

"Eradication: Pitfalls and Promise"

EIGHTH JOSEPH MOUNTIN LECTURE

Donald A. Henderson, M.D., M.P.H.

Dean

The Johns Hopkins University

School of Hygiene and Public Health

Introduction

On October 26, 1987, we celebrated the 10th anniversary of the realization of a vision - the global eradication of a disease. It was a vision worthy of Joe Mountin and so the conjunction of the two events - the anniversary and the lecture - are a happy concordance. I am also mindful that for myself and others whose specialty and life was smallpox, the detection and containment of that last case marked an abrupt ending to a major phase of our professional careers. Few of you can imagine the emotions associated with the occurrence of that last case. For years, we had been at the forefront of public health in coping with a major problem, international experts in smallpox, at the center of excitement in achieving what many once believed impossible. Suddenly, the disease vanished. It was akin to the armistice at the end of the World War - immensely gratifying but suddenly creating a void in life and rendering all but obsolete, one's professional credentials.

I've wondered how many old generals became deans for want of better employment!

Last year, Dr. Don Millar, in the Seventh Joseph Mountin Lecture, brilliantly captured in reminiscence the joys and adventures of the smallpox eradication adventure. He paid due tribute to the dedicated contributions of tens of thousands from virtually every country of the world - to the special contributions of so many of you who are here today - and to the families concerned. Let me today offer a sequel to his lecture and endeavor to cast in perspective the concept of eradication itself - its beginnings, its failures and its future.

Attitudes toward Smallpox Eradication

It is difficult today to imagine how few, only 20 years ago, believed that the eradication of smallpox or any other human disease was a feasible, let alone a practicable objective. Skepticism and disbelief were widespread and these extended from politicians to knowledgeable scientists. One of the most widely read, respected and influential of the scientists in the 1950s and 1960s was René Dubos - the Lewis Thomas of that era. In 1965, he published his eminently readable book, *Man Adapting*.⁽¹⁾ This appeared on the market just as the World Health Assembly was deciding to embark on the 10-year Intensified Smallpox Eradication Program. I quote from his chapter dealing with eradication:

"At first sight, the decision to eradicate certain microbial diseases appears to constitute but one more step forward in the development of the control policies initiated by the great sanitarians of the 19th century In reality, however, eradication involves a new biological philosophy. It implies that it is necessary and desirable to get rid of certain disease problems ... by eliminating completely the etiological agents, once and for all

"In all cases the problems posed by biological and epidemiological peculiarities of each type of infection are still further complicated by financial, administrative and political uncertainties. Even if genuine eradication of a pathogen or vector on a worldwide scale were theoretically and practically possible, the enormous effort required for reaching the goal would probably make the attempt economically and humanly unwise"

"Social considerations, in fact, make it probably useless to discuss the theoretical flaws and technical difficulties of eradication programs, because more earthy factors will certainly bring them soon to a gentle and silent death. Certain unpleasant but universal human traits will put impassable stumbling blocks on the road to eradication. For example, it is easy to write laws for compulsory vaccination against smallpox, but in most parts of the world, people would much rather buy the vaccination certificate than take the vaccine

"Public health administrators, like social planners, have to compromise with the limitations of human nature. For this reason, and many others, eradication programs will eventually become a curiosity item on library shelves, just as have all social utopias."

Dubos had cause to write as he did. The so-called global malaria eradication campaign was then in its tenth year. Enormous sums of money had been allocated for it but progress in Asia and Latin America was far behind schedule and costs were far greater than had been anticipated. Moreover, what few appreciate, neither a strategy nor a program had ever been developed for the whole of sub-Saharan Africa.

In 1959, WHO had also reluctantly launched a smallpox eradication program⁽²⁾ in response to a proposal by the Soviet Union⁽³⁾, but seven years later, there was little progress to report⁽⁴⁾. Senior staff at WHO openly opposed the program, in part because its Director General, Marcelino Candau, believed that the eradication of smallpox could only be achieved through universal vaccination. Knowing well his native Brazil, he recognized that this was quite impossible throughout the vast regions of the Amazon Basin and certainly elsewhere as well. WHO's support for smallpox eradication reflected these beliefs. In 1965, WHO spent \$63,000,000 for malaria eradication and \$233,000 for smallpox eradication - a difference of 300 fold.

Belief in the concept of eradication was at a low ebb when, in 1966, the United States and the Soviet Union took the lead in proposing that the

smallpox eradication program be given a chance of success by earmarking a larger sum in WHO's budget for its implementation. The CDC-directed and Agency for International Development (AID)-supported smallpox eradication-measles control program in western and central Africa⁽⁵⁾, agreed upon only a year before, was a major stimulus to this initiative.

In planning for global smallpox eradication, WHO foresaw a need for international support amounting to \$7 million annually.⁽⁶⁾ Voluntary contributions were expected to cover most of this. How much should be provided for in the WHO budget was heatedly debated but eventually \$2.4 million was decided upon - overall, about \$50,000 for each country where a program was thought to be required. Many countries were not enthusiastic and the WHO budget for 1967 was accepted by the margin of only 2 votes with 12 nations abstaining.⁽⁷⁾ No WHO budget, before or since, proved so divisive as this one; the lack of international support, thereafter, bore out the reservations which so many had. CDC provided crucial support to the program in Western and Central Africa and the Soviet Union contributed hundreds of millions of doses of vaccine. However, during the first seven years of the intensified program, the combined contributions of all other countries and United Nations agencies amounted to less than \$1,000,000 per year.⁽⁸⁾ Indeed, throughout its course, the smallpox eradication campaign was a precariously funded uphill battle whose achievement was anything but certain less than a year before the last case occurred.

It is important that we understand why there was such skepticism and so little support for the campaign, for it has a bearing on the lessons which the campaign offers for future health initiatives. The reasons, as we shall see, rest primarily in the history of eradication as a public health policy, a policy which led to strategies which dominated our international health agenda until little more than a decade ago.

Origins of the Concept of Eradication

Interestingly, the first planned program whose stated objective was "eradication" was one intended to eliminate a disease of cows - bovine contagious pleuropneumonia.⁽⁹⁾ This highly fatal disease had been imported into New York in 1843, and gradually spread to the Midwest. Eventually, a number of countries began to embargo imports of livestock from the United States. To deal with the problem, the Congress in 1884, created the Bureau of Animal Industries. Its stated objective was to eradicate the disease over a five-year period, the term "eradication" actually being used in its charge. And, indeed, it was successful. Soon, other animal disease eradication programs began to be conducted which likewise proved successful.⁽¹⁰⁾ Different approaches were used for each but most of these involved the isolation and/or slaughter of infected herds. (This approach was obviously not well-suited for dealing with human disease.) Moreover, they all dealt with recently imported organisms or vectors which were localized geographically and had not become enzootic. Another important characteristic of these programs was that they invested heavily in surveillance in order to identify the

prevalence and distribution of the disease or vector. Regrettably, this was a principle which was not well-heeded when human disease eradication programs began.

From these experiences, the belief grew that there might be a number of microorganisms or vectors which clung so tenuously to an ecological niche that simple measures could be found to upset the balance of nature. It was believed and so it proved that highly intensive short-term eradication programs could sometimes be less costly than long-term control efforts. By the turn of the century, planned programs for disease eradication were a familiar concept to many in veterinary medicine but were largely unknown to those concerned with human disease. For diseases such as plague, cholera, smallpox and yellow fever, quarantine regulations were adopted but until the present century, the term eradication was not applied to a planned program for the control and eventual elimination of a human disease.

Eradication of Human Diseases

Surprisingly, the first human disease to be considered for eradication was hookworm - in 1907. This was soon followed by one for yellow fever.⁽¹¹⁾ From what is now known of their biology, neither disease was a reasonable candidate. When the programs began, however, a visionary belief coupled with excessive optimism, albeit inadequate scientific knowledge, caused them to be selected. The magnitude of the efforts was extraordinary even by contemporary standards and the patterns of program

operation, especially for yellow fever, largely defined the nature of public health strategies and agendas for the next 50 years. Both were the products of the philanthropy of John D. Rockefeller.

With support from Rockefeller, hookworm eradication campaigns began throughout the southern United States in 1909. Why hookworm? In its more severe forms, it caused anemia and lassitude and, this, it was reasoned, was the underlying cause for what was perceived to be a less vigorous and productive population. Some, in fact, called hookworm infection the disease of laziness. In the belief that the eradication of hookworm would effect a fundamental economic and sociocultural transformation of a region, an eradication program was launched. The program strategy called for mobile teams to identify infected persons by stool examination and to treat them. At the same time, other teams worked to construct sanitary privies. It was anticipated that this would interrupt the cycle of transmission between infection in man and persistence of the worm in the soil. During the first five years of the program, \$1.0 million was expended, a very large sum in those days. More than 2 million persons were treated and 250,000 rural houses were inspected and sanitary privies provided. Over the succeeding years, cooperative programs were extended to 52 countries on 6 continents and to 29 island groups. It was an unprecedented global effort.

The program strategy had been based on faith, without confirmation by a pilot project that the measures employed would actually be effective in practice. Progress was measured in terms of numbers of treatments and

numbers of privies constructed. Neither surveillance for infections nor research were deemed important. Not until more than a decade after the program began were studies conducted anywhere to assess whether transmission was being interrupted. When these studies were finally conducted, they showed that even with an apparently effective program, infection rates were not diminished, although those infected had fewer worms, on average, and so, less illness.⁽¹²⁾ Clearly, eradication was beyond reach. Soon thereafter, the program began to be phased out.

Yellow Fever Eradication - A Vector Control Strategy

In 1915, the Rockefeller Foundation embarked on yet a second global eradication program - against yellow fever. Here, the scientific foundation was better laid although understanding of the epidemiology of the disease was still deficient, as later became apparent. Prospects for yellow fever eradication originated in the dramatic interruption of yellow fever transmission in Cuba in 1901. The year before, a U.S. government commission, headed by Walter Reed, demonstrated conclusively that the disease was caused by a virus and transmitted by the *Aedes aegypti* mosquito after an extrinsic incubation period of 9-16 days.⁽¹³⁾ The mosquito was shown to breed almost exclusively in and around houses. Immediately thereafter, the Chief Sanitary Officer for Cuba, Major William Gorgas, set in motion a massive control program.⁽¹⁴⁾ Patients were isolated in screened quarters; breeding sites were eliminated by the removal of bottles and cans, kerosene was applied to water surfaces and cisterns were covered with nets. The program was a military-style

operation in which teams of three inspectors were each assigned responsibility for 1,000 homes to be inspected at the rate of 30 houses per day. Only eight months later, Havana and indeed Cuba became free of yellow fever for the first time in memory. In 1902, Gorgas wrote to Brigadier General Leonard Wood "I look forward in the future to a time when yellow fever will have entirely disappeared I believe that when the yellow fever parasite has become extinct, it can no more return than the dodo."⁽¹⁴⁾

Subsequently, during construction of the Panama Canal, Gorgas confirmed the efficacy of his strategy⁽¹⁵⁾ and Oswaldo Cruz did likewise in Rio de Janeiro. Gorgas concluded that yellow fever transmission could be sustained only in population centers of 50,000 or more and that by intensive, short-term campaigns to reduce, not eliminate *Aedes aegypti* populations, yellow fever could be eradicated.⁽¹⁶⁾

In 1915, the opportunity arose to test this hypothesis. Wickliffe Rose, the director of the newly established Rockefeller Foundation, was casting about for a major undertaking befitting the new foundation. In a visit to Asia, he discovered everywhere that health officials were profoundly concerned about the possible importation of yellow fever in consequence of the opening of the Panama Canal.⁽¹⁷⁾ Given that the potential mosquito vectors were widely prevalent in Asia, they feared the occurrence of massive epidemics should yellow fever be imported. Rose, a philosopher by training, consulted then Surgeon-General Gorgas

who assured him that eradication could be achieved in a reasonable time and at a reasonable cost.

Thus, in May 1915, the Rockefeller's International Health Commission announced its intention to provide assistance wherever infection with yellow fever was endemic with the objective of global eradication. Eradication in the Americas was foreseen within five years; a timetable for Africa awaited further study. The campaign began in 1918 with Gorgas himself as its Director.

Using the same meticulously planned, quasi-military approach as had been used in Cuba, rapid progress was made - at least as measured by reports of yellow fever in the larger urban areas. Indeed, by the late 1920s, almost a year elapsed - from April 1927 to March 1928 - during which no cases were reported from anywhere in the Americas. In March 1928, however, the first cases of yellow fever in 20 years occurred in Rio de Janeiro and outbreaks rapidly spread across the country. At the same time, outbreaks whose sources were unclear also occurred in Venezuela and Colombia. Doubts about the feasibility of yellow fever eradication began to be expressed and, with a failing anti-hookworm campaign, the Rockefeller Foundation came under severe criticism for its support of disease eradication programs.⁽¹⁸⁾

What had gone wrong? The Foundation turned to one of its promising young staff members, Fred Soper, then 35 years old. He was subsequently to prove to be one of public health's most skillful administrators and a

determined, effective and articulate advocate of disease eradication as a public policy. Through his efforts, he dictated an international public health agenda and strategy which extended over the succeeding three decades.

Soper diagnosed the problem as being primarily one of failures in administration. Accordingly, Brazil's program was radically restructured. All personnel in the country working on yellow fever were brought under a single National Yellow Fever Service which Soper himself directed. Extensive, detailed manuals were prepared and rigid discipline was imposed to insure that all premises in urban areas were meticulously searched and appropriate vector control measures applied. How meticulous is conveyed by the story of the health worker whose schedule called for him to visit an armory on a day when it exploded and burned. When the health worker appeared for work the following day, Soper was pleased to find him alive but promptly fired him for not having followed his prescribed schedule.

By 1930, it had become apparent that there were a number of rural areas in which yellow fever was endemic and that this was not a new phenomenon.⁽¹⁹⁾ Thus, 12 years after the yellow fever eradication program began, efforts were finally made to establish a disease surveillance program.⁽²⁰⁾ As with the hookworm campaign, few efforts had been made until that time to measure with accuracy the effect of the massive field programs on the occurrence of the disease itself. It was

a serious omission but one which has continue to characterize most of our efforts to control human disease.

As additional information became available, it was soon apparent that there was a jungle reservoir of the yellow fever virus and that interruption of virus transmission was impossible. Soper's highly disciplined, all but autonomous Army, however, was recording extraordinary successes. In many areas, it was able not only to reduce *Aedes aegypti* breeding to extraordinarily low levels, it succeeded in eliminating the vector itself. The eradication of yellow fever was impossible but Soper proposed a bold new initiative, the eradication of *the mosquito species, Aedes aegypti.*⁽²¹⁾ The Brazilian government did not immediately agree and the Rockefeller Foundation objected although it continued to provide reluctant but diminishing support. Soper, however, pressed on.

Eradication of a Second Insect Vector - *Anopheles gambiae*

There the whole matter might have rested had not the African mosquito *Anopheles gambiae* been introduced into northeast Brazil.⁽²²⁾ This occurred soon after a rapid mail service was established between the north eastern port of Natal and Dakar in Senegal. This African mosquito was an efficient vector of malaria and major epidemics soon developed and gradually spread across two of the northeastern states of Brazil.

Soper correctly foresaw the problems that this vector could pose for the Americas and so proposed that an *Anopheles gambiae* eradication effort be initiated. Many saw this as yet one more excuse to prolong the life of Soper's army of vector control staff. Reluctantly, the Foundation provided yet more funds and an anti-malaria service was constituted by Presidential decree with Soper, of course, at its head. Four thousand workers were employed.

The *Anopheles* vector was a substantially greater challenge as it bred more widely, especially in the rainy season. Soper's strategy was to determine the boundaries of the infected area and to cordon off this area. All boats and vehicles leaving the area were fumigated. During the dry season, when the number of breeding sites diminished markedly in number, Paris green was applied to the breeding sites and pyrethrum sprayed in the houses. Amazingly, the last focus of the mosquito was discovered in November 1940, less than two years after the campaign had begun.

It was a brilliant achievement from which Soper drew a number of far-reaching conclusions.⁽²¹⁾ Most important was his belief that the eradication of selected vector species was entirely feasible, as was the eradication of certain infectious disease agents. Success, as he saw it, lay in "vigorous and effective action rather than refined measurement of the problem." He had no malariologists on his staff and saw no need for them. The major constraints of disease eradication, as he saw it, lay primarily in the lack of vision of health administrators

rather than in the lack of appropriate technology. With a meticulously executed field program, directed by dedicated and imaginative staff, the inconceivable could become possible.

Following the war, Soper, still the enthusiastic eradicationist, became director of what is now called the Pan American Health Organization. One of the first acts of its Directing Council was to agree that PAHO should undertake the eradication of *Aedes aegypti* throughout the Americas.⁽²³⁾ Three years later, the Council was persuaded to approve eradication programs against yaws, smallpox and malaria. PAHO's resources, however, were so limited that even one eradication program was beyond its reach. Soper's interest and expertise lay in vector control and so neither yaws nor smallpox eradication was vigorously pursued. The stage was set, however, for the next great adventure in eradication - a program to eliminate malaria.

Malaria Eradication

DDT was discovered in the early 1940s and where widely applied, it had had a profound effect on malaria morbidity and mortality. In Venezuela, for example, mortality rates plummeted from 179 per 100,000 in 1945 to only 2 per 100,000, four years later.⁽²⁴⁾ A Center in Atlanta for Malaria Control in War Areas began using DDT around military training areas in 1945 and later was given responsibility for a major national program for malaria eradication.⁽²⁵⁾ Malaria transmission ceased in the United States, an event which encouraged wider eradication efforts and

cemented the Center's position as a national resource for disease control programs. As Langmuir later commented, however, surveillance data were seriously deficient until the 1950s and, based on later evidence, it is probable that transmission had actually ceased, or nearly so, before the national program began. (26)

These and other successes, real or imagined, fired the imagination of the eradicationists with Soper their chief spokesman. Thus, PAHO began a regional malaria eradication program.

Substantial bilateral resources were made available by the predecessor organization of AID but far from enough. Greater support was needed and the opportunity was presented to obtain that support when evidence of DDT resistant mosquitos was uncovered.

The eradicationists argued for a massive international effort to be undertaken as an emergency measure to eradicate malaria before the problem of resistance became widespread. (27) To those who doubted its feasibility, Soper was fond of quoting the President of the U.S. National Malaria Society who said in 1945, "Malaria eradication in the U.S. is an untenable concept as we do not know where and under what conditions the disease occurs." (28) Only a few years later, it became apparent that, even as he spoke, the interruption of transmission in the U.S. was already imminent.

In 1955, WHO embarked on a global program for malaria eradication. The fact that its Director General, Marcelino Candau, had grown up in Soper's vector control program in Brazil gave the program a special impetus. The visionary goal was doubted by a number of scientists^(29,30) but uncritically welcomed by politicians and international agencies alike. They supported it as no other international health program before or since. Over the decade 1955-1965, WHO malaria staff posts increased to more than 600. One estimate prepared by AID indicates that \$1.4 billion was expended during a 10-year period.⁽³¹⁾

The organization and strategy of the program echoed that of the great *Aedes aegypti* programs of the 1920s and 1930s. A separate and autonomous malaria eradication service, entirely independent of the health authority, was called for, which would have no other duties than those concerned with malaria eradication.⁽³²⁾ Higher pay scales than those in the health service were provided in order to attract the best staff. The numbers involved were enormous. In some countries they outnumbered the total of all health personnel. Not surprisingly, the health staff resented the more affluent and well-equipped malaria service.

Highly detailed, standardized manuals of procedures were developed which described in minute particulars the duties of every person on the staff. The strategy focused on the application of DDT to the walls of dwellings. Traditional methods of mosquito control such as drainage and

larviciding were largely abandoned - as was research. The problem was perceived in Soper's terms to be primarily one of meticulous administration and application of known measures.

Through the early 1960s, reasonable progress could be documented. This was confined primarily to the more affluent countries and those where year-round mosquito breeding did not take place. By 1966, however, it had become apparent that the program was lagging seriously in many countries and that the very costly measures of the so-called "attack phase" would have to be extended over many additional years.⁽³³⁾ By 1970, international confidence and support had begun to diminish and by 1973, the demise of the malaria eradication program had been officially acknowledged. Jeffrey, one of its senior statesmen, ruefully pointed out that "The science of malaria control, developed slowly and painfully from the beginning of the century to a relatively high level of sophistication, was almost overnight converted to the rather simplistic technology of malaria eradication, which basically required that one know how to deliver 2 grams of something to every square meter of a sometimes elusive interior wall and to manage a hopeful ever-diminishing Kardex file of cases."⁽³⁵⁾ A similar view was expressed differently by McGregor, who lamented the diminishing number of "malariologists" and the proliferation of "eradicationists."⁽³⁶⁾

The Impact of the Vector-control Eradication Campaigns

Of what relevance is this ancient history to today's challenges in international health, to the prospects for disease eradication or to the

smallpox eradication campaign in particular? These events, in fact, have a great deal to do with all of the above.

Bear in mind that during a 50-year period in the Americas, the dominant and pervasive international programs were those for vector control and/or eradication to address the problems of yellow fever and malaria. In most of Asia as well as in WHO, malaria eradication campaigns dominated health agendas and budgets for well over two decades throughout the formative years of their public health programs. They operated outside of the health service structure; their demands on funds both in international assistance and of national budgets were insatiable; and they were deeply resented. Those engaged were well-meaning and preoccupied with what was truly a major health problem but, in consequence, other community-based health programs received little attention and, indeed, were ignored or opposed by those who were captivated by the Holy Grail of global malaria eradication. National immunization programs were all but non-existent, sanitation schemes received little attention and the development of basic preventive services was postponed until the "malaria eradication program could be integrated into the basic health services."

In 1953, Dr. Brock Chisholm, then in his last year as WHO's first director-general, proposed a smallpox eradication campaign.⁽³⁷⁾ However, delegates from disparate areas, including the USA, United Kingdom, India and Australia asserted that "insufficient knowledge was available, that the problem was vast and complicated and that a

world-wide machinery for such a campaign was not then available." Under the new Director-General, Dr. Candau, the proposal was buried but in the same year in which Chisholm's proposal met its demise, the goal of malaria eradication was adopted by the World Health Assembly - one which was vastly more costly and complicated and even more lacking in its scientific underpinning.

Given the extraordinary public expectations and the expenditures, it is not surprising that the collapse of malaria eradication had profound repercussions. The credibility of public health expertise was called into question. Illustrative of attitudes in the late 1960s was that of UNICEF, once a major supporter of the malaria eradication program, which withdrew its support to malaria eradication and refused to contribute to smallpox eradication.⁽⁸⁾ Most bilateral agencies responded similarly. Dislike and perhaps jealousy of the autonomous malaria programs and their better paid staffs led many in the health services to reject out of hand all other categorical programs, however structured. Family planning and smallpox eradication were both recipients of this backlash as were later immunization programs and those for oral rehydration therapy. Categorical programs of whatever stripe were suspect and so, for many years, we labored in the gray twilight of policies designed to promote integrated primary health programs, few of which had stated goals. They bore the euphemistic banner, "Health for All in the Year 2000." Meaningless interminable debates raged on all sides about "vertical" and "horizontal" programs.

Lessons from Smallpox Eradication

As I reflect on the implications which smallpox eradication has and has had for the future, I believe that most important, it provided a needed focus and direction for meaningful public health policy and gave a critical impetus to many countries to undertake other targeted community-wide prevention initiatives. However, these did not follow as obvious and inevitable consequences. The CDC programs in western and central Africa are a case in point. Nowhere in the world was the smallpox eradication program so greatly appreciated or so dramatically effective in spite of the fact that they were conducted in many of the world's poorest countries. I remember well the unanimous plea to AID from the respective U.S. Ambassadors and Ministers of Health of these countries to extend the program to include other vaccines and preventive measures - and the absolute refusal by AID. You will recall the continuing efforts of CDC Directors, Drs. David Sencer and William Foege, to sustain some momentum using CDC funds and eventually, but only much later, the support provided by AID to a program for the control of communicable childhood diseases. Time was required for the wounds and disenchantment with the global malaria eradication campaign to heal.

Smallpox eradication, operating within and as part of the health services structure, represented an important shift in strategy - from autonomous armies of vector-control technicians meticulously following manuals to the more flexible and imaginative community-based prevention programs now reflected in the expanded program of immunization, family

planning, oral rehydration therapy, Vitamin A supplementation and others. An answer as to how and why these developed and flourished is partially provided by the question put to me two years ago by the Director-General of WHO and the Secretary-General of UNICEF. They asked: "Where do we find the next generation of capable field staff?" I innocently asked as to which was the last generation. They said - "Why the smallpox eradication staff, of course but they are now fully engaged in senior positions in these other programs."

The foundation and structure of the smallpox eradication program was built by younger people who were given support, a challenge and a goal as well as an opportunity to innovate and to learn. The goal was a specific one - zero cases of smallpox. It was an outcome objective which required surveillance. In undertaking surveillance, much was learned about the epidemiology of the disease and how and where programs worked and how and where they didn't. If this bears a resemblance to the practical application of epidemiology in disease control and to the Epidemic Intelligence Service which Dr. Alex Langmuir fostered, this should be no surprise given the training which many of us had received. Notably, however, the program bore little resemblance to the many mindless programs which count the numbers vaccinated or procedures performed, which estimate coverage rates and recipients of services but wholly ignore whether or not disease incidence has actually diminished.

Smallpox eradication embraced one other important feature. It was a targeted program whose objective and progress could be understood by politicians and the public alike. To quote Soper: "The point is too

often missed by public health administrators that theirs is a selling as well as an administrative job."⁽²¹⁾ Selling an understandable and specific product is a wholly different problem than selling a vaguely defined but perhaps no less worthy general improvement in a system. Deans know only too well that they can far more readily obtain funds for research on or treatment of a disease than they can for the School's general endowment. In public health, likewise, we have had a war on cancer, a foundation for cystic fibrosis and a foundation for infantile paralysis. There is little interest in a program which vaguely proposes to develop the basic health services.

The Future of Eradication

Not surprisingly, there is renewed interest in disease eradication,⁽³⁸⁻⁴⁰⁾ an effort which would galvanize attention, garner funds and mobilize efforts. Such efforts began with hookworm eradication, migrated to yellow fever, then to *Aedes aegypti*, and finally to malaria. In each instance, these decisions, as I hope I have illustrated, were driven more by evangelism than by science, by emotions more than by reason, by the belief that answers lay in diligent administration rather than good epidemiology and innovative research, by the belief that it was better to try and fail than not to try at all. By the time smallpox eradication emerged, the most feasible of all programs, public health credibility was at a low ebb. We have recaptured some of that credibility.

Let us challenge the future as we did the past but let us be cautious that we not again squander our credibility in ill-founded delusions rather than realistic dreams.

However, we must continue to dream and to work together in realizing those dreams. I know well that my own happiest and most productive years were spent in eradicating smallpox with an incredible band of colleagues - motivated, contentious, dedicated, irreverent, imaginative, impatient and often with dress and ponytails which were quite out of place in traditional WHO and Embassy receptions - whose families tolerated absences and preoccupation, who worked hard and partied hard. who regularly reached beyond their own perceived endurance and capability - and achieved the impossible. Let us do it again!

REFERENCES

Note: A more detailed analysis of the concept of eradication has been presented by the author in Chapter 9 of Smallpox and Its Eradication by F. Fenner, D.A. Henderson, I. Arita, Z. Jezek and I. Ladnyi.

1. Dubos, R., Man Adapting, New Haven, Yale University Press, 1965.
2. World Health Organization, WHO Handbook of Resolutions and Decisions, Volume 1, 1948-1972, Geneva, 1973.
3. World Health Organization, Eradication of Smallpox. Official Records of the World Health Organization, No. 87, Annex 19, pp. 508-512, Geneva, 1958.
4. WHO Scientific Group on Smallpox Eradication Report. WHO Technical Report Series, No. 393, Geneva, 1968.
5. Henderson, D.A., Smallpox-eradication and measles-control programs in west and central Africa - theoretical and practical approaches and problems. In: Industry and tropical health: VI, Cambridge, Harvard School of Public Health.
6. World Health Organization. Smallpox Eradication Programme. Official Records of the World Health Organization, No. 151, Annex 15, pp. 106-121, Geneva, 1966.

7. World Health Organization. Smallpox eradication programme. Official Records of the World Health Organization, No. 152, pp. 258-264, 288-296, Geneva, 1966.
8. Fenner, F., Henderson, D.A., Arita, I., Jezek, Z., Ladnyi, I., Smallpox and Its Eradication, Geneva, World Health Organization, 1988.
9. Hinman, E.H., World eradication of infectious diseases, Springfield, Thomas, 1966.
10. Hagan, W.A., The control and eradication of animal diseases in the United States. Ann. rev. of microbiol., 12:127-144, 1958.
11. Fosdick, R.B., The Story of the Rockefeller Foundation, New York, Harper and Brothers, 1952.
12. Smillie, W.G., The results of hookworm disease prophylaxis in Brazil, Amer. J. Hyg. 2:77-95, 1922.
13. Reed, W., Carroll, J., Agramonte, A., Lazear, J.W., The etiology of yellow fever: A preliminary note. Philadelphia Med. J., 6:790-796, 1900.
14. Gorgas, W.C., Report of Maj. W.C. Gorgas, Medical Corps, United States Army - July 12, 1902. U.S. Senate Document No. 822, Washington, Government Printing Office, pp. 234-238, 1911.

15. McCullough, D., The Path between the Seas, New York, Simon and Schuster, 1977.
16. Gorgas, W.C., Method of the spread of yellow fever. Medical Record, 73:1062-1073, 1908.
17. Strode, G.K., ed. Yellow Fever, New York, McGraw-Hill, 1951.
18. Soper, F.L., Rehabilitation of the eradication concept in prevention of communicable diseases. Pub. Hlth. Rpts., 80:855-869, 1965.
19. Soper, F.L., Jungle yellow fever: new epidemiological entity in South America. Revista de higiene e saúde publica, 10:107-144, 1936.
20. Soper, F.L., Rickard, E.R., Crawford, P.J. The routine post-mortem removal of liver tissue from rapidly fatal fever cases for the discovery of silent yellow fever foci. Amer. J. Hyg., 19:549-566, 1934.
21. Duffy, J., ed. Ventures in World Health. The Memoirs of Fred Lowe Soper, Washington, Pan American Health Organization, 1977.
22. Soper, F.L., Wilson, D.B., Anopheles gambiae in Brazil 1930 to 1940, Rockefeller Foundation, 1943.

23. Pan American Health Organization. Handbook of resolutions of the governing bodies of the Pan American Health Organization, Washington, 1971, pp. 27-33.
24. Gabaldon, A. Nation-wide malaria eradication projects in the Americas. II Progress of the malaria campaigns in Venezuela. J. Natl. Mal. Soc., 10:124-141, 1951.
25. Andrews, J.M. Nation-wide malaria eradication projects in the Americas I The eradication program in the U.S.A. J. Natl. Mal. Soc., 10:99-121, 1951.
26. Langmuir, A.D., The surveillance of communicable diseases of national importance. New Engl. J. Med, 268:182-192, 1963.
27. Pampana, E.J., A textbook of malaria eradication, London, Oxford University Press, 1963.
28. Johnson, H.A., Malaria in the post-war era. J. Natl. Malaria Soc., 5:1-6, 1946.
29. Farid, M.A., The malaria programme - from euphoria to anarchy, World Hlth. Forum, 1:8-33, 1980.
30. Downs, W.G., A new look at yellow fever and malaria. Amer. J. Trop. Med. and Hyg, 30:516-522, 1981.

31. United States Agency for International Development, AID Malaria Strategy Workshop, Washington, 1983.
32. WHO Expert Committee on Malaria. Sixth report. WHO technical report series, No. 23, Geneva, 1957.
33. WHO Expert Committee on Malaria. Thirteenth report. WHO technical report series, No. 357, Geneva, 1967.
34. Yekutiel, P., Lessons from the big eradication campaigns. World Health forum, 2:465-481, 1981.
35. Jeffery, G.M., Malaria control in the twentieth century. Amer. J. Trop. Med. and Hyg., 25:361-371, 1976.
36. McGregor, I., Malaria-recollections and observations. Transactions of the Royal Soc. Trop. Med. and Hyg., 78:1-8, 1984.
37. World Health Organization. Proposals for world-wide campaigns: smallpox. Official Records of the World Health Organization, No. 48, pp. 211-215, 220-221, Geneva, 1953.
38. Stettin, D., Jr., Eradication. Science, 210:1203, 1980.
39. Hopkins, D.R., Hinman, A.R., Koplan, J.P., Lane, J.M., The case for global measles eradication. Lancet 1:1396-1398, 1982.

40. Hopkins, D.R., After smallpox eradication: yaws? Amer. J. Trop. Med. and Hyg., 25:860-865, 1976.

23. Pan American Health Organization. Handbook of resolutions of the governing bodies of the Pan American Health Organization, Washington, 1971, pp. 27-33.
24. Gabaldon, A. Nation-wide malaria eradication projects in the Americas. II Progress of the malaria campaigns in Venezuela. J. Natl. Mal. Soc., 10:124-141, 1951.
25. Andrews, J.M. Nation-wide malaria eradication projects in the Americas I The eradication program in the U.S.A. J. Natl. Mal. Soc., 10:99-121, 1951.
26. Langmuir, A.D., The surveillance of communicable diseases of national importance. New Engl. J. Med, 268:182-192, 1963.
27. Pampana, E.J., A textbook of malaria eradication, London, Oxford University Press, 1963.
28. Johnson, H.A., Malaria in the post-war era. J. Natl. Malaria Soc., 5:1-6, 1946.
29. Farid, M.A., The malaria programme - from euphoria to anarchy, World Hlth. Forum, 1:8-33, 1980.
30. Downs, W.G., A new look at yellow fever and malaria. Amer. J. Trop. Med. and Hyg, 30:516-522, 1981.