

Rehabilitation of the Eradication Concept in Prevention of Communicable Diseases

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THE ERADICATION concept in the prevention of communicable diseases is quite modern; it had to await the discovery of effective methods of disease prevention, the rejection of the concept of spontaneous generation, and the identification of specific etiologic agents of individual diseases.

The introduction of vaccination as a preventive of smallpox led Thomas Jefferson to enunciate the eradication concept in the early years of the 19th century (1, 2). Some decades later Pasteur said, "It is within the power of man to rid himself of every parasitic disease." ("Parasitic" for Pasteur was a general term including infectious diseases.)

In 1884, the U.S. Congress created the Bureau of Animal Industry to eradicate contagious bovine pleuropneumonia and to prevent the export of other animal diseases from this country.

In 1888, Charles V. Chapin declared that any disease which could be prevented in part could be prevented in its entirety and urged the eradication of tuberculosis (3).

In 1902, following the dramatic victory over yellow fever in Havana during the previous year, Gen. William Gorgas predicted its future eradication.

In the early years of this century, Ronald Ross worked out mathematical formulas for the disappearance of malaria (4), and Wycliffe Rose became the director of the Rockefeller Sanitary Commission for the Eradication of Hookworm Disease in the United States.

In 1915, the newly created Rockefeller Foundation established its Yellow Fever Commission, under the leadership of Gorgas, to undertake the eradication of yellow fever (5).

Of these early dreams of eradication, only that for the eradication of contagious bovine pleuropneumonia materialized (6); by 1930 the eradication concept was thoroughly discredited in this country. Health workers accepted, and the professors of public health administration taught, the philosophy of reduction of communicable disease to a reasonable level; a modicum of preventable disease became and, even today, remains respectable.

However justifiable the complacent acceptance of the persistence of preventable diseases may have appeared 30 years ago, it is no longer defensible. The success of local and national eradication efforts during the past three decades, the discovery of new methods of disease prevention, and the increasing participation of all nations in coordinated international health programs have led to rehabilitation of the eradication concept. Today the nations of the Americas are committed to the eradication of the *Aedes aegypti* mosquito, malaria, smallpox, and yaws; the nations of the world have joined in the global eradication of malaria, and the demand for the eradication of other preventable diseases is inevitable.

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Attempt to Eradicate Yellow Fever

My introduction to eradication came, in November 1919, from Wycliffe Rose, director of the International Health Board of the Rockefeller Foundation. In outlining to me, a prospective staff member, the program of the board, Rose cited yellow fever as a scourge which could be and was, in fact, being eradicated by the nations of the Americas with the aid of the foundation. Rose was confident that yellow fever would disappear within the next 5 years.

At Johns Hopkins in 1920, before my first visit to Brazil, I heard more of yellow fever eradication from General Gorgas, the hero of Havana and Panama. Gorgas cited the experience of two decades, during which campaigns against the *A. aegypti* mosquito in the large cities of endemic yellow fever regions had eradicated the disease in these regions and in the smaller communities in tributary areas.

Yellow fever was then being eradicated by the reduction of its mosquito vector in known endemic centers long enough to allow the virus to spontaneously disappear throughout the endemic zones. No consideration was given to attacking *A. aegypti* throughout its range or of eradicating it anywhere; eradication of yellow fever virus itself was the objective.

In Brazil I learned that the Government had organized its own eradication program (National Yellow Fever Commissions) in 1919, along the lines proposed by Gorgas in 1916. Yellow fever had receded as anticipated, and eradication seemed imminent. Soon after the disease had disappeared from the statistics of Brazil (1921-22), the National Yellow Fever Commissions were transformed into the joint Federal-State Services for the Prevention of Rural Endemic Diseases (Profilaxia Rural). Shortly after this transformation, however, yellow fever reappeared, and the Brazilian Government in 1923 invited the Rockefeller Foundation to collaborate in its eradication campaign.

The reorganization of the eradication campaign by the Rockefeller Foundation was essentially a repetition of the preceding Brazilian effort; the failure of the national campaign was attributed to an inadequate coverage of the endemic centers for too short a period, rather than to any weakness in the plan itself.

Again, yellow fever receded rapidly with the attack on the *A. aegypti* in the capital cities of north Brazil; optimism about the imminence of eradication grew rapidly through 1925. However, a so-considered temporary setback occurred in 1926 when nonimmune troops moving through north Brazil became infected and seeded a number of widely scattered towns with yellow fever.

Anti-mosquito work was instituted in the infected towns in the interior. Yellow fever once more receded below the threshold of visibility, and during an 11-month period in 1927-28, no case of yellow fever was recorded for the entire American continent. Optimism was such that in January 1928 the health workers of Brazil were assured that should another 3 months pass without cases of yellow fever, they could consider the disease eradicated. In March 1928, one case occurred in Sergipe and 2 months later Rio de Janeiro, Brazil's beautiful capital with almost 2 million people, became infected with yellow fever for the first time in 20 years.

This unexpected invasion of Rio, heavily infested with *A. aegypti*, provided yellow fever virus its most active center of distribution since 1910. During the next 3 years, the disease occurred in numerous towns in the interior of Brazil, on shipboard, in port cities from Buenos Aires on the south to Belém at the mouth of the Amazon, and even as far as Manaus, some 800 miles up the river.

During this period, yellow fever workers were shocked by the occurrence of the disease at Recife, Pernambuco, in 1929, after 5 years of uninterrupted anti-*aegypti* work. Investigation revealed a much greater density of *A. aegypti* there than reported by the inspectors. This led many to believe that Rio de Janeiro had been reinfected from northeast Brazil; that failure to eradicate yellow fever had again been the result of inadequate anti-*aegypti* measures in the known key centers of infection.

The contrast between the absence of reported yellow fever in the period immediately preceding its appearance in Rio and the widespread epidemicity which followed was a dramatic demonstration of the influence of the large city in the distribution of infection. This was indeed a confirmation of the key-center epidemiology on which eradication was based. On the



Belém, Pará, Brazil: A family about to travel into the Amazon Forest is inoculated with 17D virus vaccine against jungle yellow fever.

other hand, at about the same time, outbreaks of yellow fever were occurring elsewhere, and these could not be explained by the key-center theory. In 1929, isolated outbreaks were reported in Socorro, Colombia (7), and Guasapati, Venezuela (8), both small centers far from all Brazilian foci of infection, inaccessible to each other, and isolated from all large cities.

Eradication Concept Discredited

The period between the late 1920's and the early 1930's was probably this century's low point in acceptance of the eradication concept in the prevention of communicable diseases. The 1928-29 outbreak of yellow fever in Rio seemed to invalidate previous optimism about its eradication. Hookworm disease campaigns everywhere had failed to entirely eliminate hook-

worm infestation. The eradication concept was thoroughly discredited, and the Rockefeller Foundation suffered severe criticism because of its support of eradication programs.

Eradication of *Aedes aegypti*

In 1930 I became directly responsible for the administration of the Rockefeller Foundation's effort to eradicate yellow fever in South America. Before assuming direction of the cooperative Yellow Fever Service (maintained by the Brazilian Government and the Rockefeller Foundation in north Brazil), I discussed the disease and its eradication with Dr. Wade Hampton Frost, professor of epidemiology, at Johns Hopkins. He asked me if I believed that yellow fever could be eradicated from Brazil. My answer was equivocal, "If the eradication of

yellow fever was ever possible, it is definitely so at present because of the great interest aroused by the Rio outbreak and the infection of many smaller cities and towns."

Frost then inquired if I planned a blanket attack on *A. aegypti* throughout north Brazil, not to eradicate it but to get rid of unrecognized foci of infection. My protest that this would be very costly brought a reply worthy of the dean of American epidemiologists: "No matter how great the cost, the eradication of yellow fever is so important that none will question the expenditure once the job has been done." And he made it clear that getting the money was part and parcel of the job itself. (The point is too often missed by public health administrators that theirs is a selling as well as an administrative job.)

Following the meeting with Professor Frost, I returned to Brazil determined to find out if yellow fever could be eradicated. An analysis of the 1930 yellow fever situation indicated that: (a) the epidemiology of yellow fever was not fully known, the disease could continue unobserved for months or years; (b) the *A. aegypti* mosquito could maintain itself indefinitely in hidden breeding places despite trustworthy inspectors who worked under close supervision; and (c) it is difficult to maintain an efficient anti-*aegypti* service in the absence of yellow fever. Specifically, then, these problems had to be solved:

1. Silent endemic yellow fever: how to discover when and where cases occurred?
2. Hidden *A. aegypti* breeding: how to find residual breeding responsible for the continued existence of the species?
3. Supervision and checking of anti-*aegypti* operation: how to maintain safe *A. aegypti* levels and guarantee accuracy of reported breeding indices?

Seeking the answers to these questions and applying them was to occupy the best efforts of Rockefeller Foundation and Brazilian workers, aided by workers of other South American countries, during the next decade.

Determining when and where yellow fever occurred proved most difficult. Although the clinical symptoms of classic fatal yellow fever are dramatic, experience had repeatedly shown that the disease could and did continue over

long periods of time without reported cases. The then newly developed protection or neutralization test in monkeys was too expensive for routine surveys. The results of such surveys, when positive, indicated only that the disease had been present within the lifetime of persons with immune bodies, but did not establish the date of infection (9). This problem was solved through the routine collection of pathological material throughout possible yellow fever areas.

Yellow fever, when fatal, generally kills within 10 days after onset, and produces a characteristic lesion in the liver. The practical difficulty of collecting postmortem material was greatly reduced by the development of a simple instrument, termed the "viscerotome," for the rapid removal of liver tissue without autopsy. Viscerotomy was not designed to substitute for autopsy when yellow fever was suspected; rather was it applied systematically to all persons who died after less than 11 days of febrile illness (10).

A field organization of local representatives was created to collect and forward liver tissue to the central laboratory for diagnosis. Although initial opposition to the desecration of bodies soon after death was encountered, all difficulties were eventually overcome. Viscerotomy has proved the most fertile source of information of the current distribution of yellow fever infection throughout South and Central America.

The discovery of hidden *A. aegypti* breeding places came to be based on the search for adult *aegypti* mosquitoes; once a house with hidden breeding had been identified, special squads were assigned the task of uncovering the concealed breeding. This relatively simple procedure, though costly in time and effort, proved unexpectedly productive.

Yellow fever workers had previously found the capture of *A. aegypti* of little value in control campaigns where the objective was to reduce breeding to less than 5 percent of the houses. At levels of incidence below 2 percent, however, the capture of adult mosquitoes proved the most sensitive index of the presence or absence of *A. aegypti* in an area.

The supervision and checking of anti-*aegypti* work in Brazilian cities was greatly strength-

ened by careful mapping of all areas, definite delineation of individual responsibility for each area, detailed reporting of all work done, and continuous checking and cross-checking of work at all levels (11). (The declared objective was to make the reported *A. aegypti* breeding index as trustworthy and certifiable as were the bank account statements of the Yellow Fever Service.)

Viscerotomy indicated that the northeastern States of Brazil maintained a silent but widespread endemic yellow fever, transmitted by the *A. aegypti* mosquito even in the rural areas. This endemic disease had been overlooked year after year by the Yellow Fever Service with its sentinel services in the coastal cities. The endemic was limited almost entirely to Brazilian children under 15 years of age. Since viscerotomy is applied only postmortem, the falsity of the belief long held in this area that yellow fever was a "febre patriótica" which slew only foreigners became obvious.

The unusual rural distribution of the *A. aegypti* mosquito, which permitted this endemic to be self-perpetuating as an infection transmitted from man to man, had not been foreseen in the development of the key-center plan of yellow fever eradication. But once this silent endemic was uncovered, it was a relatively simple and straightforward, if tedious and expensive, task to eradicate the disease by taking anti-aegypti measures in all the towns and villages and many rural areas.

By August 1934 this final endemic focus of yellow fever in the Americas was eliminated, and had the *A. aegypti* mosquito been the only culprit in the transmission of the disease, as Gorgas believed, that year would have marked the end of yellow fever in the Western Hemisphere.

An even more unexpected result came from viscerotomy: the demonstration that yellow fever is basically an animal disease in the forests of tropical and subtropical America (12). Following this revelation, previously described epidemics in various countries were identified as jungle yellow fever.

Between 1947 and 1959 jungle yellow fever was observed in all the countries of South America except Chile and Uruguay, and in all the countries of Central and North America

except El Salvador, the United States, and Canada.

The observation of yellow fever in forested areas, involving mammals other than man and mosquitoes other than *A. aegypti*, led to recognition of jungle yellow fever as a permanent reservoir of virus for the reinfection of urban areas. Therefore, the dream of yellow fever eradication had been, from the beginning, impossible.

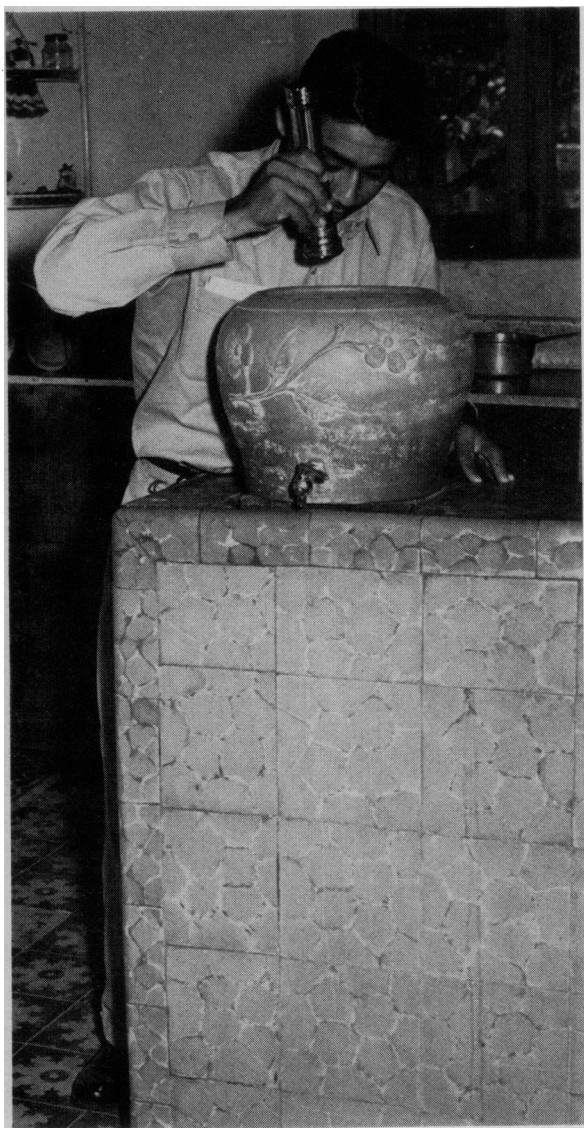
The introduction of the search for adult *A. aegypti* to reveal hidden breeding and the meticulous supervision of anti-aegypti operations led unexpectedly to the disappearance of *A. aegypti* itself. In 1933 this mosquito had disappeared completely from many of the coastal cities of northeast Brazil (13). I wish I could say that we carefully planned to eradicate *A. aegypti* and then did so. In truth, this was a free ride, so to speak; some would call it serendipity. It was not planned, but came as a reward of careful administration and of lowering the visibility of *A. aegypti* breeding below the survival threshold.

Eradication of *A. aegypti* in certain Brazilian cities came only after more than three decades of anti-aegypti campaigns, beginning with that of Gorgas in Havana in 1901. From 1927 to 1929 Rockefeller Foundation workers had made a special effort in the town of Parahiba (now Jão Pessôa), with a population of some 35,000 people. Although a point was reached when inspectors no longer found pupal or producing foci, some aegypti larvae continued to be found week after week, far beyond the maximum life-span of *A. aegypti*. The instinct of the mosquito had proved superior to the intelligence of the inspector in finding residual water containers suitable for breeding.

Failure to eradicate *A. aegypti* was explained on the basis of the sanctity of the species, the law of diminishing returns, and the irreducible minimum. But these explanations became untenable in the face of adult captures and meticulous administration. The decision to undertake such meticulous administration was based in part on the unhappy experience with false reports in Recife in 1929, mentioned previously, and in part on my experience in the field.

Before assuming the direction of the yellow fever program, I spent some weeks in the cities

of north Brazil learning the details of anti-*aegypti* work from the various inspectors. Beginning at Belém at the mouth of the Amazon River, I moved southward from city to city along the coast. In each city I worked with the man who actually inspected houses, not with the supervising inspector nor with the service physician. I started with the inspector in the morning and performed the same tasks as he all day—examined the same water containers, climbed the same roofs, and kept the same records. The experience was exciting and highly educational.



Mexico: Inspector looks for larvae of the *Aedes aegypti* mosquito, the urban vector of yellow fever.

The work was always excessive; each inspector knew he was working with the new chief of the Yellow Fever Service and, to make a good impression, he visited many more houses that day than usual. Since I worked with a different inspector each day, the routine was exhausting. Many days I would have been tempted to shirk and falsify the house visit records had I not been closely watched by the inspector.

Gorgas and Le Prince have said that to combat mosquitoes, one must think like a mosquito. After initiation in the hard school of the inspector, I felt it more important to think like the inspector—the man who, in the final analysis, alone determines whether the job is done or not. On his routine job, the inspector needs the stimulus of his supervisor's interest in the quality of his work. Nothing is so deadly to his interest and morale as visiting the same houses week after week without sympathetic, though rigid, supervision.

The "Manual of Operations" eventually prepared for the Yellow Fever Service provided detailed job descriptions, definitions of individual responsibility for carefully mapped zones, regular itineraries, immediate entries on special forms of all work done, routine checking of all reports, registers posted in all houses visited and countersigned on all visits, and bonuses to the inspector based on the efficiency of each month's work as determined by the supervisor. (The inspector came to have a special interest in having his work checked by the supervisor, since he was not eligible for a bonus in any month in which the supervisor failed to check a certain percentage of his work.)

Once organized, meticulous administration seemed logical and simple and it belied the difficulties suffered in its development. Unavoidably, such administration was criticized at times by some who overlooked the serious responsibility of the Yellow Fever Service. The press in Niterói once violently attacked the service for dismissing an inspector because he had not been killed the day before. The inspector's itinerary required him to spend much of the same morning each week in the arsenal across Guanabara Bay from Rio de Janeiro. On the morning of one scheduled visit, the arsenal was destroyed by an explosion and everyone on the premises



El Paso, Tex.: A Pan American Sanitary Bureau inspector examines old tires, an ideal breeding place for mosquitoes, during an *Aedes aegypti* survey along the United States-Mexican border. When rain water accumulates in a tire it evaporates slowly, especially if the tire is at the bottom of a large pile where it is protected from the sun and wind. Even if each tire contains only a cupful of water, an acre of tires provides a large total volume. These potential breeding places can be easily made ineffective by spraying with residual insecticide or Paris green.

perished. The press insisted that the Yellow Fever Service should have rejoiced over the inspector's escape rather than penalize him for dereliction in performance of his duty.

The observation of *A. aegypti* eradication came simultaneously with the discovery that jungle yellow fever (14) was not a chance observation but a widespread phenomenon precluding the eradication of yellow fever virus. Eventually the eradication of the *A. aegypti* became the objective of the Yellow Fever Service, since the threat of reintroduction of virus from the forests was permanent.

Eradication of *A. aegypti* started in the large cities, but the cities could not be kept free of this mosquito without clearing up the suburbs; it was cheaper to clear the suburbs than to maintain the anti-*aegypti* measures in the large cities. Of course, once the suburbs were cleared, reinfestation came occasionally from the interior. Again, it was always easier to clear the periphery than to maintain the costly central service year after year. Thus, gradually, the eradication of *A. aegypti* expanded in Brazil.

The initial proposal to undertake eradication of *A. aegypti* in Brazil was made in 1934. Eradication of this vector proved a much more identifiable goal than its reduction in endemic yellow fever centers. The campaign was waged on the basis of the existence or nonexistence of the *A. aegypti* rather than on the presence or absence of yellow fever itself.

Eradication of *Anopheles gambiae*

My return to Brazil coincided with the discovery of *Anopheles gambiae*, Africa's most effective vector of malaria, in the Americas. This dangerous immigrant was found at Natal, Rio Grande do Norte, in March 1930. The invasion of Brazil by *A. gambiae*, while not directly related to the yellow fever problem, did in effect constitute a moral obligation for the Yellow Fever Service, since it was the only organized administrative health service in the region at the time capable of taking action against this new threat.

The invasion of the Western Hemisphere by *A. gambiae* posed a problem for tropical and

subtropical America: how to eradicate this vector before it re-enacted in North, Central, and South America and the West Indies the tragedy of malaria in Africa?

The solution to this problem was long delayed. In 1930 I failed to interest the Governor of Rio Grande do Norte, the Federal health authorities, and the Rockefeller Foundation in an attempt to eradicate this African invader. My presentation may have been half-hearted; *A. aegypti* had not yet been eradicated from any Brazilian city nor was there any definite plan to propose for the eradication of *A. gambiae*. In any case, proposals for an attempt to eradicate were rejected; a lack of salesmanship on the one hand and of vision on the other.

The eradication of *A. gambiae* was delayed by the very success of partial measures which should have hastened it. Early in 1931, during the second *gambiae*-transmitted outbreak of malaria in Natal, the Rockefeller Foundation was urged by the National Director of Health to organize an emergency malaria control program. This emergency effort, based on the use of Paris green as a larvicide, relieved the pressure and, as later observations were to show, eradicated *A. gambiae* from Natal.

The full importance of *gambiae*'s disappearance from Natal was not recognized at the time, and the advantage gained was not followed up with a comprehensive eradication effort in the interior, where the infestation was in a relatively unfavorable area. *A. gambiae* spread slowly during one of Brazil's cyclical droughts. However, in 1937 it reached the Assú and Jaguaribe River Valleys where in 1938 it caused catastrophic epidemic malaria such as, from time to time, used to decimate the Indian Punjab and Ceylon.

The seriousness of the situation in Rio Grande do Norte and Ceará was a preview of what was in store for a large part of Brazil and of tropical and subtropical America if *A. gambiae* was to continue its march unchecked. There had been little support for the proposal to eradicate *A. gambiae* when only a few square miles were infested; 8 years later there was a general demand for its eradication. Yet uninfested areas of Brazil and other countries of the Americas, alarmed by the 1937-38 mortiferous epidemics of malaria in *gambiae*-infested areas, joined in

demanding its eradication. There was no choice but to attempt eradication, though we knew not how to begin. The catastrophic nature of the problem outweighed all other considerations.

Whereas in 1930-31 no obvious precedent existed for attempting eradication of *A. gambiae*, the intervening years showed a convincing example of the expanding eradication of *A. aegypti* from Brazilian cities and towns.

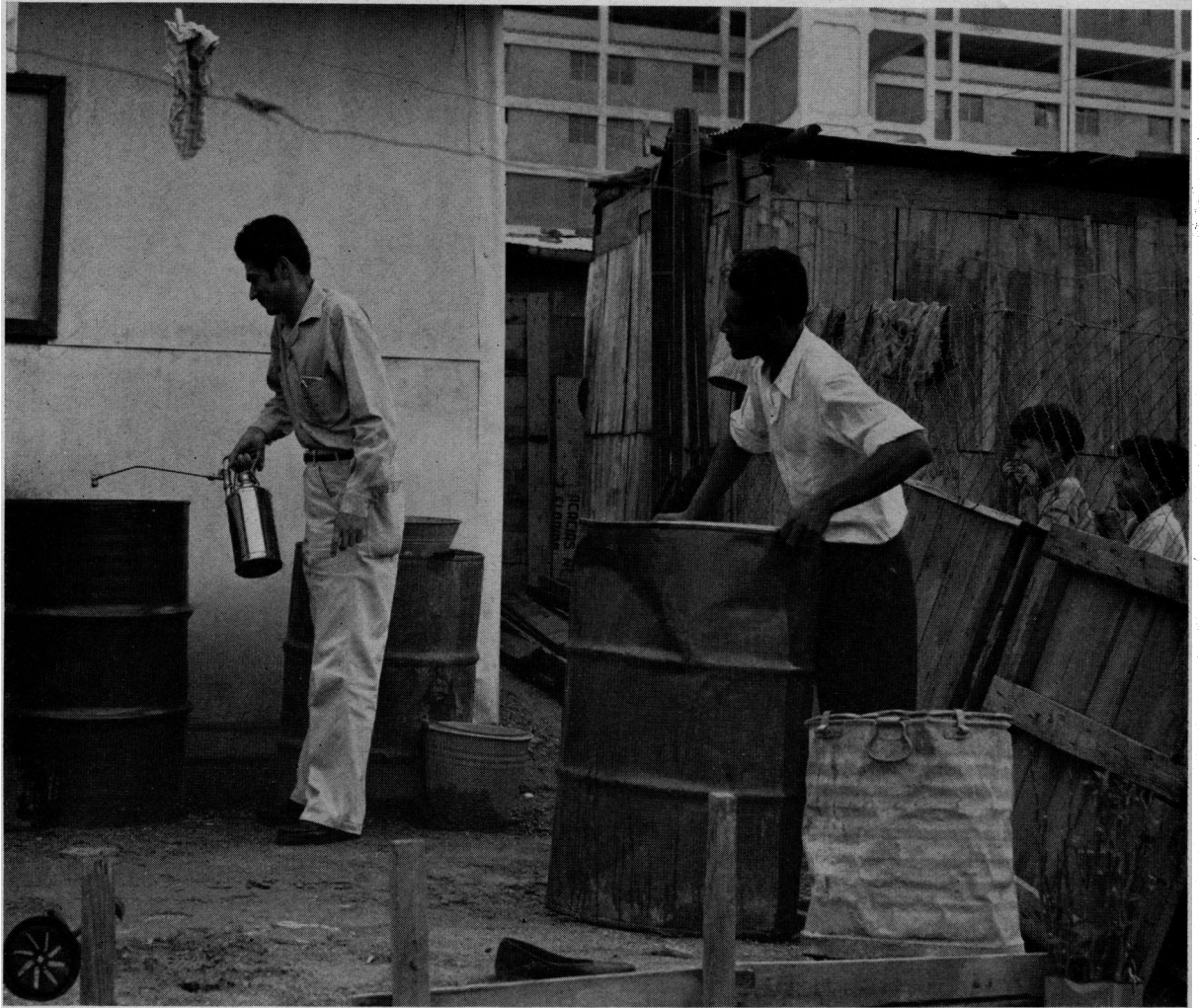
Although the Rockefeller Foundation refused, as a matter of policy, to commit itself to the eradication of *A. gambiae*, it joined late in 1938 in the organization and financing of the Malaria Service of Northeast Brazil which undertook the feat. The Malaria Service was financially and administratively independent of the Yellow Fever Service. However, disciplined skeleton staff of all grades, experienced in the eradication of *A. aegypti*, and emergency equipment, supplies, and transportation units could be made freely available from the older organization.

The administrative methods used in the eradication of *A. gambiae* were adapted directly from those which led to the eradication of *A. aegypti*.

Fortunately, the threshold of visibility of *A. gambiae* in Brazil was low; the larva, when present, was readily found in *gambiae*'s preferred breeding place—the shallow sunlit pool. The adult always rested indoors, and the invasion of any new area was soon declared by unwonted epidemic malaria. Fortunately, also, the method of attack on *A. gambiae* that proved successful in practice was quite simple—a direct chemical attack on all suitable breeding areas in the infested region.

Following the introduction of Paris green as a larvicide in the control of *Anopheles* breeding in 1921, malariologists had developed highly refined methods of diluting it with specially prepared dusts to be applied with pumps, blowers, and airplanes. Such refinement was valuable where the malaria control operation was designed to limit anopheline breeding in a circumscribed area; it proved an insuperable logistic handicap in the *A. gambiae* eradication campaign which had to cover the entire infested area.

A. gambiae was eradicated from Brazil by



Caracas, Venezuela: An *Aedes aegypti* inspector treats a water container. These "squatter" dwellings on grounds near modern apartments (background) could cause serious sanitation problems if not kept under surveillance.

inspectors, each carrying an empty pail and a small container of Paris green, who routinely visited and dusted all potential *A. gambiae* breeding areas within a carefully delineated geographic area for which each was responsible. The Paris green was mixed with whatever diluent came to hand at the site of application—dust, dirt, sand, pebbles (in the rainy season, mud)—anything which could be thrown by hand over the water surface to be treated. The dusting inspector did not search for aquatic forms of *A. gambiae* in his area; his responsibility was the routine dusting of all suitable breeding surfaces, while others made the entomological appraisal of results.

In less than 2 years *A. gambiae* was eradi-

cated in the Western Hemisphere. As in the case of *A. aegypti*, the eradication of *A. gambiae* in Brazil did not necessitate a new method of attack against the mosquito, but depended rather on the simplification of existing techniques and the complete coverage of the infested area (15).

Rehabilitation of Eradication Concept

The eradication of *A. gambiae* in Brazil, belated by a full decade, was much more effective in rehabilitating the eradication concept, after the disastrous epidemics of 1937–39, than it could have been immediately after the invasion from Africa. The high rate of mortality in these epidemics had been widely publicized

among public health workers in many countries. The final eradication of *A. gambiae* was widely hailed as an important public health victory, and eradication became once more a respectable term. It was only after the eradication of *A. gambiae* was known and accepted that the eradication of *A. aegypti* from large areas of Brazil was freely published. Even then, after 7 years' observation, the eradication of *A. aegypti* was tied in with the eradication of *A. gambiae* in a paper on species eradication (13) to make it palatable to public health administrators.

The renewed interest in the eradication concept in the prevention of communicable diseases has not been limited to insect-transmitted infections. An important contribution had been made in 1937 by Wade Hampton Frost (16) who reported that tuberculosis in man was being eradicated in the United States and certain other countries.

Following the reports on the eradication of *A. aegypti* and *A. gambiae* in Brazil, other eradication campaigns were organized. One of these was the campaign in the Nile Valley in 1943-45 for the eradication of *A. gambiae* from Egypt. This invader from the upper reaches of the Nile, discovered in Egypt in 1942, caused epidemics of a violence unheard of in Egypt; a Royal Commission appointed to investigate the situation in 1944 estimated the number of deaths at more than 135,000 in 2 epidemic years.

The invasion of Egypt by *A. gambiae* led to another lamentable failure in salesmanship with disastrous results. Arriving in Cairo early in January 1943 with the United States of America Typhus Commission, I was invited by the Egyptian health authorities, who knew of the eradication of *A. gambiae* from Brazil, to visit the invaded area at Asyut. I did not find any breeding foci in Asyut which could not be readily cleared by the Paris green technique used so successfully in Brazil. Enthusiastically, I reported that with adequate authority, personnel, and Paris green, the eradication of *A. gambiae* could be accomplished in a single season. The participation of experienced leaders from the Brazil campaign was recommended, but this suggestion was not accepted. The 1943 campaign was therefore based on larviciding with petroleum products, which failed to prevent the second tragic epidemic. This out-

break led to reorganization of the Malaria Service in the Nile Valley along the lines so successful in Brazil. The reorganization began in July 1944; the last *A. gambiae* was found 8 months later, on February 19, 1945.

The eradication of *A. gambiae* from Egypt is a striking example of the value of international pooling of information and experience (17). Other local and national eradication campaigns have been aimed at *Anopheles labranchiae* in Sardinia (18); *Anopheles elutus* in Cyprus (19); *Anopheles sergenti* in the Western Oases in Egypt; *Anopheles gambiae* and *Anopheles funestus* in Mauritius (20); *Anopheles pseudopunctipennis* in the coastal region of Peru (21); bovine tuberculosis in Costa Rica; yaws in Haiti; foot-and-mouth disease and smallpox in Mexico; vesicular exanthema of swine, bovine tuberculosis, brucellosis, the Mediterranean fruitfly, and the screw-worm in the United States; and malaria in Argentina, Greece, Italy, the United States, and Venezuela.

Eradication as a Regional Objective

Some of these campaigns have succeeded, some have failed, and some are still in progress; but all were local or at the best national efforts which, when successful, would require eternal vigilance to prevent reinfestation or reinfection. On the other hand, the Rockefeller Foundation had undertaken eradication of yellow fever from the Western Hemisphere, cooperating with each infected country to attain the common objective.

With the discovery of the jungle infection, it became obvious that yellow fever was not eradicable; only by the eradication of *A. aegypti* could the safety of urban populations be guaranteed. The observation in 1933 that *A. aegypti* had been eradicated in a number of Brazilian cities did not lead to a foundation-sponsored effort to eradicate *A. aegypti* from the Americas. Health officers of Bolivia, Colombia, Cuba, Ecuador, Paraguay, Peru, the United States, and Venezuela were trained in the eradication techniques, but foundation support of eradication efforts was limited to Brazil, Bolivia, and Paraguay. Attempts to obtain the Rockefeller Foundation's support for continental eradication failed, as did a later attempt in 1942 to

interest the newly created Institute of Inter-American Affairs.

The Rockefeller Foundation's withdrawal from anti-*aegypti* work in Brazil in January 1940 left this program fully staffed by Brazilians. This withdrawal did not handicap the national effort but did, however, destroy the mechanism through which experienced Brazilian workers could be made available for eradication projects in other countries as they had been in Bolivia and Paraguay. This withdrawal was to delay for 8 years the development of the continental program of *A. aegypti* eradication. But it was not a lost issue; it came to life eventually as a result of the continued expansion of the *A. aegypti* eradication program in Brazil.

At the time of the Rockefeller Foundation's withdrawal, *A. aegypti* could no longer be found in Brazil's capital, Rio de Janeiro, or in 6 of its 20 States. The Yellow Fever Service, after its re-incorporation into the National Health Department, boldly declared its objective to be the complete eradication of *A. aegypti* from the rest of Brazil. The continuing progress in eradication of this vector was such that by 1946 Brazil was suffering reinfestation from neighboring countries across national frontiers.

In that year, the Brazilian Yellow Fever Service suggested to the Rockefeller Foundation that it negotiate with the Government of Paraguay for the cooperation of the foundation and the Government of Brazil in the eradication of *A. aegypti* in Paraguay. The foundation demurred, pointing out that although Paraguay might be willing to sacrifice its mosquitoes, eradication there would only move the line Brazil had to defend against *A. aegypti* to Paraguay's frontiers with Argentina. Analyzing the situation in the light of its 10 frontiers with neighboring countries, the Brazilian Yellow Fever Service concluded that the defense of Brazil from reinfestation with *A. aegypti* required nothing less than the eradication of this ancient and well-established African invader from the Americas.

In 1947, Brazil proposed, and the Directing Council of the Pan American Health Organization approved, a program for the eradication of the *A. aegypti* mosquito from the Americas. This action is an important landmark in inter-

national health policy; for the first time the governments of an entire region committed themselves to the continental solution of a common health problem.

Fortunately, the introduction of DDT made the eradication of *A. aegypti* much less onerous than it had been when oil had been the insecticide of choice. Before the end of 1947, the Pan American Sanitary Bureau was collaborating with the Government of Paraguay in a truly international effort to eradicate *A. aegypti*. The Pan American Sanitary Bureau was supplying the framework of collaboration; Brazil, the technical leadership and essential technical supplies; Argentina, the motor transportation; and Paraguay, the necessary manpower.

Progress in the continental eradication of *A. aegypti* was slower than anticipated, but nevertheless gratifying. In 12 years (1947-59), during which only three cases of *aegypti*-transmitted yellow fever were reported from the entire continent, the following countries were certified as free from *A. aegypti* by the Pan American Health Organization: Bolivia, Brazil, Ecuador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, Peru, Uruguay, and British Honduras. (Additional countries certified by 1964 included Argentina, Bermuda, Costa Rica, Chile, El Salvador, the Canal Zone of Panama, and Mexico. The United States initiated, in 1963, its program for the eradication of *A. aegypti* in nine infested States, Puerto Rico, and the Virgin Islands.)

The international public health worker of 1959, accustomed to official group action of nations through the World Health Assembly, the Pan American Sanitary Conference, and the Executive Board of the United Nations Children's Fund (UNICEF), found it difficult to imagine the vacuum in which the International Health Board of the Rockefeller Foundation operated in 1920. The Pan American Sanitary Conference, established in 1902, had held no meetings between 1912 and 1920. The Office International d'Hygiène Publique, established in 1907, was limited by its charter to an exchange of information between countries on the incidence of epidemic diseases. The Health Section of the League of Nations was still to be created.

When the Rockefeller Foundation was char-

tered in 1913, there was no effective international framework through which countries could consider and act on common health problems. The foundation quite naturally operated through direct negotiation with each country concerned, whether the problem was one of internal interest only, such as hookworm disease, nursing education, and health centers, or one of truly regional international concern as was the eradication of yellow fever.

The stimulus for the Rockefeller Foundation interest in yellow fever eradication came from the fear of invasion of Asia through the Panama Canal, newly opened in 1914. The decision to undertake the eradication of yellow fever was made by the Rockefeller Foundation on the advice of consultants without the calling of an international conference, or even an expert committee, as would be done today. There was no previous agreement among the countries of the Americas to eradicate yellow fever or a willingness to collaborate in such a project.

The creation of the Pan American Health Organization in 1947, through which the Pan American Sanitary Bureau previously limited to the 21 American Republics operates throughout the Western Hemisphere, and its alliance with the World Health Organization, created in 1948, has resulted in a permanent framework through which all countries of the Americas can work together for the solution of common problems. The development of this framework has been especially significant at a time when the eradication concept is being rehabilitated, and when the introduction of residual insecticides, specific drugs, antibiotics, biological techniques, and new and improved vaccines make the eradication of certain communicable diseases feasible.

In 1947 a bus passenger from the Mexican border was found to be infected with smallpox on arrival in New York City. This caused great agitation and the emergency vaccination of millions of persons in the metropolitan area. This incident emphasized the difficulty of maintaining efficient barriers against the entry of communicable disease and the difficulty of keeping populations immunized against diseases which are not a constant threat.

Although smallpox has long been an eradicable disease, a 1948 study led to the conclusion that eradication throughout the tropics would

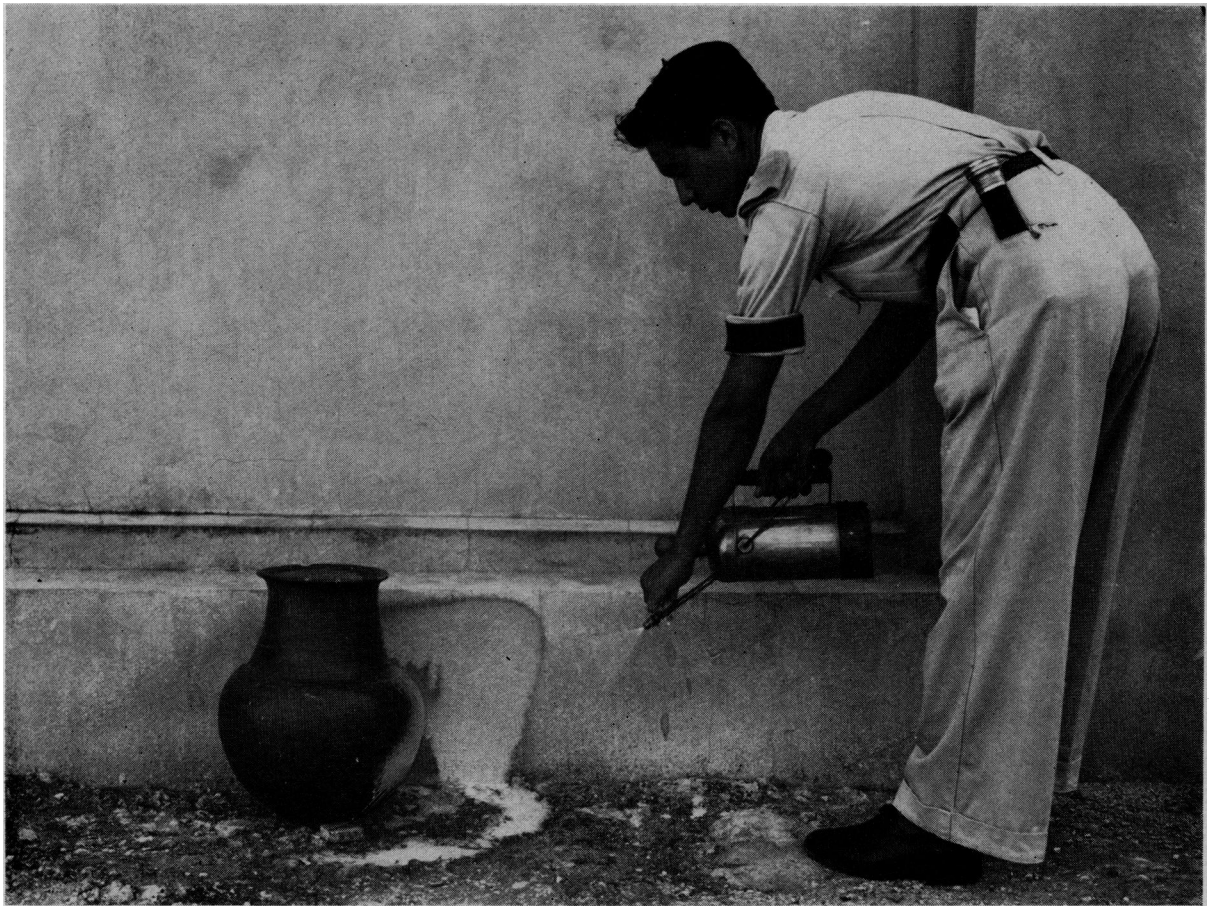
be greatly eased by perfection of a desiccated heat-resistant vaccine. As a preliminary to this eradication effort, the Pan American Sanitary Bureau requested the U.S. Public Health Service to review methods for preparation of a dry smallpox vaccine. In collaboration with the Michigan Public Health Laboratory, the Public Health Service developed a method of producing a "thermo-stable" vaccine for use in the tropics.

In 1950 the 13th Pan American Sanitary Conference approved a continental program of smallpox eradication, and established a special fund for promoting the production of desiccated vaccine and for technical assistance in the organization of national eradication campaigns. Meanwhile, Mexico had taken the lead in organizing a successful national eradication campaign with glycerinated vaccine. The disappearance of smallpox from Mexico in 1951 was followed by the absence of reported cases in North America, Central America, and the islands of the Caribbean since 1954. Considerable progress has been made in reducing the incidence of smallpox in South America.

In 1949 Haiti, stimulated by the surprising results obtained in field trials of the treatment of yaws with penicillin, requested the assistance of the Pan American Sanitary Bureau in a campaign for the eradication of this infection. The countrywide campaign, based on the mass treatment of the rural population, began with the collaboration of WHO and UNICEF in 1950. Mass treatment was justified on the basis of the high incidence of yaws in Haiti and on the necessity of treating infected contacts during the incubation period.

The yaws eradication request from Haiti led to widespread interest in the disease and to treatment campaigns in many parts of the tropics. The 1950 Pan American Sanitary Conference approved the eradication of yaws as a Pan American Sanitary Bureau-sponsored program for the Americas. To date, the standards for international certification or eradication of yaws have not been established. In any case, the incidence of yaws in Haiti is low, and eradication efforts are being carried out in many tropical areas of the world.

Reports in the late 1940's of the dramatic reduction of malaria in the United States, Brazil,



Asunción, Paraguay: Perifocal treatment of a mosquito breeding focus. This consists of spraying insecticide inside the focus and around its immediate surroundings.

Venezuela, British Guiana, and Argentina, after the introduction of DDT, led the Pan American Sanitary Bureau, in 1950, to make a reconnaissance of malaria control in the Western Hemisphere. This was followed by a recommendation of the 1950 Conference that the Pan American Sanitary Bureau collaborate with the malarious nations of the Americas in national malaria eradication programs.

The action of the conference on malaria eradication proved to be ahead of its time; the Pan American Sanitary Bureau itself was not sufficiently developed to give adequate leadership nor were the chiefs of malaria control programs in many countries willing to admit the inadequacy of their efforts.

The finding of *Anopheles* resistance to residual insecticide, the recurrence of malaria in areas believed to have been freed from all dan-

ger, and another reconnaissance of the malaria situation in 1954 which showed little advance over the position in 1950, led the 15th Conference to declare malaria eradication an emergency need and demand that the Pan American Sanitary Bureau carry out its 1950 resolution. The conference established an emergency fund of \$100,000 available immediately for administrative expenses and provided for additional voluntary financing. Developments since this October 1954 action of the conference have been startling.

Eradication as a Global Objective

In January 1955, the President of Mexico authorized the Minister of Health to arrange the financing of a national malaria eradication program. In March 1955 the Executive Board

of UNICEF, looking with favor on Mexico's appeal for aid, asked for a meeting of the UNICEF/WHO Joint Committee on Program to consider malaria eradication as a suitable program for UNICEF support. The favorable action of the UNICEF/WHO Joint Committee in May was followed almost immediately by action of the Eighth World Health Assembly sponsoring a program for world malaria eradication.

The response of the nations of the world has been almost universal, and the program has developed faster than could have been foreseen. A most important factor in this development was the decision of the U.S. Government, in 1956, to sponsor the programs of the Pan American and World Health Organizations. U.S. contributions to the Malaria Eradication Special Accounts of these organizations have been greatly increased in value by the decision to transform control projects supported by the International Cooperation Administration (AID) to eradication campaigns.

History tends to repeat itself. In the eradication of malaria, some of the same difficulties are being encountered as with yellow fever eradication in 1930. With efficient tools available, despite difficulty in some areas with anopheline resistance to residual insecticide, the problems are: (a) how to get meticulous administration and complete coverage of all human habitations in malarious areas, and (b) how to identify the residual foci of transmission once the incidence of malaria is below the threshold of easy visibility. These are the problems which are pre-occupying malaria workers in the Americas, Europe, the Middle East, and Asia.

The malaria problem in Africa is particularly difficult because of the high efficiency of the principal vectors, *A. gambiae* and *A. funestus*, the lack of trained personnel, the difficulties of transportation, and the poverty of the region. However, the factors which make the African vectors so efficient, among which is their high domesticity, should in the long run prove to be their undoing. Available evidence strongly suggests that there are no insuperable obstacles to the eradication of malaria in Africa.

The Pan American and World Health Organizations, UNICEF, and the Agency for International Development are all committed to

malaria eradication: each recognizes that the task is too great for one organization and welcomes the full collaboration of the others. This attitude augurs well, not only for malaria eradication but also for the future solution of other important health problems.

Just as the Pan American action sponsoring the eradication of the *A. aegypti* mosquito marked a milestone in international collaboration in the regional solution of a common problem, so did the action of UNICEF and the World Health Organization, in 1955, establish the precedent for global collaboration in the solution of a world problem.

At the end of the 6th decade of the 20th century, disease eradication and vector eradication, where feasible, offer great advantages in this shrinking world. Improved methods of prevention in national programs coordinated by international health organizations make certain eradication programs feasible; the rapidity of travel makes eradication in endemic foci the most logical defense against the spread of communicable diseases. With the eradication programs already organized and with continued improvement in methods of disease prevention, the public health administrator is sure to hear much of the eradication concept in the future.

Summary

The eradication concept in the prevention of communicable diseases was formulated almost as soon as modern methods of disease prevention appeared.

The first serious attempt at regional eradication was the Rockefeller Foundation's effort to eradicate yellow fever from the Americas. This effort failed because of the unrecognized existence of jungle yellow fever, a permanent source of virus for the reinfection of cities and towns. However, this failure led to a program for the eradication of yellow fever's urban vector, the *Aedes aegypti* mosquito.

The progress of this program in the Western Hemisphere and the eradication of *Anopheles gambiae*, first in Brazil and later in Egypt, began the rehabilitation of the eradication concept which had been discredited by public health workers.

Improved methods of disease prevention, both

technical and administrative, and the coordination of national efforts in regional and global programs by the Pan American and World Health Organizations make certain regional and even world eradication programs feasible.

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