AN ANALYSIS OF THE ERADICATION CONCEPT

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Foreword by the Editor

Before Harold Gray delivered his paper, "An Analysis of the Eradication Concept," at the 15th Annual Meeting of the AMCA held in Salt Lake City in April, 1959, he sent a copy of it to Dr. Louis L. Williams so that the latter could review it and be prepared to comment on it at the meeting. The program was arranged so that Dr. Williams was given time to discuss the paper immediately following its presentation. Later, it was requested that a transcript of the tape recording of Dr. Williams' remarks be published along with Mr. Gray's paper when it appeared in *Mosquito News*—a sort of "equal time" arrangement. Unfortunately, the tape recording was a total loss, so that in order to have both sides of the question presented in one number of *Mosquito News* we are publishing Mr. Gray's paper, with lettered footnotes at various points, which refer to comments made by Dr. Williams (and, in some instances, by others) in letters to Mr. Gray or to the Editor.

There is a feeling on the part of many that the difference between an eradication and a control program may often be largely semantic. The speaker and the listener do not always have the same idea as to the meaning of the term, and all too often the speaker does not listen and the listener does not speak, so that the differences never become resolved. The chief argument on the questions raised here seemed to be not whether some of the methods described should or should not be a part of the malaria eradication program, but, rather, whether they are or are not already in practice.

It is the hope of the editor and of the committee on publications, who have been consulted in the matter, that by presenting the paper of one distinguished authority with footnotes by another, the questions at issue may be somewhat clarified.—Editor

Preface. At the AMCA meeting in Washington, D. C., in February, 1958, Dr. Fred L. Soper presented a paper (1) in which he traced the change in attitude and orientation in the world-wide campaign against malaria, from the concept of control to the present concept of eradication. He described the remarkable progress which has been made in eliminating malaria from extensive areas of the world, and looked forward to the eventual consummation—the extirpation of the malaria plasmodium from the blood stream of man throughout the world.

Undoubtedly all good men agree with the desirability of the project and applaud its purposes. They also respect the able men whose skill and devotion to an ideal have brought so laudable an intention into the realm of possibility. With their purpose there can be no quarrel. But with their methods there can legitimately be some difference of opinion.

Introduction. The concept of the eradication of a vector-transmitted disease from a region, as contrasted with the concept of control, has attained world-wide acceptance in recent years. This has been particularly true of malaria, where the success of certain methods or techniques has been spectacularly successful in definite regions. This eradication technique has been based almost entirely on the use of insecticides,[a] it may be self-limiting due to a number of factors, and appears to have certain inherent problems which may prevent its success over a long period of time.

Some of these problems, or difficulties, are economic, some sociological, and others technical. They will be referred to briefly, as time will not permit an extensive or detailed examination of them. It is hoped that enough can be presented to stimulate further thinking on the subject.

The primary difficulty is a formalism which applies one and only one technique of eradication[a] under all circumstances and conditions, among peoples of widely varying cultures, under markedly different climates, with different topographies, different agricultures, divergent types of urban development, and against mosquitoes of quite varied ecologies. This use of one technique only may frequently ignore the use of other methods which may have both direct and indirect benefits of real value. Above all, it ignores one of the most important lessons in the history of disease, that certain environmental changes, some minor and some major, have resulted eventually in the elimination of a disease.[b]

Basic Postulates in the Control of a Vector Transmitted Disease. Before entering into an examination of the eradication concept it will be desirable to present briefly the basic postulates in the control of any vector-transmitted disease.

By a vector-transmitted disease we imply a disease of either man or other animals, the causative organism of which is transmitted by another living organism (a vector) which is an essential factor either in the life cycle of the causative organism or in its transmission.

Given the transmission of a communicable disease by a living vector, the disease can be controlled or even extirpated from an area, large or small, by one or more of several methods, such as

1. Exterminate the vector or reduce its numbers in relation to the number of hosts to a ratio at which the disease will not be able to maintain itself—that is, to a point at which there will be less than one new infection for every infection terminated by death, cure or departure;

[a] "I do not view it this way. Use of insecticides is, today, the basic professional technique for *control* just as it is for *eradication*. The technique which distinguishes eradication from control is an administrative technique, not a professional one. As early as 1881 Chapin pointed out that if we can control a disease we can eradicate it. Eradication is merely setting up an operational methodology which carries control to the nth degree, controls 'completely' the last focus of infection by removing it."—L.L.W. (See Foreword by the editor referring to remarks by L. L. Williams).

[b] [Residual insecticides] "are the *principal* professional techniques because of their low cost and ease of application, but are not the *one and only*. Where residuals do not work, other professional techniques are in use—and with success."—L.L.W.

2. Eliminate susceptible hosts in reservoir animals or man, or reduce their numbers by removal or immunization to the point where new infections do not keep pace with those which cease to be infective;
3. Exterminate the causative organisms in the hosts or vectors, or reduce the numbers of organisms in the hosts below the effective level for infection of the vectors;
4. Prevent the vectors from making one or the other of the TWO BITES necessary for transmission of the disease—the first (on an infected man or animal which infects the vector—the second (after the interval required to render the vector infective) on a susceptible host. This can be done by isolating the carrier or the susceptible host from the vector; by killing the vector before it can make either the first or the second bite; or by deviation of the vector to a non-infectible animal.

For simplicity in this discussion the term "vector" is restricted to the disease-transmitting arthropod, even though technically in some diseases it is the definitive host.

ANALYSIS OF THE BASIC POSTULATES. In the sixty years since the method of transmission of malaria and yellow fever has been known, all four of the aforesaid methods of control have been used with varying degrees of success. Even with the methods available prior to 1945 successful control of malaria and yellow fever had been obtained in many parts of the world by control of the specific vectors, and in at least one instance a vector species had been eradicated from a very large area (Northern Brazil) (2).

In general, however, it did not appear to be practicable to exterminate vector species in any large area, for a number of reasons, one of them being the high cost of extermination, and another being the possibility of the reintroduction of the vector after its extermination had been accomplished. The concept that the disease could be extirpated even in the presence of considerable numbers of vectors could not at that time be envisioned as a normal possibility. But it was practicable, within reasonable limits of effort, time and money, either to modify the environment in a manner adverse to the production of appreciable numbers of the vectors, or to directly attack the vectors by larvicidal measures. It was effective to use both methods, so that the ratio of vectors to victims was lowered rapidly to a point where transmission of the causative organisms ceased and the disease died out in an area.

The critical ratio of vectors to human population varies with climate, with the characteristics and transmission potential of the vector species, with the type of environment, and with the culture of the hosts. Within reasonable limits this ratio can be expressed statistically and numerically (3, 4). In some regions, mainly tropical, and with some species of vectors with a high transmission potential, the ratio of vectors to hosts is low for the continuous or endemic presence of the disease, but in other regions or with vectors of low transmission potential the ratio of vectors to hosts is much higher. In the first case control of the disease has proved to be difficult and has required a multiple attack method and considerable expenditure of effort, time and money. In the second case comparatively slight efforts have produced spectacularly successful disease control and even extirpation of the disease in limited areas.

Many efforts at control were directed at the reduction of the number of vectors by attacks against the larval stages of the vectors, since it was generally the case that attacks upon the adult stages were relatively ineffective, or inefficient in terms of effort and money. However, in some situations attempts were made to set barriers between hosts and vectors, as by screening, either as a sole method or as a supplement to larval control. And drugs were also used in the hope of minimizing the number of infected hosts available to the vectors.

Attempts to control some vector-transmitted diseases by direct attacks upon the causative organisms generally have not been successful.[c] Both the use of drugs, and the use of vaccines to produce immunity in the hosts, have been tried. In malaria control as an example, until recently no drugs were available which dependably could eliminate the parasite from the host as a mass medication scheme. Experience with recent drugs of greater effectiveness has not gone far enough for us to make too positive statements, but subject to certain known problems with mass medication of humans there appears to be hope the new drugs can be valuable adjuncts in some malaria control or eradication projects. For example, the incorporation of chloroquine or pyrimethamine in the culinary salt supply gives promise of useful results with rural and perhaps even primitive populations (5).

The basic difficulty with mass medication as either a control or an extirpative method is the practically insoluble problem of compelling all humans at risk to continuously accept and efficiently apply the prescribed and necessary drug dosages under adequate medical supervision. Even in a rigidly totalitarian state the difficulties would still be appreciable.

Therefore mass medication and/or immunization appears to be impracticable as a *primary* method for either control or eradication, although either may be valuable as a supplemental measure.[c]

A third method of attack may be used in diseases where an animal other than man acts as the reservoir of the causative organism. Plague, murine typhus, epidemic virus encephalitis, jungle yellow fever and spotted fever are examples. In some of these diseases, for example jungle yellow fever, control by extirpation of the reservoir animals is impracticable or impossible because of the inaccessibility of the reservoir monkeys. In others, as with virus encephalitis, the reservoir birds are too ubiquitous or migratory for this type of control to be practicable. With plague and murine typhus control has been reasonably successful by improved sanitation in urban areas, which has built out and starved out the rodents and minimized close association of rodents with man. But complete extirpation of rodents in urban areas does not appear to be attainable, and eradication of sylvatic plague by means of extermination of the host rodents appears to be impossible.

In recent years the trend in control measures for plague and murine typhus has usually been toward the use of insecticides to attack the rodent fleas which are the actual disease vectors.

The fourth method of control of a vector-transmitted disease has always been recognized as an applicable control measure; its limitation, until recently, has been the improbability of its effective use with the means available. As the vector must first bite an infective case or carrier, and after a suitable period of development of the causative organism in the vector must then bite an uninfected and susceptible person or animal, it is obvious that if we can prevent the vector from getting in those TWO BITES the transmission of the disease is prevented. To a limited degree house screening and bed nets have done this, but neither cases nor susceptibles will always remain within screen areas or bed nets.

The interruption of the TWO BITES cycle can also be effected by the diversion of vectors from man to non-susceptible animals. This diversion or deviation has had an appreciable effect upon the transmission of malaria, although the effect has not always been understood nor evaluated. Strongly zoophilous species of vectors are easily deviated to animals, but strongly

[c] "Chemotherapy has already proven practicable in several parts of Africa and in the Americas. On the small island of São Francisco (off the Brazilian coast near Santa Catarina) the vectors are *A. cruzii* and *A. bellator* both of which breed in bromeliads and both bite out of doors. Chloroquine has been added to all of the salt destined for the island since 1957 and has proven successful. This method (Pinotti method) is in use in other parts of Brazil and its use is to be extended."—L.L.W.

anthropophilous species are deviated with difficulty. The effectiveness of such deviation therefore depends upon the ecology and host preferences of the vector. With some species which are indifferent in their tastes the presence of numerous domestic animals may have a marked effect in reducing the transmission rate of a disease such as malaria. With strongly zoophilous species the absence of domestic animals may result in disease transmission in humans, but with strongly anthropophilous species the presence of numerous domestic animals may have little effect on the transmission of disease in man. But we should always consider the possibility of animal deviation as an aid in control especially where an animal husbandry can be a useful agricultural practice and a valuable dietary additive.

At the present time there does not appear to be an adequate appreciation of the advantages of animal husbandry, not only as a malaria control measure, but as an economic asset and as an aid to improved nutrition in many areas of the world. In the past it has been responsible, at least in part, for unintended reductions in malaria, and in a few instances has been deliberately used for this purpose. For example, on the Pontine marshes in Italy the farm houses in the 1930's were built with barns attached, and each family was required to keep at least five cows. Leguminous crops, planted for fodder, enriched the soil and the stall fed animals attracted the mosquitoes, because most of the European anophelines are definitely zoophilous.[d, e] The same is true for *quadrimaculatus* and *freeborni* in the United States.

Probably the main reason for the disappearance of malaria in northern Europe has been rotation of crops and manuring to enrich the soil with nitrogen and to stall feed cattle because pasturing usually was not economical. A similar thing appears to be happening in Russia. Hackett and Barber in 1936 (personal communication) found that wherever the Russians had cattle enough most of the anophelines were found in the stables. Given cattle enough, malaria will almost certainly die out in central Russia even if no direct attack is made on the disease.[e]

On the other hand, in China and in most of the Orient there is almost no attempt to combine animal husbandry with agriculture. Here the substitution of animal manures for human excreta in fertilizing would have a great effect in reducing intestinal parasitisms and enteric diseases, and an equally great effect in reducing malaria. In my personal opinion the control (and probably eradication) of malaria in central Honshu (Japan) can be effected by a reasonable increase in the number of cattle. Hackett has noticed recently in parts of our southern states that cotton has been completely replaced by cattle. In such areas malaria has no chance of returning, due to the ecology of *quadrimaculatus*.[e]

Eradication by Insecticides. Since 1945 certain insecticides have become available which have changed the situation by making the interruption of the TWO BITE cycle a practical method. I refer, of course, to the residual effect chemicals such as DDT and dieldrin. Applied to walls and ceilings of human habitations these chemicals kill many insects on contact. With strongly anthropophilous species, and particularly with those which remain within domiciles for a period of time after feeding, the TWO BITE cycle is interrupted. A rapid reduction in the disease rate is obtained, even though no attempt is made to reduce the rate of reproduction of the vectors by attacks upon its larval forms.

If this method is effectively applied in an area, such diseases as malaria can be eradicated in time even though the mosquitoes are still present in appreciable numbers. It has also been possible, as in British Guiana, to exterminate the vector mosquito as well, but more generally we

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[d] "You are on dangerous ground in referring to the *maculipennis* complex in Europe. This comprises a number of races and, certainly, some of them such as *labranchiae* and *socharovi* are primarily anthropophilic. *Labranchiae* is the principal vector in Italy where maliria has been eradicated."—L.L.W.

[e] Several of the reviewers disagreed with the statements involving "zooprophylaxis."—Ed.

would expect the end result would be what is termed "anophelism without malaria."

This method, as applied in recent years, has been spectacularly successful in reducing malaria in many regions, and it appears to be possible, providing no interruptions or contingencies occur, that malaria may be extirpated from very large areas, entire countries, and even entire continents.

However, there are certain possibilities and contingencies which may in the long run prevent this desired result. Attention is called to these adverse possibilities, and alternative procedures are suggested below.

Some of the presently foreseeable contingencies are:

1. Insecticide failure
2. Economic breakdown
3. A general, world-wide war

Of these, the failure of the presently available insecticides to maintain their effectiveness against the vectors may be the most immediately important. Many species of mosquitoes and flies have shown an increasing tolerance (resistance) to several of the chlorinated hydrocarbons, such as DDT and dieldrin, and some have shown a tolerance to the organic phosphates such as malathion and parathion. While these tolerances have been most pronounced among the muscid flies and certain *Culex* and *Aedes* mosquitoes, a number of *Anopheles* species also have shown appreciable resistance.

If the present increase of resistance continues that has occurred in the past twelve years, it is possible that in another decade or so none of these insecticides will be effective within rates of application which will be practicable or economically reasonable. And it is doubtful that malaria can be extirpated from the entire world during such a small period of time. If, then, we have depended for the eradication of the disease upon this one method, and if it fails, even if it is only a partial failure, we shall have been defeated in the attempt at the eradication of the disease via this particular method of application of the concept of preventing the vector from getting TWO BITES.[a]

The second contingency unfavorable to the eradication concept is a debacle in the economy in even a few of the major industrial nations. None of us care to face such a possibility but it cannot be ignored, given certain continuing trends in governmental expenditures. This might bring us, if not to a major economic collapse, at least to this dilemma—which comes first, DDT or hydrogen bombs and ICBM missiles? A real tight economic squeeze will almost certainly stop the financial and material aid being given to various disease eradication or control projects in Asia, Africa and South America. In this case diseases such as malaria, yellow fever, plague and cholera could return in epidemic form with very high mortality rates. The concept of eradication will then have been defeated for at least another generation.

A third possibility is a general war. Since 1917 we have been living in one of the major revolutionary periods of history, and the culmination of this period may be a major war. Regardless of which social and economic structure of human society emerges victorious, or even survives, the damage to the social, governmental and economic organization can be expected to be so great that the present concept of eradication will of necessity be abandoned for lack of means, perhaps of will, and perhaps even of lack of knowledge to carry it on to completion. Time will not permit elaboration on this contingency, but it appears to be a definite danger. Certainly the next major war will immediately interrupt the shipment of insecticides to tropical regions, and cause the withdrawal, where and if possible, of the technical staffs supervising the operations.[f]

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[a] Already cited on a previous page.

[f] "History does not bear you out on the effect of wars. During and after World War I the U.S. had its first surge of antimalaria works. Also, during and after World War II its greatest surge, graduating to our eradication campaign. The same is true on a global basis following World War II." —L.L.W.

There are certain other facets of the present eradication concept which may be objectionable for various reasons which I have not heard discussed and which may be briefly mentioned. One of them is the invasion of personal and domiciliary privacy which is involved in the residual spraying of homes. With some cultures this may be a matter of slight resentment, to be accepted passively; in other cultures this invasion of privacy may be resisted or at least resented. It is a fact, however, that up to the present time the men directing the house spraying program have seldom encountered resentment.[g]

One further factor in relation to the eradication concept, by whatever means accomplished, is the requirement that a re-introduction of infection shall be prevented if possible, and if the measures for prevention of such re-introduction fail, the eradication method or methods shall be reactivated until eradication is again accomplished. This facet of the concept appears to be a plausible and a practicable working hypothesis.

Proponents of the eradication concept within its presently used method of reliance on the house residual spray technique [h] claim that this method is the most economical in the long run. It is assumed that the method initially involves larger expenditures of labor and materials than do the so-called "control" methods heretofore used. But when eradication has been accomplished all such expenditures cease, with only a slight outlay being necessary for technical surveillance to watch for possible re-introduction of the disease. The assumption is made that the "control" types of measures involve continuing major expenditures for an indefinite period of time, perhaps unending.[i]

It would appear, however, that the advocates of the present eradication concept have ignored certain factors of importance.[i] These may be set forth seriatim as follows:

1. Some methods which have been used and may be used to control the vectors frequently have considerable economic value. Drainage of agricultural lands is one illustration; the reclamation of swamps for agricultural or industrial use is another;
2. Modification of the environment, whether consciously intended or resulting unconsciously from such modification, has greatly reduced the incidence of certain vectors and their transmitted diseases in a number of areas, and has eventually extirpated them in some areas;
3. While the house residual spray method contributes materially to human comfort *within* dwellings, it may have little effect upon vectors *outside* of dwellings, and in some climates and with some species of vectors it may not be entirely effective, and may not effect out-door comfort. Strongly anthropophilous species which enter houses persistently would be most affected, but other vectors may be little affected by house residual spraying;
4. Some species of anophelines, such as *aquasalis, cruzii* and *bellator,* tend to avoid lethal contact with residual insecticides, which makes this technique of less value against these species;
5. A further problem with this technique is the difficulty in spraying brush huts of primitive people in the jungles of Africa and South America. Lack of time prevents more than its mere mention here, but this difficulty severely limits the applicability of the present eradication concept to two extensive areas of malaria endemicity.[i]

THE NATURAL DECLINE OF SOME COMMUNICABLE DISEASES. Certain things can

[g] "Home-owner resistance to antimalaria or anti-*aegypti* workers has never been a problem."—L.L.W.

[h] See note b, above.

[i] Many workers do not agree that these factors have been ignored in the eradication efforts, but rather, they have been allowed for and utilized in *both* control and eradication efforts which in most cases differ chiefly in scope and administration rather than method.—Ed.

be learned from the natural decline and eventual disappearance of malaria and yellow fever in particular areas.

During the nineteenth century yellow fever declined and died out along the Atlantic seaboard of the United States, although nothing was known as to the method of its transmission until the very end of the century. Severe epidemics occurred early in the century as far north as Halifax in Canada, and in Boston, New Haven, New York, Baltimore and Philadelphia. The reason for this decline, as we now know, was the introduction of public water supplies with piped systems, accompanied by the gradual abandonment, in urban areas, of private wells, cisterns and large water containers such as barrels, which were the favored larval habitats of *Aedes aegypti,* the vector.

This change in environment progressed more slowly in the southern states, and yellow fever continued there for many years, and in New Orleans an epidemic occurred as late as 1905. The effect of the change in method of water supply was accelerated, in urban areas, by the introduction of municipal sewerage systems, which usually followed upon the introduction of public water supplies.[1] These were profound environmental changes which did much to reduce the incidence of other diseases such as typhoid and cholera. But neither the builders nor the users of these facilities, nor the medical profession, realized that they were helping to prevent the transmission of yellow fever. There is also at least an inference that these facilities in a minor degree helped to reduce the prevalence of malaria in cities.

Another illustration is the natural decline and disappearance of malaria in the upper Mississippi Valley (7). As Americans penetrated the Ohio and Mississippi valleys malaria accompanied them, and was for many decades a severe and prevalent infection. But as the homesteaders cleared the forests, ploughed the land and introduced cattle, malaria declined and eventually died out by the early years of the present century. As nothing was known about the method of transmission of the disease until 1898, the cause of the decline must have been environmental changes unfavorable to the effective operation of the principal vectors. In the more southern states there is evidence of a similar natural decline of malaria, although at a much slower pace, and this might eventually have resulted in the elimination of the disease through unfavorable environmental changes.

A similar natural decline of malaria occurred in the central valley of California due to environmental changes (8), but it was accelerated after 1910 by *Anopheles* control measures. Today, even with large populations of one of the vectors (*Anopheles freeborni*) in extensive areas, malaria is extirpated in California, although occasional small outbreaks occur upon the introduction of infected persons from other countries, in special situations (9).

The foregoing examples of the natural decline of malaria and yellow fever admittedly have occurred in what may be termed "fringe areas" of the disease prevalence, or, in the case of malaria, under conditions which G. Macdonald terms "unstable malaria." On the other hand, there is appreciable evidence that even in areas of Macdonald's "stable malaria" relatively simple intended changes in environment have produced valuable results in reducing the prevalence of malaria. Some of the methods of malaria control have been termed "naturalistic" control methods.

These "naturalistic" control methods are of particular value in many tropical regions for the reason that they can be applied with the means available to the native peoples, and by the native peoples, without the importation of mechanical equipment and insecticides.

These brief illustrations of the effects of modification of the environment in controlling a vector-transmitted disease can

[1] "Urban water supplies helped reduce densities of *Aedes aegypti* by reducing breeding places but this mosquito is yet present in sixteen U.S. states. Our real protection from yellow fever was by removing foci of the disease from Havana, Tampico and Veracruz plus a bit of good quarantine work at our ports."—Rev.

be extended to such infections as plague and murine typhus. Modification of the environment obviously has been of great importance in the control of such bacterial infections as typhoid and cholera, and of helminth infestations such as hookworm and ascaris.

Frequently these changes in environment have been made with no thought of disease prevention. Clearing, ground breaking, levelling and drainage for agricultural purposes, and the introduction of animal husbandry, in some instances have had a marked effect in reducing malaria, even though there was no intent or design in these operations for the prevention of malaria. And in an opposite degree, drainage or filling for the prevention of malaria has sometimes resulted in the reclamation of land useful for agriculture or industry.

There have been some situations where environmental changes have contributed to increases in the number of vectors and an increase in disease transmission. These have been situations where the ecologies of the vectors were not understood, or were ignored. Clearing will increase the sun-loving *Anopheles maculatus,* and ditching may be advantageous to *Anopheles minimus.* In contrast, clearing is disadvantageous to *Anopheles umbrosus* and to *Anopheles punctipennis.* Rice-growing usually results in the production of large numbers of *Anopheles hyrcanus sinensis* in China and Japan, or of *Anopheles freeborni* in California. Irrigated pastures will produce large hatches of *Culex tarsalis,* a vector of epidemic virus encephalitis, unless the application of water and the removal of surplus water is properly controlled. Therefore a continuing study of mosquito ecology is necessary to prevent man-made malaria. This list can be extended to other conditions, other vectors and varied environments. But with all vector-transmitted diseases environmental conditions are decisive. And man is the only animal who appreciably modifies his environment.

Conclusions. It has been the purpose of this discussion to examine the concept of eradication of a vector-transmitted disease (primarily malaria) by the sole means[b] of insecticidal attack upon the adult vectors, as contrasted with the concept of control, in which modification of the environment is a basic factor, but where the use of several methods of attack is envisioned, including the use of insecticides, according to their applicability under specific conditions.

There appears to be no question, in the case of malaria in tropical areas, that under many situations the house residual spraying method produces the most rapid reduction in the prevalence of the disease. But there are several contingencies under which this single and particular method may fail at some time in the future, with disastrous results in mortality and morbidity. We therefore should emphasize also the use of environmental control measures wherever applicable.

It is probable the World Health Organization will raise the proposed $600,000,000 for the next scheduled five-year malaria eradication campaign. This amount of money does not appear to be excessive in view of the possible results. But it cannot exterminate *all* human malaria in *all* the world. In areas with reasonably stable governments and stable agricultural economies the eradication of malaria may be achieved—say in regions such as Mexico and India. Barring political upheavals it may also be attained in the semi-arid regions of the Middle East. But in some Asiatic countries eradication appears to me to be unlikely within the ten years assumed to be available before insect resistance builds up to the point where insecticides are ineffective. In China we can be certain of nothing. And in the Congo and Amazon river basins eradication by house residual spraying is almost certainly not obtainable.

Therefore, it is important to include environmental modification techniques, based on vector ecology, in the present and future campaigns of eradication, wherever such environmental changes

[b] See footnote b already cited.

will help to improve the people's economy and nutrition, and in the end lead to a more stable and effective eradication.

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