing Routine Childhood Smallpox Vaccination in the United States," *Am J Epidemiol*, 93:245-247.

Neff, J. M., J. M. Lane, J. H. Pert, R. Moore, J. D. Millar, and D. A. Henderson, 1967. "Complications of Smallpox Vaccination -I. National Survey in the United States," *New Engl J Med*, 276: 125-132.

Neff, J. M., R. H. Levine, J. M. Lane, E. A. Ager, H. Moore, B. J. Rosenstein, J. D. Millar, and D. A. Henderson, 1967. "Complications of Smallpox Vaccination, United States, 1963," *Pediatrics*, 39:916-923.

Smith, J. W., L. G. Seidl, and J. E. Johnson, III, 1966. "Smallpox Vaccination in Hospital Personnel. Results of a Survey and Vaccination Program at the Johns Hopkins Hospital," *JAMA*, 197:309-314.

Thompson, R. S., J. M. Lane, and B. J. Francis, 1971. "Complications of Smallpox Vaccination in Washington, 1968," *Northw Med*, 70:180-184, 220.

Index

Ademola, Dr. Adeniji, 34, 69

Adolfo Lutz Institute, 94

Advisory Committee on Immunization Practice of the PHS, 78

Afghanistan: smallpox eradication program in, 89, 97-98; variolation practiced in, 97

AFRO. *See* World Health Organization's Regional Office for Africa (AFRO)

Agle, Andrew N., 68, 69, 70, 97-98, 105

AID. *See* U.S. Agency for International Development (AID)

Alexander the Great, 2

Altman, Dr. Lawrence K., 22

American Hospital Association, 14

animals, poxvirus diseases in, 89. *See also* monkeypox

Argentina, 92, 93

Arita, Dr. Isao, 102, 108, 109

Arnt, Dr. Nilton, 95

Asamoah, Rebecca Ansah, 45

assessment of vaccination, 40, 66, 87

Austria, smallpox free, 11

Bangladesh, 89, 109, 111; early CDC aid in, 13-14; smallpox eradication program in, 90, 91, 92, 98, 104-107

Banu, Rahima, 106

Bassett, David C., 107, 108

Benin. *See* Dahomey

Biafra, smallpox eradication program in, 46, 49. *See* also Nigeria

bifurcated needle, used in WHO Intensified Program, 88

Binson, Col. Gaston, 55-56

Blood, Dr. Benjamin, 45

Boletim Semanal da Campanha de Erradicacao da Variola, 94, 95

Bolivia, 92; smallpox vaccination campaign in, 40

Botswana, 90

Boyce, Dr., 64

Brazil, 3, 23, 78, 85, 86, 100; key to South American smallpox eradication program, 17-18, 93; smallpox eradication program in, 84, 89, 90, 92-95

Breman, Dr. Joel G., 66, 99

Brink, Dr. Edward W., 73

Brother's Brother, 56

Burkina Faso. *See* Upper Volta

Burundi, 89

Cameroon, 19, 21, 23, 89; smallpox eradication program in, 62-63

Canada, smallpox free, 11

Candau, Dr. Marcolino, 25, 27, 32, 86

CASE Manual, 82

CDC. *See* Centers for Disease Control (CDC)

Centers for Disease Control (CDC): Epidemic Intelligence Service, 9, 13; epidemiology at, 9, 32; field manual of, for West and Central African program, 31, 32; first West African venture of, 22-23; history of, 8-9; immunization assistance programs of, 9; relations of, with AID, 34, 41-42, 72; responsibilities of, 8-9; role of, in global smallpox eradication, 91-92, 96; Smallpox Eradication Program, 9, 83; Smallpox Program, 77, 78; venereal disease control program of, 9. *See also* smallpox laboratory, CDC; Smallpox Surveillance Unit, CDC

Central African Republic, 19, 23, 62

Ceylon, smallpox free, 11

Chad, 19, 23, 42; smallpox eradication program in, 63-64

Chagas' disease, 86

Challenor, Dr. Bernard, 29, 31, 55, 67, 68, 69

China, smallpox in ancient, 2-3; variolation practiced in, 6

Cholera, controlled in West Africa during smallpox eradication program, 73

Colombia, 92

Congo, *See* Peoples Republic of

Conrad, Dr. J. Lyle, 99

containment of smallpox outbreaks, 41, 47, 48, 55, 63, 68, 78, 87, 106; in India, 100, 101, 102, 103, 104

Cote d'Ivoire, *See* Ivory Coast

cowpox, used in smallpox vaccine, 6

Curtis, Dr. Clayton, 26, 42

Czechoslovakia, measles transmission interrupted in, 73

Dahomey, 19, 21, 22, 44, 50, 55, 89; program agreement for, 38; smallpox eradication program in, 67-69; variolation practiced in, 67-69

D'Amanda, Dr. Christopher, 60-61

da Silva, Dr. Oswaldo, 94

Democratic Republic of the Congo. *See* Zaire

de Quadros, Dr. Ciro, 95, 108

Diesh, Dr. P., 100

Division of Biologics Standards, NIH, 21, 33

dracunculiasis, targeted for eradication, 111-112

Drake, Dr. Thomas, 38, 57

East Pakistan. *See* Bangladesh

Ecuador, 92

Egypt, smallpox in ancient, 2, 3

electron microscopy, for smallpox diagnosis, 83

Elizabeth I, 3

Endemic Disease Control Unit (Sierra Leone), 65

England, smallpox free, 11

Equatorial Guinea, smallpox eradication program in, 47

eradication, *See* global eradication of smallpox

Eradication Escalation (E^2), 39, 46-47, 65, 68, 72

Eradication of Smallpox from India, The (WHO), 99

Eradicator, The, 65, 66

Ethiopia, 3, 89, 90, 91, 107; smallpox eradication program in, 108; variolation practiced in, 108

Europe: eighteenth-century epidemics in, 3-4; importations of smallpox to, 14, 77, 78, 79-81

Expanded Program on Immunization (WHO), 111

Foege, Dr. William H., 15, 31, 48, 49, 50, 64, 74, 91-92, 113; becomes head of CDC Smallpox Program, 72; and Dahomey smallpox eradication program, 68; "evangelist" for global smallpox eradication, 84; and Indian smallpox eradication program, 99-100, 102, 103; and measles eradication, 112; proposes E^2, 46-47; and Somalian smallpox eradication program, 109; and Tongan vaccination program, 17; and U.S. vaccination policy, 78

Fogarty International Center of the National Institutes of Health, 112

Foreign Assistance Act, delays in approval of, 29, 30, 33

Foreign Quarantine Program, 74-75

Foster, Dr. Stanley O., 51, 52, 54, 69, 73, 105, 106, 109

Francis, Dr. Donald P., 107

Frederiksen, Dr. Harold, 40

French colonial medical system: philosophy of, 62; resistance of, to surveillance, 32, 41

French Equatorial Africa, 20, 21, 62

French West Africa, 20, 21

Friedman, Jay S., 58-59, 98

Gabon, 19, 62

Galen, 5

Gambia, The, 19; measles transmission interrupted in, 57, 72-73; program agreement for, 38; smallpox eradication program in, 57

Gardner, Dr. Pierce, 17

Gelfand, Dr. Henry, 25, 26, 29, 31, 42, 64, 79, 83, 87, 99

Ghana, 19, 20, 24, 25, 43, 50; smallpox eradication program in, 53-55, 89; 25-millionth vaccination in, 44-45

Ghanaian importation, misdiagnosis of, 15, 16, 77, 82-83

global eradication of smallpox: CDC role in 91-92, 96; economic justification for, 75

Glokpor, Dr. G. F., 68

Godfrey, Harry R., 102, 108

Gowan, Gen. Y., 34, 35, 51

Grant, Dr. Frank, 54

Grasset, Dr. Nicole, 100

Griggs, Billy G., 29, 34, 42, 92, 102

Grigsby, Dr. Margaret E., 51

Guinea. *See* Equatorial Guinea; People's Republic of Guinea

Handbook for Smallpox Eradication in Endemic Areas (WHO), 31, 87

Health for All by the Year 2000, 8

Helmholz, Robert C., 57

Henderson, Dr. D. A., 14, 16, 23, 25, 26, 28, 31, 41, 67, 86; advocates global eradication, 84; argues for immediate African program, 39; assigned to WHO, 27, 40; directs CDC Smallpox Eradication Program, 29; and Indian eradication program, 99

Henderson, Dr. Ralph, 22, 29, 31, 40, 42, 50, 66, 69, 99

Higgins, William, 17

Hippocrates, 5

Hogan, Robert C., 56

Hopkins, Dr. Donald R., 65, 102, 108, 109; agrees to try E^2, 47

immunity: of smallpox survivors, 2, 6; of U.S. population, 77, 79; of vaccinated, 6

Imperato, Dr. Pascal J., 58-59

importations of smallpox: to Europe, 77, 78, 79-81; procedures for control of, 82; to U.S., 76; to U.S., likelihood of, 77-78

India, 89, 90, 105, 109, 111; cultural resistance to vaccination in, 100; eighteenth-century epidemics in, 4; smallpox eradication program in, 89, 91, 92, 98-104; smallpox in ancient, 2; variolation practiced in, 6

Indonesia, smallpox eradication program in, 89, 90, 96

inoculation. *See* variolation

Intensified Global Smallpox Eradication Program (WHO), 85, 86, 87, 88, 90, 92, 107, 109, 111, 112, 113

Iraq, 90

Iran, 90

Ismach, Aaron, 16, 17, 31

isolation of smallpox victims, 5, 109. *See also* containment of smallpox outbreaks

Ivory Coast, 19, 20, 21, 22; program agreement for, 38; smallpox eradication program in, 55-56

Jamot, Dr. Eugene, 20, 54

Jefferson, Thomas, 4

Jenner, Dr. Edward, 4, 104, 109

jet injector, 38, 88, 92; development of, 11, 16-17. *See also* ped-o-jet

Johnson, Lyndon B., 23

Kargbo-Reffell, Alfred, 65

Keita, Modibo, 59

Kempe, Dr. C. Henry, 15-16, 76-77

Kenya, 89, 90

Koswara, Dr. P. A., 96

Labusquière, Col. René, 21, 62

Ladnyi, Dr. Ivan, 32

Lagos Regional Office, 29, 30, 72; communication problems of, 42-43; office space for, 39

Lake Chad area, smallpox eradication program in, 63-64

Lambin, Dr. Paul, 22

Lane, Dr. J. Michael, 14, 15, 22, 52, 61-62, 84, 98; and Indonesian smallpox eradication program, 96; and U.S. smallpox vaccination policy, 76, 77, 78, 80

Langmuir, Dr. Alexander D., 9, 13, 32, 107

Leake, Dr.James, 15

Leonard, Thomas A., 57-58, 73

Lewis, Geoffrey, 58

Lewis, James O., 45, 50, 54

Liberia, 19, 26, 89; smallpox eradication program in, 41, 55-56, 64

Libya, 3

Lichfield, Paul, 46, 48, 49, 50, 64

Livingstone, Dr. David, 20

Louis XV, 3

Lourie, Dr. Bernard, 63-64, 96

Lythcott, Dr. George I., 28, 29, 31, 43, 44, 45, 46, 54, 58, 59, 109; obtains signature on Nigerian program agreement, 35, 37

Mack, Dr. Thomas M., 14, 46

malaria, 7, 8, 86; eradication effort, unsuccessful, 10, 112

Malaria Control in War Areas unit, predecessor of CDC, 8

Malawi, 89

Malberg, Donald R., 66

Mali, 19, 20, 21, 22, 38, 44, 61, 89; cultures of, 59; program agreement for, 38; smallpox eradication program in, 41, 58-60; variolation practiced in, 59

Masso, Anthony R., 61

mass vaccination, 40, 46, 47, 55, 87; as basis of West and Central African program, 31-32; technology developed for, 16

Mather, Cotton, 6

Mauritania, 19, 21, 22, 38, 41; program agreement for, 38; smallpox eradication program in, 57-58

Mayer, Dr. Hans, 32, 58

McDonald, Dr. George, 73

McEnaney, John P., 63

measles: death rate of, 21; difficulties of eradication of, 24, 72; epidemiology of, 72; targeted for eradication, 111, 112

measles vaccine: Edmonston B strain, 21-22, 33; refrigeration required for, 23, 34, 72; Schwarz strain, 33

Melchinger, Dr. David B., 50, 55

Meschede smallpox outbreak, 79-80

Meyer, Dr. Harry, 21-22, 33

Middle East, 3, 78

Millar, Dr. J. Donald, 13, 14, 15, 16, 29, 37, 41, 42, 45, 46, 84, 92; argues for gradual African program, 39-40; becomes Director of Bureau of State Services, 71; and Brazilian campaign, 17-18; directs Smallpox Eradication Program (CDC), 40; and E^2, 39-40, 46-47

monkeypox, 73-74, 83

Moore, Dr. Donald J., 61

Morais, Dr. Nelson, 94

Morbidity and Mortality Weekly Report (CDC), 94

Morris, Dr. Leo, 29, 31; and Brazilian eradication program, 18, 84, 92, 93, 94, 95

Moser, C. Randy, 73

Mountin, Dr. Joseph W., 8

Mozambique, 89, 90

Music, Dr. Stanley I., 105

Nakano, Dr. James H., 15, 83, 84, 109

National Institutes of Health (NIH), 21, 22

Nedvidek, Dr. Jeri, 59

Neff, Dr. John M., 14, 15, 17, 18, 31, 76, 77

Nepal, 90, 91; smallpox eradication program in, 89, 98

Nicaise, Saint, 4-5

Niger, 19, 21, 22, 44, 60, 63, 89; program agreement for, 38; smallpox eradication program in, 60-62; variolation practiced in, 61

Nigeria, 19, 26, 30, 34, 39, 46, 69, 89, 90, 97, 99; civil war in, 34, 42-43, 46, 49, 50, 51; cultural resistance to eradication program in, 51; exportations of smallpox from, 62, 63, 64; importance of, for West and Central African program, 24-25, 34, 54; last case of smallpox in, 44, 70; program agreement for, 34-35, 38; smallpox eradication program in, 46, 48-53, 70

Nineteenth World Health Assembly, 10, 27

Noble, Dr. John, Jr., 83

North America, eighteenth-century epidemics in, 4, 6

Ogoja episode of smallpox containment, 48

Olsen, Dennis G., 73

Organization de Coordination et de Coopération pour la Lutte contre Grandes Endemies (OCCGE), 21, 41, 74

Organization de Coordination pour la Lutte contre Endemies d'Afrique Central (OCEAC), 21, 26, 41, 74; policies of, 62

Organization of American States, 7

orthopox virus family, 1

Pakistan, 46, 79, 81, 89, 90, 91, 97, 98

Pan American Health Organization (PAHO), 10, 17, 92, 112

Pan American Sanitary Bureau. *See* Pan American Health Organization (PAHO)

Peace Corps volunteers, used in smallpox eradication programs, 65, 97, 108

ped-o-jet, 17, 31, 49, 64, 88

People's Republic of Guinea, 19, 20, 21, 22, 26, 38, 44, 89; smallpox eradication program in, 20, 64-67

People's Republic of the Congo, 19, 26, 27, 28, 41, 62

Peru, 17, 92-93

Philippines, smallpox free, 11

Pifer, Dr. John, 99

poliomyelitis, targeted for eradication, 111, 112

program agreements, for West and Central African program, 29, 38

"protection without walls," 75, 82

quarantine, 74-75; CDC's approach to, 81-82

Quenum, Dr. C. A., 28

Ramses V, 2

Rangaraj, Dr. A. G., 97, 98

Raska, Dr. Karel, 10, 25, 27

"recognition card," WHO, 105, 111

Research Institute for Viral Preparations (Moscow), 84

Rhazes, 5

Richet, Gen. Pierre, 21, 45

Robbins, Gordon E., 68

Roberto, Dr. Ronald R., 14, 17, 99

Rosenbloom, Dr. Arlan L., 63

Roy, Jeannel A., 69

Rwanda, 89

Sanneh, Kebba A. M., 57

Sansarricq, Dr. Hubert, 38

Scardaci, Anthony, 99

schistosomiasis, 86

Schultz, Dr. Myron G., 16

Selivanov, Dr. I., 102

Sencer, Dr. David J., 18, 40, 43, 45, 46, 71, 74, 104, 113; commitment of, to smallpox eradication, 91-92; and Indian smallpox eradication program, 99

Senegal, 19, 21, 57; program agreement for, 38; smallpox eradication program in, 56

Service des Grandes Endemies (SGE), 20, 56

Shapona, West African god of smallpox, 4, 5, 67

Sharma, Dr. M. I. D., 100

Shitala Mata, Indian goddess of smallpox, 4, 5, 100

Siegel, Milton, 25

Sierra Leone, 19, 20, 26, 44, 89; smallpox eradication program in, 47, 64-66, 67

Singh, Dr. Karan, 100

smallpox: and American Revolution, 4; ancient evidence of, 2; ancient history of, 2-3; and battle of Quebec, 4, 6-7; associated with deities, 4-5, 51, 67, 100; cause of, 1; early accounts of, 2 4, 5; early beliefs about cause of, 5-6; early treatments for, 5-7; eighteenth-century epidemics of, 3-4; endemic, extent of, 3, 10, 11, 44, 77, 78, 85, 89-91, 100-101; epidemics of, 2-4; epidemiological zones of, 85; epidemiology of, progress in, 46, 47, 48, 78, 82, 88-89, 112; eradication of, linked to measles control, 24; global eradication of, first proposed, 10; hospital acquired, 14, 79, 80, 81; importation of, *see* importations of smallpox; last naturally occurring case of, 84, 91, 109; origins of, 2; and religion, 4-5, 6, 51, 67-68, 69, 100; routine vaccination for, controversy over, 15-16; among royalty, 3; scars from, 1, 2; seasonality of occurrence of, 46-47, 66-67, 68; spread of, 3; strains of, 1; transmission of, 2, 5, 65, 66-67, 78; in twentieth-century U.S., 11, 13, 76. *See also* smallpox vaccination; smallpox vaccine

Smallpox Eradication Program (CDC), 9, 83

Smallpox Eradication Program (WHO), budgetary support for, 10, 27

Smallpox Expert Committee (WHO), 87

smallpox laboratory, CDC, 15, 82-84, 89, 92, 109; safety in, 83

Smallpox Program (CDC), 77, 78

Smallpox Surveillance Unit (CDC), 14, 15, 76; early field experience of, 16-17; misdiagnosis of Ghanaian importation by, 15, 16; moved to Office of the Director, 28-29, 91

smallpox vaccination: advantages of, over variolation, 6; complications from, 15, 16, 76-77; compulsory, 75-76; controversy over, 75-79; cultural resistance to, 51, 59, 67-69, 97, 100; deaths from, 6, 15, 76, 77; routine, 15, 16, 75-79; U.S. policy of, 15, 16, 76-79

smallpox vaccine: freeze-dried, 11; optimal dilution of, 16-17

Somalia, 91, 107, 108-109; smallpox eradication program in, 109

Soper, Dr. Fred L., 92

South Africa, 89

South America: eighteenth-century epidemics in, 4; endemic smallpox in, 92-93

South East Regional Office, WHO (SEARO), 96, 100, 101

Sri Lanka, smallpox free, 11

Stewart, Dr. William H., 40

Sudan, 89, 90; postvaccination surveillance in, 107; smallpox eradication program in, 90, 107

Suliman, Omar el Haj, 107

surveillance, 9; in Bangladesh program, 105; in Brazilian program, 93, 94-95; in Guinean program, 66; importance of, 32, 40-41, 75, 87-88; in Indian program, 100-101, 102, 103; in Indonesian program, 96; in Nigerian program, 70; resistance to, 32, 41, 60, 87; in Togo program, 68; in Upper Volta program, 60-61; and Yugoslavian outbreak, 80-81

Sweden, smallpox free, 11

Swedish International Development Agency, 101

Syria, 90

Tanzania, 89

Terry, Dr. Luther L., 27

Thompson, Dr. David M., 46, 48, 50, 64

Thornton, James M., 65

Thucydides, 3

Togo, 19, 21, 23, 44, 55, 89, 97; smallpox eradication program in, 67-68, 69; variolation practiced in, 67-69

Tonga, testing of smallpox vaccine in, 17

T'ou-Shen Niang-Niang, Chinese goddess of smallpox, 4

Twentieth World Health Assembly, commits WHO to global smallpox eradication, 10, 85

Uganda, 89

United Nations Children's Fund (UNICEF), 8

United States: immunity level of population of, 77, 79; importations of smallpox to, 76, 77-78; last cases of smallpox in, 11, 13, 76

Upper Volta, 19, 21, 26, 50, 55, 56, 60, 89, 97; measles vaccination program in, 22, 33; program agreement for, 38; smallpox eradication program in, 60-61

U.S. Agency for International Development (AID): accepts CDC smallpox-measles program, 24-25; history of, 9-10; philosophy of, 26; relations of, with CDC, 34, 41-42, 72; supports West African measles program, 22-23; withdraws support for program in Africa, 72, 74

U.S. Public Health Service (PHS), 8, 22, 24, 27, 74-75, 78, 79

USSR, smallpox free, 11

U.S. Supreme Court, 75

vaccination. *See* smallpox vaccination

vaccine. *See* measles vaccine; smallpox vaccine

vaccinia virus, 1, 33

variola intermedius, 1

variola major: characteristics of, 1-2; death rate of, 1; last case of naturally occurring, 106; symptoms of, 1; in U.S., 76

variola minor, 1, 2; death rate of, 2; in U.S., 76

variolation: in Afghanistan, 97; controversy over, 6-7; in Dahomey and Togo, 67-69; death rate of, 6; in Ethiopia, 107; in Mali, 59; in Niger, 61; origins of, 6

Waddy, Dr. B. B., 54

Wade, Lloyd W., 51

Watson, William C., Jr., 102

Weekly Epidemiological Record (WHO), 90

Wehrle, Dr. Paul H., 79, 96

Weisfeld, Dr. Jason S., 109

West and Central Africa: cultures of, 19; difficulties of travel and communication in, 19; geography of, 18; health services in, 20-21; last case of smallpox in, 44, 70; measles campaign in, 22-23; peoples of, 19; political history of, 19-20; politics of, 38

West and Central African Smallpox Eradication/Measles Control Program: as beginning of global smallpox eradication, 11, 32; expenses of, 28; housing for personnel of, 34, 39; maintenance phase of, 72; objectives of, 28; other contributions of, 73; personnel for, 29-30; summary of, 44-47; training of personnel for, 30-32; U.S. expenditures for, 28; vaccination procedures of, 40; vehicles for, 33-34. *See also names of individual countries*

White, William J., Jr., 60-61

WHO. *See* World Health Organization (WHO)

Williams, Franklin, 44, 45, 54

Winkelstein, Dr. Warren, 26

Work, Dr. Telford, 83

World Health Assembly, 7, 23, 39; Nineteenth, 10, 27; Twentieth, 10, 85

World Health Organization (WHO), 7-8, 24, 38, 58, 59, 79, 84, 85, 86, 88, 105, 107, 109; assessment methodology of, 40; financial commitment of, to smallpox eradication, 10, 27, 41; regional nature of, 7, 27, 86

World Health Organization Collaborating Center for Smallpox and Other Poxvirus Infections, 83

World Health Organization Secretariat, 7, 39

World Health Organization's Regional Office for Africa (AFRO), 25, 27-28; relations of, with CDC, 41

yaws, 65; targeted for eradication, 10, 111, 112

yellow fever, 7, 75; contained during West and Central African program, 73; targeted for eradication, 10

Yemen, 89, 90

Yugoslavian smallpox outbreak, 80-81, 90

Zaire, 90; smallpox eradication program in, 89; monkeypox in, 74

Zambia, smallpox eradication program in, 89

Zeigler, Dr. Pierre, 63

Zimbabwe, 89

