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A review is presented of the phases that had led to the present concept of and efforts aimed at the eradication of diseases. Some of the results and problems are discussed, and the possibilities for future successes are evaluated.

THE PHILOSOPHY OF DISEASE ERADICATION

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WE SHALL discuss certain generalizations regarding principles and practices which rationalize efforts to eradicate communicable diseases, vis-a-vis those aimed at their control. While the unqualified word "eradication" may be understood to signify the world-wide extermination of a biologic species, e.g., of an agent or a vector or a reservoir of human disease, our use of the expression, disease eradication, is restricted to its application on a state, regional, island-wide, continental, or on any substantial area or population basis, so long as its extent is clearly delineated.

Our understanding and use of the terms "eradication" and "control" of endemic disease is one used previously[1] and is as follows: "Control is the purposeful reduction of specific disease prevalence to relatively low levels of occurrence, though transmission occurs frequently enough to prevent its permanent disappearance; eradication, ditto but to the point of continued absence of transmission within a specified area."

Mathematically, the approach to either of these objectives is under way when the general trend in the evolution of a particular disease in a specified population area is for successive crops of new cases to be generally less numerous than preceding ones, that is, on the average, each new case is succeeded by less than one new case. As long as this relationship prevails, the specific morbidity trend will be downward, and the negative slope must ultimately approach the baseline. If this reductive process continues until the number of newly transmitted cases reaches and remains at zero, eradication of the disease has been achieved. If, on the other hand, the decline in new cases is halted by circumstances which slow it down to a fluctuating equilibrium at some point approaching but not quite reaching zero, the disease may be declared administratively to be under control, though it is certainly not eliminated. Thus control is a more relative and less absolute term than eradication.

The above model illustrates but perhaps oversimplifies actual developments in disease eradication. For example, the downward slope of diminishing endemicity may be distorted by the introduction of infected immigrants into the population or area, or by the occurrence of healthy carriers, or of relapsing cases in those diseases where chronicity is characteristic.

Therefore, to achieve and maintain the eradication status of a specific disease within an area, it is necessary (1) to obstruct transmission until endemicity ceases, and (2) to prevent or nullify the reestablishment of the disease from carriers, relapsing cases, or imported sources of infection. Accordingly, an adequate surveillance organization must be developed to identify and to cope with these threats to the achievement of disease eradication. The first two hazards, i.e., carriers and relapsing cases, may be nullified by cure, emigration, or death; but vigilance against imported agents of infection must be continued until these agents are extinct.

Our approach in this discussion of disease eradication is essentially historical, and we have identified different time phases in connection with changing attitudes toward this subject. The first of these extends roughly from prehistoric times to the early years of this century.

As long as man believed that sickness was caused by mischievous demons, disgruntled deities, or reckless practitioners of the black arts, he did not feel there was much he could do about it. But as scientific understanding of the causes and transmission of infectious and parasitic disease started to become available during the latter part of the last century, he became increasingly concerned with their prevention and control—and even with their eradication.

Thus the concept of disease eradication is not a recent one; it is at least 60 years old. At that time, and since colonial days, the more important infections had been the pestilential ones—plague, yellow fever, epidemic typhus, typhoid fever, cholera, and smallpox. The latter was being controlled by vaccination, and microbiologic research during the late 19th and the early 20th centuries had revealed that typhoid and cholera were transmitted largely by polluted water, plague by rat fleas, yellow fever by Aedes aegypti mosquitoes, and epidemic typhus by lice. Thus, the necessary measures for preventing these diseases appeared evident. Moreover, if these were pursued diligently and their effects amplified by the specific immunization procedures which had been developed; these important diseases could be eliminated from this country. The term "eradication" was used freely and optimistically. It was even embodied repeatedly in the description of the huge programs supported by the Rockefeller Foundation against hookworm disease, yellow fever, malaria, and anopheline species in specific areas. A point that should be made about all these developments is that the term "eradication," while clearly directed to the reduction of disease agents or vectors to the vanishing point, was qualified to the extent that this proposed accomplishment was to be undertaken on something less than a world-wide basis.

The second attitudinal development concerning disease eradication occurred largely during the present century in the interval between the two World Wars. Further research revealed more subtle mechanisms of agent survival and transfer than had been previously discovered. Typhoid organisms were found to be transmitted by chronic carriers. Typhus fever reappeared as Brill's disease. Infectious plague bacilli were found in many species of sylvatic rodents as well as in domestic rats, from whom the organisms could be transmitted by fleas directly to man or to

other domestic rodents whose fleas could spread them to man. With respect to hookworm disease, it was shown that while anthelmintic therapy usually reduced hookworm burdens, it rarely eliminated them—and that unless shoes were worn and sanitary toilets used, reinfestation occurred promptly. Yellow fever was discovered to have a reservoir in arboreal monkeys among whom it was transmitted by tree-top mosquitoes and occasionally introduced into human populations, from which it could and did become involved in the Aedes aegypti-to-man cycle. Thus the hope of reducing these diseases to extinction became more and more remote.

Furthermore, during this era, epidemiology, which had long been recognized as a contributory scientific discipline in public health, developed into an important professional specialty in hygiene and was supported by schools, foundations, and government. It advanced both operationally and in the exploration of many areas of disease in addition to its classic one of communicable infections. With regard to the latter, increasing emphasis was given to the examination of the interrelationships of agent, host, and environment, exploring their delicate but important ecologic balances and assessing their significance in nature.

Some of the conclusions reached as a result of these considerations have had what appears to be the odd public health effect of disparaging such ventures as the eradication of disease, as indicated in the following quotation from an eminent and respected leader in this field.

"The attempt to eradicate communicable or other mass disease is neither realistic nor logical. The practical aim is to modify the condition to innocuousness, in imitation of the processes of nature; to bring about an adjusted equilibrium between host and environment through encouraging some ecologic influences and inhibiting others. Both host and agent thus survive, but without material damage to either."[2]

Thus the influence of this second phase has been more to frustrate than to motivate health workers, both because of the increasing complications in practical sanitation, and in the authoritative epidemiologic admonition to learn to live successfully with our parasites rather than to destroy them.

The third phase overlaps with the second, and it started in 1925, when Dr. Fred Soper and his associates undertook successfully the control of yellow fever and the eradication of its mosquito vector, Aedes aegypti, in cities and large rural areas of northern and eastern Brazil.[3] The same group succeeded in the early 1940's in eliminating fulminant malaria and its introduced African vector, Anopheles gambiae, from northeast Brazil.[4] These were brilliant eradicational achievements, the more remarkable because they were accomplished with relatively simple insecticides and dispensing equipment. Their success was due to the planned development and meticulous application of a system of administrative supervision and verification which insured complete inspectorial and insecticidal coverage. The fact that both Aedes aegypti and Anopheles gambiae were not indigenous but were introduced species does not detract, in our opinion, from the high significance of this achievement. Both vectors were present in astronomic numbers over huge areas and were causing sickness and death on colossal scales. This superb accomplishment stands as a challenge to those who decry the possibility, feasibility, or desirability of disease eradication on a large scale by vector annihilation.

World War II nearly compensated humanity for its toll of life and limb by providing the opportunity for the initial testing of DDT. This was done on a vast scale against the vectors of malaria and of epidemic typhus in all theaters of operation where these diseases were of significance. Many insect control

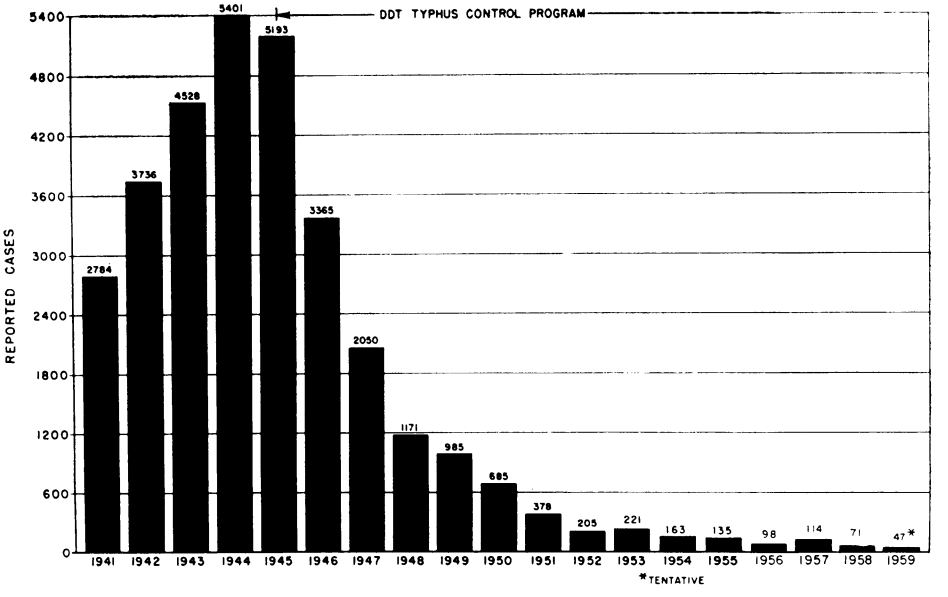


Figure 1—Annual Total of Reported Murine Typhus Fever Cases in the United States, 1941-1959

specialists acquired their introductory experiences with this miraculous insecticide under campaign conditions in various parts of the world, and returned to their homelands trained and eager to use this remarkable compound against insect pests and vectors of disease. DDT was made available in the United States during the last year of the war and was immediately employed by the U. S. Public Health Service (Malaria Control in War Areas; known later as the Communicable Disease Center) and by state health departments.

The number of reported endemic typhus cases (Figure 1), 5,400 in 1944, the year before DDT became available, fell sharply and has since become asymptotic to the baseline. The number of reported cases per year now stands at a varying level of about 50, less than 1 per cent of the reported total six years ago, with real doubt concerning diagnostic accuracy of case reports in many instances. Whether this number will diminish still further remains to be seen. We do not believe that endemic typhus is eradicated at present.

The annual analyses of the United States malaria cases[5] made at the Communicable Disease Center indicate that nearly all of the confirmed cases reported in this country occur in civilians who have traveled overseas, military personnel returning from foreign assignments, and imported labor. It is probable that this country will continue to receive 50 to 75 such cases annually as long as malaria infection occurs overseas, i.e., until malaria is eradicated on a global basis.

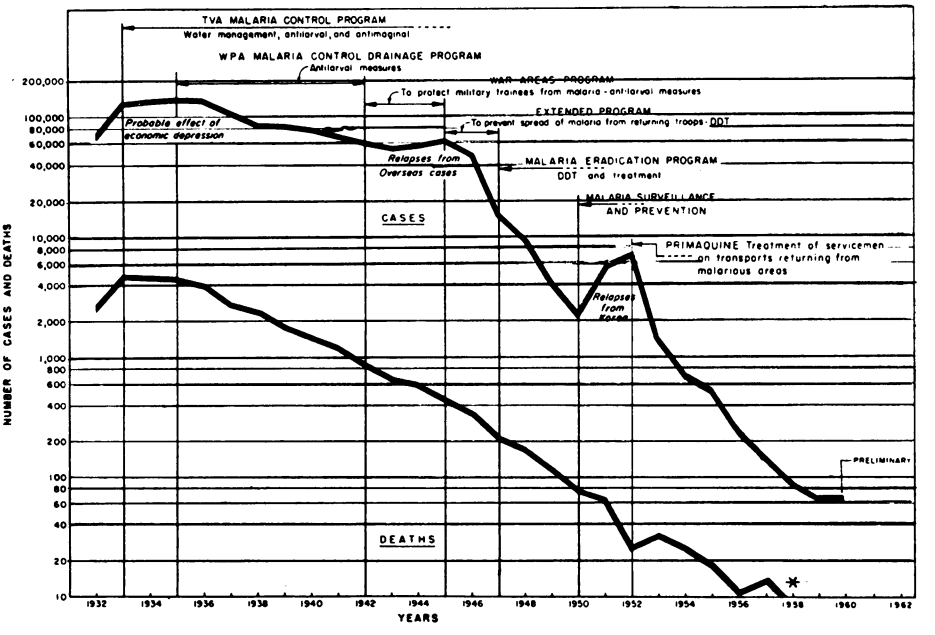
In spite of rare experiences with transmission from returning veterans[6] and of missed areas in DDT application,[7] we believe that malaria is eradicated as an endemic disease in this country, in the sense that transmission has ceased (Figure 2). The population of the nation has shown nothing more than a temporary reaction to the mass

introduction of relapsing cases on two major occasions. The first of these was the return of infected soldiers from World War II in 1945-1946; the second was the repatriation of service men from Korea in 1951 and 1952.[8] In both instances the downward slope of case numbers deviated only temporarily from the general pattern of decline.

Reflecting the almost boundless optimism which characterizes this third and present attitudinal phase regarding disease eradication, both the WHO and AID, on the advice of competent technical authorities and with the financial assistance of other international agencies and the countries concerned, have embarked upon world-wide programs of malaria eradication, using methods which have proved successful elsewhere. This is the most ambitious undertaking of its kind to date, but the accomplishments are already significant. As of January 1, 1960,[9] eradication had been completed in 18 countries or territories, previously malarious, with a population of 108 million. Eradication programs are under way in 66 countries in which over 893 million inhabitants were exposed to malaria before the initiation of eradication activities. Some 32 countries with a total population of 209 million persons exposed to malaria are said to be in various stages of planning for malaria eradication. This leaves 37 countries, with 43 million inhabitants exposed to malaria, in which no malaria eradication plans are yet contemplated.

Our own convictions with respect to disease eradication are that efforts should always be made to achieve the highest degree of control compatible with existing knowledge, means, and conditions. Where these involve infec-

Figure 2—Reported Malaria Morbidity and Mortality in the United States, 1932-1960



* In succeeding years starting with 1958, the total reported deaths were as follows: 1958—0; 1959—1; 1960—0.

tions with specific vulnerabilities, as regards agent, vector, or reservoir, and where the price of toleration is high, the technical feasibility of disease eradication should be assayed experimentally and not dismissed on the basis of ivory tower speculation. We suspect that the possibilities of local failure are more likely to derive from problems of logistics and of inadvertent offense against the mores of primitive peoples than from purely technical considerations. Of even greater significance may be the future socioeconomic and demographic consequences of disease eradication, and these considerations merit no less study and evaluation.

If we do not succeed in experimental efforts at specific communicable disease eradication, it is almost certain that higher orders of control will be produced than would have been accomplished otherwise. Success would doubtless stimulate other nations to participate in international efforts which hopefully may lead to the global extinction of one or more disease-producing agents, the supreme victory of preventive medicine!

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