CONFERENCE ON THE
ECOLOGICAL ASPECTS OF
INTERNATIONAL DEVELOPMENT
AIRLIE HOUSE, WARRENTON, VA. DEC. 9-11, 1968

INFLUENCE OF ENVIRONMENTAL TRANSFORMATION IN CHANGING THE MAP OF DISEASE

By Jacques M. May, M.D.

I

The title that was first suggested to me for my contribution to this conference was "Influence of Environmental Transformation in Promoting of Dominance of Plasmodium Falciparum." This was intriguing, and I gave it much thought.

Predominance is an ecological term that indicates the greater importance of one species of a living thing in a given habitat. Plasmodium falciparum has two habitats: the blood and hematopoietic organs of man; and the digestive and, as far as we know, the connective tissue of certain species and strains of Anopheline mosquitoes. Since the mosquito is the definitive host of Plasmodium falciparum and man only an intermediate one, the problem boils down to a discussion of the ecology of Plasmodium falciparum in relation to other parasites competing for dominance in the human economy and to a discussion of the ecology of the strains of Anopheline mosquitoes which would compete with each other wherever Plasmodium falciparum was available for accidental ingestion during a blood meal.

A. Plasmodium-Related Factors

These two facets of the assignment were, of course, of fascinating interest. They raised problems of considerable obscurity: what are the needs of Plasmodium falciparum for survival in the mammal economy? While some facts are known to parasitologists on the subject, the relationship with other parasites competing for dominance has been little explored.

It is known that Plasmodium falciparum synthetizes its proteins from the amino acids of the erythrocytes of the host. It is known that a certain degree of immunity or rather imperviousness to Plasmodium falciparum exists among people endowed with Hemoglobin S.[2] Undoubtedly, an essential requirement of Plasmodium falciparum is, in this case, absent from the erythrocytes of people affected by sickle-cell anemia.

In all likelihood, other chemicals or biophysical properties required for Plasmodium falciparum survival in human blood are needed. Is it possible that there are normal or near-normal components of the human erythrocytes that might either hinder or assist the survival and the development of the human cycle of the parasite? Could there be some competition in the biotic world of the "internal milieu" that would result in arresting the development of Plasmodium falciparum? We have no evidence of this and the attempts made with the better-known antibiotics to treat malaria due to Plasmodium falciparum have given no evidence that they influence the survival of the parasite. We know, of course, that certain chemicals are effective in doing this and this is the basis of the eminently successful chemotherapy of malaria. But there is surely more to learn and this is a field into which I did not feel competent to walk.

B. Mosquito-Related Factors

Turning now to the mosquito, what are the ecological factors that favor (a) the growth and development of *Plasmodium falciparum* in the mosquito, and (b) the dominance of *Plasmodium falciparum*-prone-mosquitoes in the environment?

1. Growth and development of the *Plasmodium* in the mosquito.

Some of the factors that determine the growth and development of the parasite in the mosquito are probably genetic in nature. Certain strains infect more readily than others the vectors available in the environment. Marston Bates(8) reports the work of James, Nicol and Shute who were unable to infect an English *Anopheles atroparvus* with an Indian strain of *Plasmodium falciparum* while they could do so with an Italian strain. The mechanism of this susceptibility on the part of the mosquito, adaptability on the part of the parasite, must have genotypical as well as environmental causes. Conversely, the species of the mosquito vary in their susceptibility to strains of parasites and this susceptibility to *Plasmodium falciparum* seems also to be related to genetic factors.(8) Bates also states (p. 236) that as far as he is aware, "there is no evidence that the cycle with a given strain of *Plasmodium* varies with the species of mosquito host."

However, authors agree that the most important factor governing the development of *Plasmodium falciparum* inside the mosquito is environmental temperature, very high or very low temperatures preventing the establishment of mosquito infectiousness. The local temperature governs the time required for the mosquito to become infective after absorbing its blood and plasmodial meal. This relationship to temperature explains the predominance of _Plasmodium vivax_ and _Plasmodium malariae_ in the temperate zone and that of _Plasmodium falciparum_ in the tropical belt. It may also explain the earlier occurrence of _Plasmodium vivax_ and _Plasmodium malariae_ cases in the spring and the later appearance in summer or autumn of _Plasmodium falciparum_ infection.

Since temperature varies with altitude, it regulates the time limits of the transmission period in mountainous regions. Winds indirectly influence rainfall which, in turn, influences temperature and therefore has an effect on the development of the agent. No doubt other physical factors influence the life of the parasites in the vector but these have not, as yet, been discovered.

These temperature changes in the environment are usually due to natural factors rather than to man-made changes. However, the transformation of certain cities in the tropical belt has definitely resulted in the transformation of the average temperature as well as the extremes in the same areas. The phenomenon is easily observable in a metropolis like Bangkok where the maximum level of temperature has risen by several degrees in the last decade because of the erection of tall buildings that impede the cooling breezes from the sea and because of heat reflected from extended asphalt surfaces; yet the filling of the marshes and "klongs" has reduced the chances for mosquito breeding and it is difficult to assess the respective importance of all these coincidental factors in modifying Plasmodium dominance.

These environmental factors influence the parasites through the physiology of the mosquito vector and its survival rather than through their possible influence on the parasite itself. For instance, it is well-known that the relative humidity of the environment influences the survival of the mosquito to a great extent but seems to have no effect on the parasite in the mosquito host. The survival of the mosquito is then the key to Plasmodium dominance and obscures the Plasmodium-related factors which, however, combine to create the range between high and low endemicity.

2. Dominance of *P. falciparum*-prone-mosquitoes.

Given this close relationship between Plasmodium dominance and mosquito survival and this affinity between Plasmodium and vector species, the study of environmental changes that can influence the map of Plasmodia through the map of mosquito is the most rewarding. Mosquitoes, like men, are concerned with food, breeding, and shelter, but as with men, their tastes differ. They can feed on human or animal blood or both. All mosquitoes require water for breeding but it can be clear or turbid, sunlit or shaded, running or stagnant, warm or cold, salty or fresh, acid or alkaline. At certain hours the mosquitoes seek shelter. Some prefer to dwell indoors, others outdoors. Some cruise high under the canopy of the forest, others low above the ground. Rainfall and temperature, as well as topography of the soil, combine to create situations in which mosquitoes multiply or stop breeding. Excessive downpours increase occurrence of malaria throughout the tropics because of the multiple breeding sites they create but droughts in the equatorial tropics also increase occurrence because small depressions hold accumulations of stagnant water that favor the breeding of certain species. Rainfall, under certain circumstances, favors the growth of plants, such as bamboos, or epiphytes, such as bromeliads, whose physical structures create receptacles where physical and chemical conditions favor certain species of vectors. Temperature influences the mosquito and breeding does not occur unless the temperature is appropriate. Winds help or hinder the flights of the vector. Some vectors, such as A. pharoensis, have been known to fly more than 20 miles across the desert. In certain parts of the Trobriand Islands[5] (South Pacific), the transmission season corresponds to the periods of northwest winds so that localities of the south, being more sheltered than those in the north, have less malaria, which implies that if a house or a village or a city is built away from the flight path of the mosquitoes, the chances for malaria epidemics are lessened. On the contrary, if these factors are not taken into consideration and the village, city, factory, or camp is erected within the flight path of the mosquitoes, the change in the environment will be accompanied by an increased malaria transmission. The requirements of Plasmodium falciparum-susceptible strains of mosquitoes vary with the larva and with the adult of the mosquito vector.

The requirements of the larva being more limited than those of the adult, the dominance of Plasmodium falciparum will also be limited by the spectrum of environmental factors which govern larval survival. The larvae of all known species need water and oxygen for survival. They almost always confine their habitats to the upper layers of the bodies of water they occupy whence they can get at the air. It is interesting to note that no breeding occurs on open waters. The breeding places of the effective vector Anopheles gambiae melas are almost entirely confined to parts of the coastal swamps flooded by high spring tides and characterized by the presence of Avicennia mangroves and wide stretches of coarse marsh grass Paspalum vaginatum.[10] Any new transformation of the environment that would make this vegetation unavailable or modify the current of the spring tides might well have an influence on the breeding of A. gambiae melas and hence on the predominance of Plasmodium falciparum.

The characteristics of the water, possibly of the air above the surface, especially in terms of temperature and chemical composition, govern the presence or absence of mosquito larvae. The temperature of the waters is related, for the most part, to climatic conditions that seem permanently established, but the settlement of man can transform the temperature of waters. Should a factory establish itself in the vicinity of breeding sites, the temperature of the waters enriched by sewerage of all kinds will change. The larval habitat may become uninhabitable both because of temperature changes and chemical transformation through industrial waste and pollution. Anopheles quadrimaculatus has been found to disappear from certain areas where nascent industry has brought about that kind of change.[8] It has also been found that the degree of light and shade influences the breedings of Anopheles albimanus (it also influences the adult form of the vector A. funestus, which enters houses after midnight, especially during moonlight).[15] Since light seems to be essential to survival of these larvae, it has been recommended to plant trees in order to control breeding. Other species (A. darlingi) prefer shade but it is difficult to identify whether this factor acts upon the larva itself or upon the organic life in the medium on which the larva feeds. The movements of the waters also influence the species prevailing in an environment; hence modifying the dynamism of a stream--either by slowing it down above a dam or accelerating it below--may favor the growth of this or that larval type. Yet, most Anopheline prefer still to running water for their breeding.

Since the larva usually breathes the air from the surface, it is to be expected that access to the surface must be unhindered; hence, the surface tension conceivably modified by artificial (oil spreads) or natural (pollen, leaves) factors, will also govern the dominance of this or that Anopheline species and the Plasmodium most adapted to the strain.

Opinions vary as to the importance of alkaline versus acidic composition of waters as authors' observations vary with the location of their observations. Neither is it known whether, in nature, the degree of acidity influences directly the larva or the other organisms whose presence creates or negates the existence of a survival-worthy environment for the species.

The requirements of the adult mosquito should be added to those of the larva in governing Plasmodium falciparum dominance. These requirements will play an important role in qualifying one species of mosquito as an effective or weak Plasmodium falciparum vector, and it is interesting to note that the species that can be an effective malaria vector in one area may not be effective in another. With Russell,[13] we can list the characteristics of an effective vector as follows:

a. The mosquito must enter human dwellings and be domestic, so to speak (example: Anopheles minimus).

b. The mosquito must prefer human to animal blood; in other words, be anthropophilic (example: Anopheles gambiae).

c. The mosquito must be long-lived, since the vector must remain alive long enough to allow the sporogony (sexual phase) to take place so that the vector harbors the agent in a form transmissible to man.

d. The mosquito, as indicated earlier, must possess the constitutional characteristics (genotype) that make him a desirable host for Plasmodium falciparum. Now, all these characteristics of the adult mosquito are dependent upon environmental conditions most of which may undergo transformation for many causes.

The characteristics of human dwellings that are attractive to the vector will vary with light, composition and mobility (drafts, closeness, smoke, smells, etc.) of the air inside the house, availability of resting places after the blood meal, and a multitude of home factors best known to the mosquitoes themselves. These will thus enhance or limit the effectiveness of a species in promoting Plasmodium falciparum dominance. Any changes occurring in the site and characteristics of the house will influence the mosquito presence.

The anthropophilic tendencies of the mosquito, themselves linked to some unknown need of the insect's physiology and to some unidentified ability to provide for the needs of the Plasmodium, will make a certain Anopheline species a promoter of Plasmodium falciparum or of some of the other three malaria agents or of none of them.

The longevity of the mosquito depends, of course, on two orders of factors. Some are totally unknown because they are inherent to the genetic constitution of the mosquito while others depend again on environmental circumstances, such as temperature, humidity, winds and light, a presence or absence of some lethal element, natural or artificially added to the environment by the presence of a competing animal, insect, or human.

Finally, the ecology of the human host influences, to a considerable degree, the dominance of Plasmodium falciparum in a certain area. It affects the chances of contact between the host and the vector. If the houses are built on the ground or on pilings, infection will result, depending upon the flight level of the vector. If the cooking is done indoors or outdoors, the smoke will chase the mosquitoes away or keep them inside. The presence of animals in the vicinity or at a distance would increase or diminish the risk of man being bitten. The example of the farmers of North Viet Nam is interesting and illustrative.(9) In the delta region of the Red River these people live in one of the two or three most densely-crowded areas of the world. The density of population is around 900 per square mile. The houses and the villages they form represent, from the point of view of the way they are built, a compromise between the material that is available and the need to save as much soil as possible for food crops. The material available is mud and rice straw which does not lend itself to skyscraping architecture. Thus, there are very few two-story houses in the villages of the Red River Delta. The dwelling place usually consists of a mud bungalow with the pigsty on one side and the kitchen on the other. There are no fierce effective malaria vectors in the area.

Some 60 miles to the north, in the hills, we find a different cultural trait, also very much influenced by the physical environment. In these hills lumber is abundant but there is little rice straw and little mud. The people, for reasons that are not as yet fully understood, build their houses on wooden pilings which place what we would call their living room at an elevation of 12, 15, and sometimes 20 feet above the ground. In these hills, _Anopheles minimus_, a very fierce malaria vector, abounds, its breeding enhanced by the network of mountain streams. However, it so happens that _Anopheles minimus_ does not fly much higher than 10 feet above the ground. As a result, although it is essentially a man-biting insect, when it has a chance, it feeds on the cattle herded under the house between the pilings because that is what it finds at its normal flight altitude. Furthermore, the cooking takes place in the house, not outside as in the Delta. This fills the living room with smoke and chases away any stray vector.

Due to the congestion of the Delta, several schemes have been carried out at different times in history to try to relocate Delta people in the hills. These people carried their culture to the new location and started to live at ground level, to cook outside the house, and to shelter their pigs away from the dwellings. The results have been disastrous. Malaria epidemics decimated the newcomers and the reputation of the hilly regions among the lowland dwellers is that it is full of evil spirits and that no man of the Delta should ever go to the hills, in which belief they are right.

The type of agriculture also has an effect, as in rice cultivation where seeds sown by broadcasting require a longer period of irrigation than do transplanted nursery shoots. This longer period of irrigation and the resulting transformation of the environment that is the result is an increased factor for malaria transmission and for the predominance of Plasmodium falciparum in the tropical belt.

The habit of watching the crops at night against thieves in Turkey, or just to be on the spot for work the next day as in Madagascar, Sarawak, and many other places, also influences the chances of being bitten and of spreading the dominance of Plasmodium falciparum.[10] The type of walls used in house building, mud or bamboo, rough or smooth, would influence the efficiency of D.D.T. house spraying as would the habit of washing with lime or frequent replastering of the walls. Finally, and perhaps more than anything else, economic levels, corresponding with ability to train public health workers to practice sanitation, to sleep under mosquito nets permanently, and to understand the value of prophylactic measures, all combine with each other and with those factors listed above to create in the land a suitable habitat for Plasmodium falciparum.

In the light of the above, it seems that the dominance of Plasmodium falciparum in a given environment is dependent, as stated at the beginning, upon a number of factors, parasite-related, vector-related, and man-related. In addition, the environment is in constant change, both as a result of natural causes and as a result of man's actions. The latter should, of course, not be singled out as deserving any special treatment. Every animal, man included, must control his environment or die. The way man controls his, by spreading oil on marshes, planting trees, building skyscrapers higher than the level of mosquito flight, taking drugs,and spraying houses, is just as "natural", is just as essentially inherent to man's nature as is the building of a hive to a bee, a nest to a bird, a dam to a beaver.

Under the constant changes of the environment from the minute amount of organic matter in the water that makes the life of a larva possible, to the erection of many 80-story buildings, the dominance of Plasmodium falciparum will change. Most of the importance of the significant factors governing these changes are unknown and those that are not known are obviously the most intriguing.

Hence, after reviewing the data available to me for the completion of this assignment, I felt compelled to enlarge it, because the transformation of the environment modifies not only the dominance of one man-oriented lethal parasite but of all possible stimuli with which man has to contend to survive. Thus, I felt compelled to relate my observations to the global system of man's adjustment to the environment.

II

Before analyzing the phenomenon described as the Map of Diseases, it may be well to define once more what we call "disease". It is surprising how many students of medicine of all ages limit their concept to "the opposite of health." I suggest that what we call disease is that alteration of living cells or tissues which jeopardizes their survival in the environment. This definition stresses as its criterion survival, which is, of course, the basic dynamic force of any living thing. I believe it is better to define disease in terms of survival than to define it in terms of health, since health is also a very relative concept.

Disease must be understood on an area basis. The area provides stimuli with which living things have to cope to survive, to which they must provide a response. The degree of this response, of course, depends upon the amount of stimulus applied in relation to the genetic makeup of the host and of the acuity of the physician's ability to detect. The disease pattern is also governed by the operation between stimuli and host in the edifice of customs, habits, and techniques that we call "culture."

Cultural traits either bring stimulus and host together, thus creating the chance for disease occurrence, or keep them separate, thus preventing the disease. When this happens, there is, at the place considered, a disease potential which is replaced by actual disease, if and when the cultural trait separating stimulus and host breaks down or disappears. It is on this three-cornered basis--stimulus, host, and culture--that the science of the ecology of disease is established. It is the study of these disease factors--their geography, their mapping--that gives us our understanding of disease occurrence on an area basis and forms the structure of global epidemiology.

All three orders of factors are intimately related to the environment and the transformation of the environment will automatically bring about a change in the mutual relationship of these closely-knit complexes. Environmental stimuli can be arbitrarily but conveniently classified into physical, biological, and cultural.

A. Physical Stimuli

Physicists and geographers of the last 50 years have gone very deeply into the study of the component elements of the environment in which man lives. Physicians, however, have taken only cursory interest in these relationships. As a result, our knowledge of the influence of these components on the survival of our cells and tissues and on the survival of the cells and tissues of other living things closely related to us is amazingly small.

Taking first the physical stimuli, Lee[7] established an interesting diagram based on the combined plotting of temperatures and humidity. Within this area Lee defines several zones: a zone of comfort below or beyond which nobody is comfortable; a zone where muscular performance begins to deteriorate; a zone where mental performance deteriorates; and a zone of distress. It is possible to superimpose on this chart another chart based on the range of mean monthly temperature and humidity for sample locations. Thus it can be seen which days of the year the people of Rio de Janeiro or of Basra are in comfort or discomfort and under which limits exertions can be expected from them. Beyond these measurements, loosely expressed in the terms "comfort" and "distress", our gaps of knowledge on the effects of climate on man are considerable.

The reasons for our ignorance on matters of climatic influence on men is that it is impossible to separate in nature the physical elements of climate from the living things that have established their habitats in this climate. When our grandfathers used to speak of good or bad climates, they meant climates where no outside aggressions attacked the body or climates where such aggressions occurred. What they considered to be climates essentially meant the disease agents that, unrecognized by them, existed in these climates. When climates are reproduced in artificial chambers, the result is a distorted picture because many elements existing in the outside world, such as radiation, cosmic rays, and many others, are not included among the variables used in the experiments.

We are just beginning to realize the existence and possible importance of such unknown variables as cosmic rays, static electricity, radiation, and probably still other material forces that have as yet no names. If it is possible that flares in the sun may disrupt "macroscopic" electronic communications on earth, as happens on airplanes and with submarines, then it is likely that they also may produce changes in the microscopic electronic communications that occur in our cells, and probably are infinitely involved in the makeup of what we call life.

The forces of climate conceivably may influence our resilience to disease in the same way they do in chickens. Pasteur, experimenting with these animals, had to lower their body temperature by plunging them into an icy bath to be able to inoculate them with a number of pathogenic agents. The conditions of "stress" thus created resulted in a susceptibility to the agents that had not existed before.

Further, the physical elements of climate, those we know how to measure and those we do not, influence the things we eat as well as the agents, vectors, intermediate hosts and reservoirs of pathogens that bring us our transmissible diseases. The whole field of climatically-induced mutations in agents, vectors, and intermediate hosts that could modify virulence, susceptibility and immunity is practically unexplored and will be alluded to again below when we discuss biological stimuli.

So far, we physicians have done little to explore the fields of geology, geography, climatology, meteorology, and physics, with the purpose of relating the findings of these sciences with disease occurrence. Let us agree once more that investing in the organization of interdisciplinary research would, in all likelihood, yield large dividends.

B. Biological Stimuli

Let us come now to a second group of stimuli challenging human survival in the environment in which they live. These comprise all the living things which have elected to inhabit the macro- and the microclimates surrounding man. An important aspect of the coexistence agreement developed by these living things, which the physician and even the public health officer often forgets, is that these living things, like men, live in societies. I like to think of a society as a pattern of mutual tolerance that occurs temporarily among living things when the dynamism of reciprocal exclusion has been exhausted.

The idea in these condensed words is to stress that a social structure is essentially temporary, based on mutual tolerance. Mutual tolerance implies dominance and submission and the moment anything happens to disturb the equilibrium of this pyramid, of this compromise, the pattern is upset--new dominants come to the top with unpredictable results. The reason for all this, of course is that, whatever size they are, infinitely small or tremendously big, living things always compete for food and shelter and organize themselves temporarily on a pattern of mutual strength and power.

I believe that it is profitable for the medical ecologist studying the occurrence of transmissible diseases throughout the world to remember that, in all likelihood, bacteria, snails, mosquitoes, rodents, mammals all live in society. It is on this concept that the modern therapy by antibiotics and, in many instances disease control, is based. Indeed, in a room loaded with aerosols of *Penicillium notatum* the transmission of pneumonia among human hosts would not occur for lack of a live pneumococcus. In a paddy field sown with "gambusia", *Anopheles jeyporiensis candidiensis* would have a tough time surviving and so would *Plasmodium vivax* for lack of adult mosquito habitat in which to spend its sexual life. It has been shown that it was difficult to have yellow fever virus multiply in an *Aedes aegypti* previously fed on dengue virus.[14] Could it be that these two viruses do not belong to the same social structure in spite or because of their relationship?

These social structures of living things are closely dependent upon the geographic factors and the food availability discussed above, which is why we find these societies closely integrated and almost identified with the map of the geographical area in which they occur. Hence, a good understanding of the map of disease should be based on a study in depth of the relationship in time and space between physical environmental factors, biological environmental factors, and the cells, tissues, and organs of the host. Health and disease, in final analysis, should be conceived solely as the ability of a living thing to adjust to the environment in which it lives. Sometimes these adjustments are orderly and unconscious; sometimes they shake the tissues, disturb the functions, and upset the whole organism beyond the range of unconscious integration and the individual is aware of the change. Until adjustment is eventually made, this change can be called "disease." If adjustment is not made, death occurs. If it is made, a scar is left which will play its role in the future behavior of the tissues and in future adjustments to new stresses. A study of the changing map of disease implies, therefore, first a study of all the stimuli we have discussed above and then a study of the factors that govern responses from the host. These are all important.

C. Responses from the Host

Given all and many other aggressive stimuli, the living hosts respond, each according to their respective genius in a way that modifies the map of disease. Very little is known on this subject. We have paid scant attention in the past to the factors governing the attitudes of the hosts. Our textbooks and our literature are full of studies on the living stimuli but offer very little information on the host structure, on the genetic makeup of the man who presents the symptoms we study, and on the relationship between genetics and the development of human disease. No discussion of the changing map of diseases can afford to ignore the changes that occur in the host as a result of insults from the environment; neither can such a discussion afford to ignore changes occurring in the emotional system as a result of significant environmental changes. Crowding of a habitat, for example, strongly influences adjustment in man and animal, not solely through the physical problems of spatial occupancy but could conceivably influence susceptibility or immunity through the obscure pathway of emotional changes.

Because the relationship between genetics and response to environmental stimuli is not known, we have so far not been able to manage any classification of hosts on the basis of these responses to environmental stimuli. We have no map of susceptibilities and immunities. Obviously, the genetic makeup of the individual lies at the basis of the responses any individual or any population offers to environmental challenges. We all know that the genetic makeup of an individual is represented by the sum total of his genes (his genotype) and by the appearance of his genotype at a given time (his phenotype). If it is true that the concept of one gene, one enzyme, has value, then we can understand why certain people or animals are susceptible to certain diseases and others are not. Why is leprosy essentially a human disease? Why is foot-and-mouth disease essentially a cattle pathology? Why do cholera Vibrios multiply in the intestines of guinea pigs without causing them any harm? Why cannot birds catch human malaria? The enzymes governing these agent-host relationships governed by the genes that support the enzymes might be the field in which answers to these questions could be found. All these problems underline the considerable importance of the terrains.

Interesting possibilities have recently been brought to light: some studies seem to indicate that individuals belonging to the blood group O are particularly susceptible to the stimuli that results in the development of peptic ulcers,(1) and as already mentioned, the role of the so-called hemoglobinoses in shaping the responses to pathogenic stimuli is certainly worth exploring thoroughly.(2)(3)

The genetic establishment of an individual or of a population is more closely linked with the environment than we currently realize. I have already hinted on page 17 at this relationship: the genotype of a population is what it is, and becomes what it shall, because of the presence of environmental stimuli which to link disease patterns with geographic pressures.

In the same way, the environment in which man lives, pressuring his genotype, brings about new shapes, new phenotypes that may be useful for continuation of living in that same place, or that can be detrimental. If a man has lived for a certain time in a certain environment, he has been bitten and hurt, he has suffered emotions that are specific to the place. All these stimuli have left scars, the sum of which form his personality and govern his future response to future stimuli. Some of these scars are beneficial--such as immunities and education--some are detrimental--such as allergies and neuroses; and it is the total of these scars that governs the disease pattern by governing responses to the stimuli present in the environment.

D. Cultural Factors

The third group of forces that intervenes in the disease pattern is the "culture" of the various human groups that grow in the infinite variety of physical and biological environments. Here we come to the definition of the word culture. To the global epidemiologist, culture is the sum total of the concepts and techniques that individuals or populations devise and use in order to survive in a given environment. That, of course, does not mean that all cultural traits are survival-worthy. It is quite possible that many cultural traits will lead the group to its destruction rather than to its survival. A case probably could be made to show that originally cultural traits have developed because they were mistakenly thought to promote survival or because they did promote survival at the time when they were adopted but have ceased to do so when circumstances change.

People do not give up their culture easily. They like to feel the protection of their ancestors around them and they would rather die doing something that has always been done than survive by not doing it or trying something that has not been tried before. The origin of culture is truly the job of anthropologists and I am not competent to discuss it. My point of view is that of the epidemiologist and I am only interested in finding out whether a cultural trait promotes disease or prevents it.

CONCLUSIONS

We have now discussed the various factors combined to aggress a given host in his environment. It seems, therefore, that the transformation of the environment is bound to bring about changes that will modify the adaptation of man to the milieu. Environment changes: alluviums fill up estuaries, isolated villages are replaced by large cities, vast populations multiply and create crowded environments, people migrate, genes segregate, and new genotypes build themselves up that modify the responses given to the environmental stimuli.

The diseases which were prevalent among the sparse population of Manhattan when Captain Hudson came sailing to our shores are not the same as those that prevail today at the same place. When jungles are cleared, as in parts of Malaya, or are allowed to reconquer the land, as on the site of the dead city of Angkor, new societies of agents, vectors, and hosts nestle themselves in the new niches. Each culture brings about its set of diseases, and we have just now begun to study the chapter of the diseases brought about by radiation. Thus, at all times the health of tomorrow is prepared and hatched in the remotest corners of the world, as shown, for instance, by the spread of Asian flu which may have started with a few sneezes in some obscure countryside of the Chinese mainland. There is no doubt that we must increase our informations in regard to these events. We should try to recognize the birth of new stimuli to disease, the changes that occur among social structures of agents and vectors, the changes in the maps of immunities and susceptibilities. We must keep abreast of the cultural changes that either create new links between agents and hosts or erect protective shields between them, and we must gauge the development programs that we so liberally and perhaps so foolishly encourage throughout the world. Drainage, irrigation, pest control, deforestation, afforestation, pollution, construction and destruction of cities, create a change in the habitat which eventually and inescapably will bring about challenges to human adaptation and thus will bring about changes in the map of diseases.

Bibliography

1. Aird, Ian; Bentall, H. H.; Mehigan, J. A.; and Roberts, J. A. F. "Blood Groups in Relation to Peptic Ulceration and Carcinoma of Colon, Rectum, Breast and Bronchus; Association Between ABO Groups and Peptic Ulceration." British Medical Journal, Volume 2, pp. 315-321, August 7, 1954.

2. Allison, A. C. "Protection Afforded by Sickle-Cell Trait Against Subtertian Malaria Infection." British Medical Journal, Volume 1, pp. 290-294.

3. Allison, A. C. "Distribution of Sickle-Cell Trait in East Africa and Elsewhere and its Apparent Relationship to Incidence of Subtertian Malaria." British Royal Society of Tropical Medicine & Hygiene, Volume 48, pp. 312-318, July, 1954.

4. Augustine, D. L. and Smillie, W. G. "The Relation of the Types of Soils of Alabama to the Distribution of Hookworm Disease." American Journal of Hygiene, Volume 6, pp. 36-62, March Supplement, 1926.

5. Black, R. H. Malaria in the Trobriand Islands (Territory of Papua and New Guinea). Technical Paper No. 61. Noumea, New Caledonia, South Pacific Commission.

6. Faust, E. C. Human Helminthology. Philadelphia, Lea & Febiger, 1949.

7. Lee, Douglas H. K. Climate and Economic Development in the Tropics, pp. 97-98. New York, Council on Foreign Relations Publications, Harper & Brothers, 1957.

8. Marston Bates. The Natural History of Mosquitoes. New York, The Macmillan Company, 1949.

9. May, Jacques M. "Ecology of Disease in World Health." United States Armed Forces Medical Journal, Volume 9, Number 6, pp. 232-234, June, 1958.

10. May, Jacques M. Ecology of Human Disease. Volume 1. New York, M. D. Publications, 1958.

11. May, Jacques M. Studies in Disease Ecology. Volume 2. New York, Hafner Publishing Company, 1961.

12. Rogers, L. "The Incidence and Spread of Cholera in India; Forecasting and Control of Epidemics." Indian Journal of Medical Records & Memoirs, Volume 9, March, 1928.

13. Russell, P. F. Malaria--Basic Principles Briefly Stated. Oxford, Blackwell Scientific Publications, 1952.

14. Proceedings of the 4th International Congress on Tropical Medicine and Malaria. Abstract of Discussion by Dr. Albert B. Sabine, pp. 534 and 535, following J. E. Druger's Studies in Dengue Fever.

15. World Health Organization. Malaria Conference in Equatorial Africa. Tech. Rep. Ser. No. 38. Geneva, 1951.