1 Disease Ecology:
Basic Concepts and Review of Earlier Iterature

1.1 Introduction

The transformation of the environment is the major factor modifying the relationships of all the possible stimuli with which man has to contend in order to survive. Any discussion of disease as an alteration of living cells or tissues, which jeopardizes their survival in the environment, must be based upon the global system of what is termed as environmental stimuli and man's adjustment to these stimuli. The data concerning the relationships between the malaria parasite, its two hosts, man and mosquito, and the environment in which these hosts live together illustrate clearly the three aspects of environmental stimuli physical, biological, and cultural which modify the dominance of this parasite and any other of the vast number of stimuli with which man has to contend. There are many gaps in our knowledge about the nature of these three factors and their intricate interrelationships with changing disease dominance. In the diseases of man, the cultural factor is crucial, since cultural traits either bring stimulus or host together or erect barriers to keep them apart.

Each culture brings about its own set of diseases. It is necessary to recognize the birth of new stimuli to disease, the changes that occur among dominance patterns of agents and vectors, and the changes in the maps of
immunities and susceptibilities. Widespread changes in the habitat will bring about changes in the map of disease and challenges to human adaptation which could in some instances be impossible to manage. For example, the manipulation of the environmental complex in Southeast Asia by means of drugs for parasite control and insecticides for control of the vector has created a serious situation. Mosquito resistance to insecticides on the one hand, and parasite resistance to chemotherapeutic agents on the other, has caused an apparently insurmountable dilemma. There are large areas in Southeast Asia where any military force entering the area will almost certainly contract Plasmodium falciparum malaria at infection rates approaching 100 per cent. The study of all the environmental factors mentioned and their mapping on an area basis form the structure of global epidemiology. As the map of disease changes, one must study all the stimuli discussed above and then study all the factors that govern responses from the host.

_Dominance is an ecological term that indicates the greater importance of one species of a living thing in a given habitat._ Plasmodium falciparum, the parasite responsible (in part) for the most severe form of malaria, has two habitats: the blood and hematopoietic (blood cell producing) organs of man; and the digestive and the connective tissue of certain species and strains of anopheline mosquitoes. Since the mosquito is the definitive host of _P. falciparum_ and man the intermediate one and not only factors affecting the ecology of _P. falciparum_ as it relates to other parasites competing for dominance in the human ecology, but also the ecology of competitive strains of anopheline mosquitoes which might ingest _P. falciparum_ during a blood meal.
1.2 Mosquito-Related Factors

Turning now to the mosquito, what are the ecological factors that favor (a) the growth and development of *P. falciparum* in the mosquito, and (b) the dominance of *P. falciparum*-prone mosquitoes in the environment? Some of the factors that determine the growth and development of the parasite in the mosquito are probably genetic in nature. Certain strains infect the vectors available in their environment more readily than others. Marston Bates (1949) reports the work of James, Nicol, and Shute, who were unable to infect an English *Anopheles atroparvus* with an Italian strain of *P. falciparum* while they could infect an Italian strain. The mechanism of this mosquito susceptibility and parasite adaptability must have genotypical as well as environmental cases. Conversely, mosquito species vary in their susceptibility to strains of parasites; susceptibility to *P. falciparum* seems also to be related to genetic factors (Bates, 1949). Bates also states 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 *P. falciparum* inside the mosquito is environmental temperature. Very high or very low temperatures prevent the establishment of mosquito infectiousness. The local temperature governs the time required for the mosquito to become infective after its blood and plasmodial meal. This relationship to temperature explains the predominance of *P. vivax* and *P. malariae* in the Temperate Zone and that of *P. falciparum* in the tropical belt. It may also explain the earlier occurrence of *P. vivax* and *P. malariae* cases in the spring and the later appearance of *P. falciparum* infection in summer or autumn. Since temperature varies with altitude,
temperature also regulates the time limits of the transmission period in mountainous regions. Winds indirectly influence rainfall, which, in turn, influences temperature and therefore affects infectiousness. No doubt other physical factors influence the life of the parasites in the vector but these have not, as yet, been discovered. Temperature changes in the environment are usually due to natural factors rather than to man-made changes.

1.3 Man-made Environmental Factors

However, man-made changes in certain cities in the tropical belt have definitely resulted in the transformation of the average and extremes of temperature 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 tall buildings that impede the cooling breezes from the sea and because of heat reflected from extended asphalt surfaces. Concurrently, however, the filling of the marshes and klongs has reduced the chances for mosquito breeding, making it difficult to assess the respective importance of these coincidental factors in modifying Plasmodium dominance? Environmental factors influence the parasites through the physiology of the mosquito vector and its survival rather than through influence on the parasite itself. For instance, 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 inside the mosquito host.

1.4 Mosquito Survival

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. Given this close relationship
between *Plasmodium* dominance and mosquito survival, the study of environmental changes that can influence the map of plasmodia through the map of mosquitoes 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 mosquitoes seek shelter. Some prefer to dwell indoors, others outdoors. Some cruise high under the canopy of the forest and others low above the ground. Rainfall and temperature, as well as the topography of the soil, combine to create situations in which mosquitoes either multiply or stop breeding.

**1.5 Malaria incidences**

Heavy 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 promotes the growth of plants such as bamboos or epiphytes (e.g., bromeliads) whose physical structures create water 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 may help or hinder the flights of the mosquito vector. Some vectors, such as *Anopheles pharoensis*, have been known to fly more than twenty miles across the desert. In certain parts of the Trobriand Islands of the South Pacific, the transmission season
corresponds to the periods of northwest winds (Black, 1952). 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, chances of malaria epidemics are lessened. If, on the contrary, 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 \textit{P. falciparum}-susceptible strains of mosquitoes vary both with the larva and with the adult. Because the requirements of the larva are more limited than those of the adult, the dominance of \textit{P. 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.

1.6 Vector breeding sites

The breeding places of the effective vector \textit{Anopheles gambiae melas} are almost entirely confined to parts of the coastal swamps flooded by high spring tides and characterized by the presence of \textit{Avicennia} mangroves and wide stretches of coarse marsh grass, \textit{Paspalum vaginatum} (May, 1961). 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 \textit{A. gambiae} melas and hence on the predominance of \textit{P. falciparum}. The characteristics of the water and 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 be established in the vicinity of breeding sites, the temperature of the waters enriched by sewage of all kinds will change?

1.7 Larval Habitat and Survival

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 (Bates, 1949). It has also been found that the degree of light and shade influences the breeding of *Anopheles albimanus*. It also influences the adult form of the vector *A. funestus*, which enters houses after midnight, especially during moonlight (WHO, 1951). Since light seems to be essential to survival of these larvae, it has been recommended that trees be planted in order to control breeding. Other species (e.g., *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; modifying the dynamism of a stream either by slowing it down above a dam or accelerating it below—may favor the growth of a larval type. Yet, most anophelines prefer still water 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 modified by artificial (oil spreads) or
natural (pollen, leaves) factors will also govern the dominance of certain anopheline species and the plasmodium most adapted to each strain. It is not known whether, in nature, the degree of acidity directly influences 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 as factors governing _P. falciparum_ dominance. These requirements will play an important role in qualifying a species of mosquito as an effective or weak vector of _P. falciparum_. It is interesting to note that the species that can be effective malaria vector in one area may not be effective in another.

### 1.8 Effective Vector Characteristics

According to Russell (1952), one can list the characteristics of an effective vector as follows:

a. the mosquito must enter human dwellings and be domestic (example: _Anopheles minimus_).

b. The mosquito must prefer human to animal blood; in other words, it must be anthropophilic (example: _A. 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 must possess the constitutional characteristics (genotype) that make it a desirable host for _P. falciparum_. 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, the composition and mobility of the air inside the house (drafts, closeness, smoke, smells; etc.), availability of resting places after the blood meal, and a multitude of home factors best
known to the mosquitoes themselves. Any changes occurring in the site and characteristics of the house will influence the mosquito presence and will thus enhance or limit the effectiveness of a species in promoting *P. falciparum* dominance. The anthropophilic tendencies of the mosquito are linked to some unknown need of the insect’s physiology and to some unidentified ability to provide for the needs of the *Plasmodium*. These tendencies will make a certain anopheline species a promoter of *P. falciparum* or of some of the other three malaria agents, or of none of them.

**1.9 Environmental conditions for vector survival**

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. 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 will also influence mosquito longevity. Finally, ecology of the human host influences to a considerable degree the dominance of *P. falciparum* in an 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 depend upon the flight level of the vector. If the cooking is done indoors or outdoors, the smoke will either chase the mosquitoes away or keep them inside. The presence of animals in the vicinity or at a distance would respectively increase or diminish the risk of man being bitten. The example of the farmers of North Vietnam is illustrative of these human factors (May, 1958). 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 nine hundred per square mile. The houses and the villages they form represent, from the point of view of construction, a compromise between the material that is available and the need to save as much soil as possible for food crops. The materials available are mud and rice straw, which do not lend them 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 sixty miles to the north, in the hills, one can 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 mud. The people, for reasons that are not as yet fully understood, build their houses on wooden pilings, which place what would call their living room at an elevation of 4, 5, and sometimes 6 or 7 meters above the ground. In these hills, *A. minimus*, a very fierce malaria vector, abounds, its breeding enhanced by the network of mountain streams. However, it so happens that *A. minimus* does not fly much higher than 3 meters above the ground. As a result, although it is essentially a man-biting insect wherever possible, it feeds on the cattle herded under the house between the pilings because it finds them 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 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 a belief which is, given the above circumstances, essentially correct. The type of agriculture also has an effect. In rice cultivation, 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 increase malaria transmission and the predominance of *P. falciparum* in the tropical belt. The habit of watching the crops at night, to guard against thieves (as in Turkey), birds (as in Liberia), or just to be on the spot for work the next day (as in Madagascar, Sarawak, and many other paces), also influences the chances of being bitten and of spreading the dominance of *P. falciparum* (May, 1961).

The type of walls used in house building, mud or bamboo, rough or smooth, influences the efficiency of DDT house-spraying, as does the habit of washing the walls with lime or frequently re-plastering them. Finally, and perhaps more than anything else, economics, implying various levels of ability to train public health workers, to practice sanitation, to sleep under mosquito nets permanently, and to understand the value of prophylactic measures, combine with the other factors listed to create a suitable habitat for *P. falciparum*. In the light of the above, it seems that the dominance of *P. falciparum* in a given environment is dependent 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. Under the constant changes of the environment, from those involving the minute amount of organic matter in the water that makes the life of a larva possible, to the erection of eighty-story buildings, the dominance of *P. falciparum* will change. Most of the significant factors governing these changes are unknown, and those that are not known are obviously the most intriguing. This is probably the time to focus on the fact that *P. falciparum* is not one parasite but many parasites whose various strains are gradually being identified in increasing numbers by malariologists.

As our knowledge of the microbiochemistry or microphysiology of living things increases and one can discover that there may be as many genotypes of *P. falciparum* as there are genotypes of men. Up to 1948, the existence of drug-resistant strains of malaria parasites was not recognized and malariologists the world over believed that the existing therapeutic armamentarium would eradicate the disease. During the decade 1948 to 1958, cases of resistance to a number of drugs hitherto believed almost 100% effective in eradicating the parasite began to appear in such widely scattered parts of the world as South America, tropical Africa, the Middle East, the South Pacific, and Southeast Asia.

### 1.10 Environment and Stimuli concept

Disease must be understood on an area basis. The immediate environment provides stimuli with which living things have to cope in order to survive and to which they must provide a response. This response as one can evaluate, it depends upon the amount of stimulus in relation to the genetic makeup of the host and upon 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 are termed as culture." Cultural traits either bring stimulus or host together, creating the chance for disease occurrence, or keep them separate, thus preventing the disease. Thus, at any place considered there is 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 subject of global epidemiology. All three 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 as physical, biological, and cultural.

1.11 Physical Stimuli

Physicists and geographers of the last fifty 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 relations. 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 in the human environment, Lee (1957) established an interesting diagram based on the combined plotting of temperatures and humidity. Within this chart 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 on which days of the year the people of Rio de Janeiro, Brazil, or of Basra, Iraq, are in comfort or discomfort and under what conditions they can function well. Beyond such measurements, loosely expressed in the terms comfort and distress, our lack of knowledge about the effects of climate on man is considerable. An important reason for our ignorance on matters of climatic influence on man 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 a good climate, they meant, without realizing it, a climate where no outside bacteria, parasites, or viruses attacked the body; whereas a bad climate was one where such aggressions did occur. The considered climates were, in fact, unrecognized disease agents. When climates are reproduced in artificial chambers, devoid of aggressive living things, the result is nevertheless distorted because many elements existing in the outside world, such as radiation and cosmic rays, are not included among the variables used in the experiments.

The people are just beginning to realize the existence and possible importance of such unknown variables as cosmic rays, static electricity, radiation, and other material forces that are as yet nameless. If it is possible that flares in the sun may disrupt macroscopic electronic communications on earth, as happens on airplanes and with submarines, it is also likely that they
produce changes in the microscopic electronic communications that occur in our cells, and are probably infinitely involved in the makeup of what is called life.

The forces of climate may conceivably influence resilience to disease in us as 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 one should know how to measure and those and 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 below biological stimuli. So far the 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.

1.12 Biological Stimuli

Let us come now to a second group of environmental stimuli challenging human survival, comprising all the living things which have elected to inhabit the macroclimates and 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. It is similar to 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 stressed in these words is that a social structure is essentially temporary, based on mutual tolerance, which implies dominance and submission. The moment anything happens to disturb the equilibrium 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, living things always compete for food and shelter and organize themselves temporarily on a pattern of mutual strength and power.

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, and mammals all live in societies. It is on this concept that modern therapy with antibiotics and 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," the mosquito *Anopheles jeyporiensis candidiensis* would have a difficult time surviving and so would the parasite *Plasmodium vivax* for lack of adult mosquito habitat in which to spend its sexual life. It has been shown that it is difficult to have the yellow fever virus multiply in an *Aedes aegypti* previously fed on dengue virus (Sabin, 1948). Could it be that these two viruses cannot belong to the same social structure because of some competition that is not yet understood? The social structures of living things are closely dependent upon the geographic factors and the food availability
discussed above, which is why one can 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 an in-depth study 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 the final analysis, should be conceived solely as a function of 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 made 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 first a study of all the stimuli have been discussed and then a study of the factors that govern responses from the host. These are all important. Given many aggressive stimuli, the living hosts respond according to their respective genius in a way that modifies the map of disease. Very little is known about this subject. Our textbooks and our literature are full of studies on the living stimuli but offer very little information on the host structure, the genetic makeup of the man who presents the symptoms that one can study, and 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 the adjustment of both man and animal, not solely through the physical problems of spatial occupancy but conceivably by affecting susceptibility or immunity through the obscure pathway of emotional changes. Because the relationship between genetics and response to environmental stimuli is not known, so far we have 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 lays 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 one 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 cattle pathology? Why does cholera Vibrios multiply in the intestines of guinea pigs without causing them any harm? Why cannot birds catch human malaria? The enzymes controlling 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. 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 result in the development of peptic
ulcers (Aird et al., 1954), and, as already mentioned, the pathological significance of certain types of hemoglobin is certainly worth exploring thoroughly (Allison, 1954a; Allison, 1954b).

The genetic constitution of an individual or of a population is more closely linked with the environment than we currently realize: the present and future genotype of a population is dependent upon the presence of environmental stimuli which cause mutations and on the pressures which force living things into migrations. Mutagenic factors are little known; however, heat, chemicals, radiation, and probably others are specific to environmental niches: the way these factors combine determines the microclimates or macroclimates for all living things. These climates exert their influence on the genes of plants and animals alike, causing mutations that upset the social patterns referred to above, causing dominants to lose their dominance and submissive elements to acquire dominance. Thus is disease patterns genetically linked with geographic pressures. In the same way, the environment in which man lives pressures his genotype, and brings about new shapes and new phenotypes that may be useful or detrimental to the continuation of his living in that same place. 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 that 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.
1.13 Cultural Stimuli

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. To the global epidemiologist, culture is the sum totals of the concepts and techniques that individuals or populations devise and use in order to survive in a given environment. Of course, not 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 cultural traits originally developed because they were thought to promote survival or because they did promote survival when they were adopted, but that they often have ceased to do so under changing circumstances. People do not give up their culture easily. They often like to feel the protection of their ancestors around them and they often 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.

It seems that a transformation of the environment will bring about changes that will modify the adaptation of man to his milieu. These environment changes occur as follows: alluviums fill up estuaries; isolated villages are replaced by large cities; vast populations multiply and create crowded situations; people migrate; genes segregate; and new genotypes are created which result in new responses to the environmental stimuli. The diseases prevalent among the sparse population of Manhattan when Captain Hudson sailed to these shores are not the same as those that prevail there today. 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 new niches. Each culture brings about its set of diseases; we have just now begun to study 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 information about 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, and 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. One must gauge the development programs that, so liberally and, perhaps, so foolishly encourage throughout the world. Drainage, irrigation, pest control, deforestation, afforestation, pollution, and destruction of cities create changes in the habitat which eventually and inescapably will bring about challenges to human adaptation, and hence changes in the map of diseases.

1.14 Ecology of Malarial Parasites
There are over 400 species of the malarial parasite (*Plasmodium spp.*) many of which infect a wide variety of cold-and-warm-blooded animals and among them only four routinely infect humans. Each one of the latter is transmitted by the bite of an infected female *Anopheles spp.* mosquito. It follows then, that ecological alterations favoring the spread of these insects also facilitate the spread of the infection wherever malaria occurs. To get some idea of the complexity of the ecological differences among the numerous malaria
endemic zones, one must consider at least four different, yet related, aspects: the host, the insect vectors, the parasites, and the physical conditions under which transmission occurs. Integration of these seemingly disparate subject areas into a unified view with respect to geographic locale is essential to begin identifying environmental factors that might be taken advantage of for the purpose of controlling the spread of the parasite.

Yuri Romanovsky, working in Russia, independently developed the stains needed to clearly identify the parasites in blood smears, allowing anyone with the interest and a microscope to become involved in malaria research. In 1897-1898, Ronald Ross, a future Nobel laureate, discovered during his work in India that female culicine mosquitoes were the transmitters and definitive hosts for bird malaria (i.e., they harbored the sexual stages of the parasite). A protozoan belonging to the genus Plasmodium causes malaria. Although there are over 400 species, four routinely cause disease in humans: *Plasmodium falciparum*, *P. vivax*, *P. ovale*, and *P. malariae*. While they all belong to the same genus, each species behaves quite differently in most aspects of their biology within the human and mosquito host. They also vary with respect to geographic distribution. *P. falciparum* is found in most tropical regions throughout the world, and is the most dangerous of the four in terms of both its lethality and morbidity. Relapses cannot occur with this species. In contrast, relapses due to *P. vivax* can routinely occur due to a latency period, during which time the parasites in the infected hepatocytes remain dormant. The longevity of relapse is apparently dependent on the particular geographical region in which the organism is found. *P. vivax* is
prevalent in many sub-tropical zones, as well as in the tropics. *P. ovale* is similar to *P. vivax* in its biology, but is found primarily in West Africa.

1.15 Climatic Conditions for Vectors

Each environmental change in the mosquito habitat, whether occurring as the result of a natural process or through human intervention, rearranges the ecological landscape in which these vectors breed. Every *Anopheles spp.* occupies a particular ecological niche that is genetically determined. Changes in temperature, humidity, altitude, population density of humans, and deforestation are just a few ecological factors that each play essential parts in the transmission of malaria.

Temperature and humidity have a direct effect on the longevity of the mosquito. Each species can thrive at an optimal level as a result of ecological adaptation. The spread of malaria requires that conditions are favorable for the survival of both the mosquito and the parasite. Temperatures from approximately 21°-32°C and a relative humidity of at least 60% are most conducive for maintenance of transmission. Mosquito density is conveniently measured in terms of the number of female mosquitoes per human inhabitant of the area. Thus, malaria transmission is proportional to mosquito density. Mosquito longevity affects malaria transmission, because it takes time (approximately 1 week) for the parasite to develop. Typically, female mosquitoes live 2.5-3 weeks. The minimum length of development is temperature dependent in all mosquito habitats, even the tropics.
1.16 Altitude and Distribution

Altitude is significant in determining the distribution of malaria and its seasonal impact on many regions of the world. In Africa, for example, altitudes above 1,000-1,500 m are considered safe from malaria. However, it must be cautioned that with continuing global climate change, these figures may change, extending the range of mosquitoes well above those altitudes as ambient temperatures rise. One of the most disruptive changes affecting mosquito populations is deforestation. When forest is cleared, erosion of the soil occurs, stripping away nutrients. It may take up to 50 years or more before a deforested area in the tropics returns to normal. During this time, cleared tropical forest is typically converted into grazing pastures, agricultural plots, and human settlements. These ecological disturbances allow for the proliferation of mosquitoes that prefer human habitation to natural settings.

In Trinidad, following deforestation during the 1940's, *Erythrina micropteryx* (Immortelle) trees were imported from Peru to shade the cocoa trees. Bromeliads (epiphytes) began to grow on them. This in turn, provided a breeding habitat for *An. bellator* and *An. homunculus*, while also increasing the opportunity for effective transmission of *P. malaria* in rural areas. As a result, a large malaria epidemic occurred, because the water-collecting bromeliads are the preferred breeding site for *An. bellator*. When the bromeliads were eventually removed by spraying dilute solutions of copper sulfate into them, the prevalence of malaria was greatly reduced. This illustration shows how a simple change in the ecological niche, such as the importation of immortelle trees, created a favorable transmission environment.
where none existed before. Fortunately, in this case, a solution was forthcoming.

1.17 Vector Ecological Zones

Construction of water control projects can also lead to shifts in vector mosquito populations. Reservoirs, irrigation canals, and dams are closely associated with the increase of a variety of parasitic diseases that are water dependent. Throughout the world, especially in developing countries, dams and other related water projects continue to be planned, constructed, and operated to meet human needs such as drinking water, energy generation, and agricultural production.

For most countries, dams are a crucial part of economic and social development, and represent a double-edged sword. The potential for dams to alleviate poverty significantly contributes to the enhancement of human health, and simultaneously increases the likelihood of human infection due to schistosomiasis, malaria, dysentery, and river blindness. During the construction of dams and canals, excavation pits provide temporary breeding sites for mosquitos. Such negative consequences are not only the direct result of encroachment, but are also due to the establishment of new strains of malaria brought in by migrant labors working on these dam sites. In these situations, disease transmission occurs at the ecotone.

1.18 Mosquito Breeding Sites

The breeding sites of infected mosquitos vary greatly with regards to species. Some prefer clear water, inhabiting the edges of streams, while
others thrive in irrigation ditches and reservoirs. Some species require extensive vegetative cover, preferring swamps and other permanent bodies of water laden with dissolved organic matter. Mosquito breeding sites are found anywhere fresh water collects. In fact, there is a direct correlation between the availability of water and the frequency in which mosquitoes feed on humans. Permanent natural bodies of water, such as swamps, serve as unique breeding grounds. In the tropics, as mentioned, mosquito breeding sites have emerged due to construction of dams and canals. Many of these sites develop into zones of transmission due to the concomitant increase of human populations moving to these areas. The number of possible breeding sites is extensive, and describing a few more of them will help to illustrate the difficulty in finding a common solution to control of malaria transmission by limiting mosquito populations.

1.19 Ecological Disturbance

Ecological disturbance as a direct result of human activity may also increase the number of breeding sites. Road building and maintenance projects often impede drainage of runoff from rainfall. Clogged drainage ditches along roads left by logging and construction activities are ideal places for floodwater mosquitoes. Around the house, objects such as empty cans, discarded tires, potted plants, and similar objects collect rainwater and allow mosquitoes to breed within the limits of human habitation. Remote sensing from outer space can identify many of these ecological settings.
1.20 Mapping Vector Zones by Remote Sensing Technology

Satellites acquire information through a variety of modes, helping to identify potential breeding sites. Vegetation with unique reflection spectra and human settlements that emit weak electromagnetic radiation signals are keys to making the correlation between potential breeding sites adjacent to human habitation, and the potential spread of malaria. Remote sensing technologies have allowed medical ecologists to view vast areas of malaria transmission, and have provided a new and important tool for mapping the breeding habitats of infected mosquitoes, predicting densities of vector species, and even developing risk maps for malaria transmission.

1.21 Vector Behaviour

The biting behavior of the vector is dependent on several factors. To be an effective transmitter of malaria, the mosquito must fulfill certain requirements. These include, but are not limited to, their frequency of taking a blood meal, the mean longevity of the breeding season, and the density of vectors in relation to human population density.

Most Anopheles spp. are nocturnal in their blood meal feeding habits. Some species, such as An. albimanus found in Central and South America, bite mainly indoors from sunset to 21.00 hours. In contrast, in Africa, the An. gambiae species, also an indoors feeder, bite mainly after 23.00 hours. Feeding preferences vary considerably with respect to time, place, and host species availability. Anopheles spp. feed on a wide variety of hosts, including birds, cows, pigs, and all primate species. Most of these mosquitoes are not
exclusive in regards to their preferred host species. For example, \textit{An. culicifacies}, an important malaria vector throughout most of tropical India, commonly feeds on cattle as well as humans. In Africa, however, \textit{An. gambiae} feeds rarely on cattle, and more frequently on humans. This is one of the reasons why \textit{An. gambiae} is a more efficient malaria vector than \textit{An. culicifacies} when they are found together in the same ecological setting with human populations.

Originating in Africa, the \textit{Anopheles gambiae} complex of mosquitoes include the most efficient malaria vectors on Earth. This is because they have adapted well to human habitation, and feed almost exclusively on human blood for egg production. It has a wide distribution, and usually occurs in large numbers wherever found. It is also highly susceptible to the parasite. The female bites mainly at night, but in several studies, 12 percent of bites occurred after sunrise. \textit{An. gambiae} lay eggs in a wide variety of aquatic environments. Some breed in small pools that are partially or completely exposed to the sun, while others prefer to breed in shaded stagnant pools, or even in slow moving water. They have been captured from water-filled holes of rocks, coral outcrops, trees, and stumps of felled banana trees. Wherever agriculture or gardening activities result in the collection of significant amounts of stagnant water, \textit{An. gambiae} is there to take advantage. Because of its high degree of ecological adaptability, this vector species has become the dominant one throughout Africa. An investigation by the World Health Organization showed the following regarding \textit{An. gambiae} breeding sites. Under laboratory conditions, this species carries out normal development when the pH varies as much as from 4.0 to 7.8, as long as there is sufficient
phytoplankton and zooplankton for it to consume. The maximum temperature at which *An. gambiae* larvae can survive is 41°C. Rarely does this temperature occur in nature, even in the intense heat of equatorial Africa.

### 1.22 Malaria Transmission

*An. quadrimaculatus* is the dominant vector in the southeastern half of the United States. Malaria transmission is rare, however, due to lack of the presence of the parasite. Introduced infections are common during the height of the tourist season, when many travelers return from endemic tropical regions with sub-clinical cases of malaria, and serve as foci of domestic infections. During the early history of the United States, malaria was common, and did not completely disappear until the early 1950s.

*Anopheles quadrimaculatus* is essentially a pond breeder, wherever sunshine and emerging vegetation are available. Larvae are found along the littoral zone. It also breeds in rivers or swamps where conditions are similar to those found in ponds. Unlike *An. gambiae*, *An. quadrimaculatus* prefers slightly alkaline water. *An. quadrimaculatus* enters occupied houses freely and rests within the darker corners in the daytime. They are even found in large numbers in stables and other animal shelters. Moreover, they are sometimes exceedingly abundant in tree holes, under bridges, and in caves.

### 1.23 Filariasis

A dominant *Anopheles spp.* has been emerging throughout Asia, the *Anopheles punctulatus* complex, and consists of *Anopheles punctulatus*, *An. koliensis*, and at least three species of *An. farauti*. Members of this complex
are important vectors of human malaria and periodic Bancroftian filariasis throughout Asia. *An. punctulatus* biting activity occurs nocturnally, usually peaking at approximately 10:00 p.m. These related species of mosquitoes are typically larger and more robust than those found at lower elevations. This makes them better vectors because of the relatively large blood meals that they take.

*An. Punctulatus* is the dominant vector of Papua New Guinea. This species is associated with varying rainfall patterns and can survive in casual surface waters. In Papua New Guinea, the clearing of native vegetation and poorly maintained irrigation ditches around houses in that tropical region creates and maintains many breeding conditions for these vectors. In Amapá state in the northeastern region of Amazonia, a new neotropical species of anopheles has been identified as an emerging dominant malaria vector. In five collections taken from three replicated sites near the city of Macapá, Amapá state in 1996-97, *An. marajoara* was found in greater abundance during the peak transmission months of June-August and November-December than the previously dominant vector in the area, *An. darlingi*. In addition, *P. falciparum* and *P. vivax* were also found with significantly higher frequency in the *An. marajoara* population than *An. darlingi*. Data from the Fundacao Nacional de Saude also indicated the occurrence of new malaria cases during months when no *An. darlingi* were collected. Instead, in Amapá state, a high prevalence of *An. marajoara* was demonstrated. There are an estimated 500,000 yearly malaria cases in Brazil, for which, in the past, the primary vector has been *An. darlingi*. Over the last few years, ELISA, in conjunction with microscopic examination of mosquito stomachs, researchers
have identified new set of neo-tropical species as potentially important malaria vectors. The species complex *An. albitarsis s.l.* consists of 4 species: *An. albitarsis s.s.*, *An. deaneorum*, *An. marajoara*, and *An. albitarsis* sp. B.

1.24 Japanese Encephalitis

Japanese encephalitis is a viral disease that infects animals and humans. It is transmitted by mosquitoes and in humans causes inflammation of the membranes around the brain. Intensification and expansion of irrigated rice production systems in South and South-East Asia over the past 20 years have had an important impact on the disease burden caused by Japanese encephalitis. Where irrigation expands into semi-arid areas, the flooding of the fields at the start of each cropping cycle leads to an explosive build-up of the mosquito population. This may cause the circulation of the virus to spill over from their usual hosts (birds and pigs) into the human population.

Japanese encephalitis (JE) is a disease caused by a flavivirus that affects the membranes around the brain. Most JE virus infections are mild (fever and headache) or without apparent symptoms, but approximately 1 in 200 infections results in severe disease characterized by rapid onset of high fever, headache, neck stiffness, disorientation, coma, seizures, spastic paralysis and death. The case fatality rate can be as high as 60 per cent among those with disease symptoms; 30 per cent of those who survive suffer from lasting damage to the central nervous system. In areas where the JE virus is common, encephalitis occurs mainly in young children because older children and adults have already been infected and are immune.
Mosquitoes belonging to the Culex tritaeniorhynchus and Culex vishnui groups, which breed particularly in flooded rice fields, transmit the virus causing Japanese encephalitis. The virus circulates in ardeid birds (herons and egrets). Pigs are amplifying hosts, in that the virus reproduces in pigs and infects mosquitoes that take blood meals, but does not cause disease. The virus tends to spill over into human populations when infected mosquito populations build up explosively and the human biting rate increases (these culicines are normally zoophilic, i.e. they prefer to take blood meals from animals).

Japanese encephalitis is a leading cause of viral encephalitis in Asia with 30,000-50,000 clinical cases reported annually. It occurs from the islands of the Western Pacific in the east to the Pakistani border in the west, and from Korea in the north to Papua New Guinea in the south. Because of the critical role of pigs, its presence in Muslim countries is negligible. JE distribution is very significantly linked to irrigated rice production combined with pig rearing.

1.25 Ecological and Environmental Factors for New Vector

Three ecological factors led to the emergence of An. marajoara as the new dominant vector in northeastern Amazonia: recent alterations in land use in Amapá state; human migration, population influx and invasion of primary mosquito breeding sites; and An. marajoara’s more anthropophilic tendencies than An. darlingi. At the time the tests were conducted (1990-1998), the capital city of Amapá, Macapá, underwent significant industrial developments, including the construction of roads through several forests, and was established as a duty free zone. Both changes generated a significantly larger
increase in human traffic through the area than before, and also attracted an increased influx of immigrants. Many immigrant populations of adjacent states were already infected with malaria, and consequently the percentage of the population infected in Amapá state rose from 4.3 per cent to 15 per cent between 1990 and 1998.

Furthermore, the advent of roads through sections of virgin forest, and urban development, has resulted in encroachment into primary mosquito breeding sites. Large, undisturbed areas of unshaded, unpolluted and stagnant water sources were disrupted, and many forested areas were cleared. These changes have selected against *An. darlingi*, and inadvertently created new sites for other species, such as *An. marajoara*, to emerge. It is likely that these environmental changes led directly to the population increase of *An. marajoara* and its new position as the primary malaria vector in that region. It was previously believed that malaria could be limited by controlling *An. darlingi*. Unfortunately this is no longer the case, as there are now more factors to consider.

1.26 Public Health

Public health, the improvement of a population’s health through the organized means of society, has a long tradition. Public health has always depended on sufficient food, clean water and protection from disasters. Infectious diseases have been reduced through isolation, immunization and specific treatments; measures to combat chronic diseases have also been based on epidemiology. The World Health Organization health for all pro-gramme emphasizes the broad scope of public health at national level and Healthy
Cities affirms the fundamental contribution of local organizations – municipal, professional and voluntary.

1.26.1 Positive Health

The Ottawa Charter for Health Promotion adopted in 1986 provides the strategic framework to implement the health for all principles. It says: "Health is a positive concept emphasizing social and personal resources, as well as physical capacities. Health promotion therefore, is not only the responsibility of the health sector, but goes beyond healthy life-styles to well-being". Positive health thus has three linked dimensions – social, psychological and physical – which should all be included when measuring health.

The Centre for Health Promotion conceptual model is seen as applicable to all persons, with or without developmental disabilities. It was developed on the basis of an analysis of the literature on quality of life and qualitative data we collected in the context of focus groups and in-depth interviews with persons with and without developmental disabilities.

Following the preliminary development of the conceptual model, it was tested for relevance and refined by means of rigorous review by adults with and without physical and developmental disabilities, adolescents, and older adults living in the community. In each case, the applicability of these concepts was examined for relevancy for the population, instruments and methods were created, and collection of data carried out. The model is multidimensional and assumes that quality of life is holistic in nature.

The Quality of Life Profile was developed to provide a measure that considers both the components and determinants of health and well-being.
draws upon a conceptual model that is consistent with recent definitions of health and health promotion as provided by the World Health Organization. The profile emphasizes individuals' physical, psychological, and spiritual functioning; their connections with their environments; and opportunities for maintaining and enhancing skills.

1.27 Conceptual Framework

Our conceptualization defines Quality of Life as: The degree to which a person enjoys the important possibilities of his or her life. Possibilities result from the opportunities and limitations each person has in his/her life and reflect the interaction of personal and environmental factors. Enjoyment has two components: the experience of satisfaction or the possession or achievement of some characteristic, as illustrated by the expression that 'every one enjoys good health'. Our conceptual framework has three life domains, each of which has three sub-domains. Physical being is physical health, personal hygiene, nutrition, exercise, grooming and clothing, general physical appearance;

1.28 Review of Earlier Literature

To the extent recent literature focuses on differences in outcomes across countries or over time in terms of levels of various environmental indicators. The following literatures indicate the environmental Kuznetscurve (Shafik and Bandopadhyay (1992) for the 1992 World Development Report, Grossman and Kreuger (1995), and Andreoni and Levinsohn (1998)) and recent literature on trade and environment (Copeland and Taylor (1994, 1995)) and (Antweiler, Copeland and Taylor (1998)). While authors contributing to these literatures
are clear in labeling their analyses to be primarily of pollutant levels, users of this research naturally tend to think of the results as giving audience on the wider environmental situation in the countries and without explicit reference to degradation effects the picture once again can be incomplete. The studies referred here is to suggest that internalization gains relative to GDP are significant for developing countries (and probably larger than for developed countries) raising the issue of why a higher degree of internalization has not occurred. It is discussed here briefly whether this outcome reflects income elastic ties of demand for environmental quality above one; or whether it reflects technology and capital intensity of environmental management and policy enforcement, so that abatement costs in developing countries are the barriers.

We interpret the term "environmental regime" applied to the developing countries as meaning the set of externality related problems often characterized as environmental, as well as the policy response they have induced. Individually these cover soil erosion, open access resources (forests, fisheries), congestion (traffic), household emissions (fuel burning), industrial emissions, ground and surface water resources (shared aquifers and water table problems), untreated human and non-human waste, and other problems. Property rights and a lack of their clear definition, and compliance with environmental controls are two factors closely connected with these problems. Policy responses include regulation (command and control), local actions (village level on soil erosion), resource management policies (forests) and infrastructure development (urban congestion).
For the purpose we classify these externalities into two broad headings; pollutants, covering industrial and household emissions of various forms, and untreated waste; and degradation, covering soil erosion, congestion, and open access resources. For both of the problem areas one can identify the classical externality literature applies: a Pigouvian tax will internalize the externality, the Coasian issues of the assignment of property rights and whether partial internalization can take place through bi (or pluri) lateral deals once property rights are established also arise.

One could group these in other ways such as agriculture and rural activity externality problems, urban externality problems, and environmental problems associated with varying forms of industrial waste. The reasons for grouping these environmental problems in the way we do relate primarily to measurement issues. They do not reflect any major analytical distinction in terms of the economics, even though, for instance, open access externality problems for renewable resources have a complex analytical literature characterizing both how replacement of the stock occurs, and what constitutes optimal policy across sustainable harvests. Pollutants capture emissions and contaminants of various forms. Degradation captures environmental effects for which emissions and contaminants are not the central issue, and direct monitoring is more problematic.

We note in passing that the developing countries in which these regimes occur are far from being a homogenous group of countries. They vary by per capita income, GDP growth rates, size, the volume and pattern of their international trade, their degrees of urbanization, and many other characteristics. They also vary in the form their environmental problems take;
some countries are heavily endowed with environmental assets such as tropical forests, while others are arid and desert; some are mountainous, others are low lying and flood prone. Generalizing across all developing countries and categorizing the environmental regimes they each face is thus difficult. A few generalizations seem to hold, though: lower income countries have proportionately more significant agricultural and rural sectors, for instance.

Notwithstanding these problems we see as the main elements in our characterization of the environmental regime in developing countries using the broad categories of pollutants and degradation discussed above. Pollutants in the form of toxic contaminants cover effluents of various types which come largely from mines, chemical production, pulp and paper plants, and leather and tanning. Toxic contaminants - Organo-chlorines, dioxins, pesticides, grease and oil, acid and caustic metals; mainly discharges from mines, chemical producers, pulp and paper plants, and leather tanning factories. Untreated fluid waste Untreated sewage discharges into rivers, streams, open ditches - water borne disease Domestic solid waste poorly managed solid waste spreads infectious disease, blocks urban drainage channels, with risk of flooding and water borne disease.

Shared access to water through common aquifers and ground water is a yet further manifestation of the problem; this results in reduced water tables, causing especially severe problems in the North China plain. Finally, within this regime under the heading of degradation come urban congestion problems. Rapid growth in urban populations and vehicle densities, especially in high growth economies, leads to congestion. This lowers air quality,
increases the spread of infectious disease, generates significant time loss from traffic and with it high accident rates, and noise. A 1990 study by Japan's International Cooperation Agency produced the estimate that road congestion in Thailand (one of the worst cases) reduces potential output in the Bangkok region by $\frac{1}{3}$.

Estimates of the costs of damage from a series of environmental sources in India in 1992 are put at about 6 per cent of GDP in the ADB studies. The elements included cover urban air pollution, health costs from water quality, soil erosion, and deforestation, while the study excludes traffic related costs, pollution costs from toxic wastes, and biodiversity losses. The study in this area by Shafik and Bandopadhyay (1992) with results given prominent profile in the Report itself) examined a range of environmental indicators. These included lack of clean water, lack of urban sanitation, ambient levels of suspended particulate matter, ambient sulfur oxides, change in forest area during the period 1961-86, the annual rate of deforestation between 1961 and 1986, dissolved oxygen in rivers, fecal coli forms in rivers, municipal waste per capita and carbon emissions per capita. Their sample consisted of observations on up to 149 countries for the period 1960-90, although their coverage was incomplete. Some of the dependent variables were observed for cities within countries, in other cases for countries as a whole. Only in the case of air pollutants was an EKC type relation found. Lack of clean water and lack of urban sanitation were found to decline uniformly both with increasing income and over time. Deforestation seemed to be unrelated to income. River quality tended to monotonically worsen with income. Selden and Song (1994) following Shafik and Bandopadhyay focused
exclusively on air pollutants in their examination of possible EKC relationships. They studied emissions of SO$_2$, NO$_3$, SPM and CO. Emissions were measured as kilograms per capita on a national basis with pooled cross-section and time-series data drawn from World Resources Institute (1991). The data were averages for 1973-75, 1979-81 and 1982-84. There were 30 countries in their sample: 22 high income countries, 6 middle incomes and 2 low incomes. Their results indicated that emissions of CO were independent of income, whereas emissions of other pollutants followed an EKC pattern. However, the turning points occurred at much higher levels of income than in the Safik and Bandopadhyay study.

Grossman and Krueger (1995) subsequently investigated EKC relationships using the GEM Scross country data on air quality over the period 1977-1984 and isolated a series of environmental indicators: SO$_2$ concentration in selected cities, smoke, dissolved oxygen in water, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrates, fecal coliform, total coliform, lead, cadmium, arsenic, mercury and nickel. The data measured ambient air quality at two or three locations in each of a group of cities in a number of countries over the period 1977-88. The number of observations varied over time (52 cities in 32 countries in 1982, but only 27 cities in 14 countries in 1988). The authors claimed that the data were representative of countries at varying levels of economic development and with different geographical conditions, and found an EKC type relation for SO$_2$, smoke, dissolved oxygen, BOD, COD, nitrates, fecal contamination of rivers and arsenic.
Geographic Information Systems/Science (GIS) seem to be a natural fit for epidemiology, the study of the origin and transmission of disease. Epidemiology attempts to integrate a vast array of risk factors such as temperature, moisture, vegetation type/percent cover, the presence and density of disease vectors (i.e. mosquitoes, ticks, etc.), the presence and density of susceptible hosts, pathogen transmission rates- even the molecular, cellular, reproductive and behavioral biology of the host(s)- in an orderly way. This information is used to identify which factors are necessary for disease, the areas that support disease vectors, and the risk of disease transmission and outbreak. A GIS provides us with the ability to overlay many of the larger-scale risk factors and spatially analyze the data in an attempt to better understand which factors are essential, or how the factors influence each other, to increase or decrease the occurrence of a particular disease. The articles summarized below provide an introduction to some epidemiological studies, which have utilized GIS technology.

The study entitled "Mapping soil-transmitted helminthes in southeast Asia and implications for parasite control," utilized remote satellite sensing and GIS to develop a model of helminth infections and isolate environmental surrogates, which successfully predicted higher soil helminth densities. Because actual soil helminth survey data was sparse, the authors first entered all available data on infection prevalence and special distribution into digital form. Using these findings, they analyzed the data from AVHRR (advanced very high resolution radiometer) satellite sensors for land surface temperature (LST) and normalized difference vegetation index (NDVI) to identify, temporally and spatially, those areas conducive to the development of
helminths (which are limited by max temperature and soil moisture) and the
spread of the corresponding parasitic diseases (maximum value compositing
was used to reduce the effects of atmospheric contamination). From here,
they went on to suggest ecological variables, which correlated with infection
patterns, and to generate predictive maps of infection risk by province.

Regan (1998) outlined the potential uses of GIS and satellite sensing in
the predictive impacts of global warming on human health, particularly via
indirect routes (disease). The authors suggest that increases in average
temperature, temperature extremes, relative humidity and seasonal rainfall in
some regions pose a potential threat to human health via vector range
extension- especially for insects and arthropods, which are vectors for some
of the most severe vector-borne human diseases (dengue fever, malaria,
many of the emerging flu viruses). They go on to a general discussion of
which regions would be most severely affected (coastal regions of what are
now temperate regions), but they fail to actually use GIS, conduct any
analysis, or produce maps identifying the regions that would be affected by
increases in the above factors, or by combinations thereof. Their paper is
thus largely conjecture; for a better review of how GIS and remote sensing
can be used in epidemiology, see the review paper section below.

Cherkasskiy (1999) reviewed the history of naturally occurring anthrax
(Bacillus anthracis) infections in ruminants and humans in the former Soviet
Union. Anthrax bacteria live in soil and sporulate under adverse conditions;
they can exist in this stable, dormant form for decades before reactivating
(typically by ruminant ingestion) and causing disease. Because record
keeping was mandatory, excellent records exist for the period from 1935-1991, but since the dissolution of the USSR, monitoring and vaccination efforts have dissolved and the occurrence of the disease has increased. The author cites a number of soil factors proposed to influence the occurrence of anthrax outbreaks: low-lying soil depression, eroded shallow soil, deep rich alluvial soil, neutral or slightly alkaline soil pH, organic matter, high relative humidity, adequate temperature without excessive freeze-thaw cycles, and the presence of certain cations. In addition, a number of environmental and anthropogenic activities increase the chance of spore activation: wet spring weather followed by short, hot summers; landslides, "dusty tempests", increased intensity of land reclamation activities, land excavation, and an excessive density of livestock per acre of pasture. The author has compiled these records into a database and outlines future strategies to analyze and verify the above risk factors using a GIS, as well as to investigate the temporal, often sporadic component of anthrax outbreak.

Omumbo et al (1998) had suggested that the clinical outcome of malarial infection is a function of the age and intensity of exposure; this study used GIS to determine the areas of Kenya in which chronic, low-level exposures to Plasmodium falciparum occurred in an effort to identify those areas expected to have the most severe cases. The authors searched the literature for previous studies and entered those results with known geographic locations into a database, then generated a "parasite ratio" based on the proportion of children in a given area with detectable parasitaemia. Known cases, environmental factors known to affect parasite abundance (here: temperature, elevation and rainfall), and population densities were
combined using IDRISI in a model to predict locations where the probability of disease transmission was >5% per cent. This information was overlaid with population densities to identify those zones with the greatest potential for severe malarial infections (in this case, districts around Lake Victoria and along the southern coastal region). The outcome predicted that in 1997, for children <10 years old, 1.33 million, 3.02 million, and 0.86 million children were exposed to low, moderate, and high intensities of infection (respectively). The authors propose that vector interruption methods (insecticides, etc.) be focused on the areas identified as highest in risk.

Kitron (1997) analyzed the distribution of reported cases of Lyme disease (*Borrelia burgdorferi*), present in Wisconsin (USA) since 1991, against the presence of wooded areas, tick (*Ixodes scapularis*) density, and human population density by county (n=72). Satellite imagery (remote sensing) was used to generate a maximum normalized difference vegetation index (NDVI), which correlated with disease incidence in the spring and fall, when wooded vegetation could be differentiated from agricultural cropland via analysis of near infrared and visible wavelength values. Although only a small percentage of cases could be positively identified with the county of exposure (travelers may have come in contact with ticks outside their home county), spatial analysis showed that counties in the central and northwestern regions of the state had the highest disease incidence. When further analyzed by dividing the state into three regions, the western region was identified as that with the highest human risk for Lyme disease. The positive correlation between vegetation type and increased disease risk contradicted the results.
of the study below (authored by Nicholson and Mather), although different methods were used to identify "forested" areas.

Nicholson (1996) analyzed the transmission of *Borrelia burgdorferi*, the bacteria which cause Lyme disease, to humans via the black-legged tick, *Ixodes scapularis*. The state of Rhode Island (USA) was broken up into 42 quadrats and the hydrography, vegetation cover (by aerial photography), tick density, and percentage of ticks infected with *B. burgdorferi* were taken into account to generate an entomological risk analysis for the disease (kriging was used to interpolate tick densities in the areas between the actual tick sampling stations). Overlays were used to identify areas where tick density, vegetation, human population density and the number of cases reported (by location) coincided; these areas were then further analyzed to look for causation between the variables and the incidence of disease. Interestingly, the authors concluded that the risk of contracting Lyme disease was most highly correlated with latitude; the northern parts of the state had lower tick densities, perhaps due to biological requirements of the tick. They found no correlation between disease risk and vegetation (percent forested), which had been hypothesized as a risk factor because it is the habitat for white-tailed deer and mice, the "normal" hosts for the tick.

Graham (2004) has outlined introduction to the volume, provides an excellent overview of the strengths of GIS and remote sensing as applied to epidemiology. The authors point out the emergence of GIS in the study of disease, and briefly discuss how spatial analysis, remote sensing, scale, temporal components and spatial statistics can be integrated to model and
predict factors which promote both the survival of the host and pathogen and the transmission of disease.

Thompson (2000) reviewed satellite-based remote sensing techniques in epidemiology. Many of these techniques have been used in the papers summarized above; the authors discuss how satellite imagery/remote sensing has provided epidemiologists with an inexpensive, data-rich source for the analysis of risk factors, which has typically been lacking for underdeveloped countries.

1.29 Statement of the problem
Ariyalur is one of the most polluted towns in Tamil Nadu and many calcite mines surround the town. Due to its mining activities nearby areas of this region forms a major industrial activity of cement industries. Lime stone lakes surround this region and many of them are abandoned filled with stagnant and waste water. The town has the highest pig population and the field investigation in this region clearly depicts that it has no proper drainage system in almost all the 18 wards. The town has always been an endemic zone of many infectious diseases due to its improper environmental conditions. The most important disease very often affects this town is the 'Japanese Encephalitis', which means 'Brain Fever' that affect the children within the age group of 6. During and aftermath of the seasonal rainfall this town is worst affected to many infectious diseases. The worst problem this town is facing is that it has several pig sheds which is located in the densely population zones and each shed ranging from 100 to 150 pigs. Even in some of the mixed residential (built and huts) complexes do have 10 to 20 pigs and
keeping as a domestic animal. It is evident from the above that this zone is an epidemic zone for Japanese Encephalitis and it is easy to evaluate the nature of physical, spatial, ecological, environmental, social and economic condition in which the people survive in this town and disturbing the balance between the host and environment relationship. When the balance is not maintained the infectious diseases finds the places of most adverse environmental condition zones. A study relating to assess the spatio-environmental conditions of the city is very limited and after afflicting the infectious diseases very often a detailed study about the spatial environment and people’s perception about their environment is necessary to suggest few remedial measures, to curtail the facing problem of this town.

1.30 Aim and objectives

The Main aim of the present study is to find the existing spatial and environmental conditions and also investigate how far this town has been deteriorated that lead to several infectious diseases reported with particular reference to the ‘Japanese Encephalitis’ or Brain Fever that affects the child population in the town. To precede further in this study the following two broad objectives were formulated to investigate the problem in an in-depth.

1. To study the existing spatial, environmental, ecological, social and psychological factors that affect the status of health in the town that favors for a conducive environment to emanate various types of infectious diseases that affects the status of health, particularly among the children,

2. To identify the disease ecological zone of Japanese Encephalitis, particularly the location and character of pig sheds with huge pig population and their disastrous environmental conditions which would create a conducive atmosphere for the vector growth, using the satellite remote sensing technology,
3. To investigate the peoples' perception about the environmental conditions in which they create/ live and its impact on their health and also to assess the ecological conditions through sample survey methods,

1.31 Research questions

The present research has several research questions based on the field investigation method that was carried out during the pilot survey. There are supporting evidences in different time periods that the outbreak of vector borne diseases in the town and particularly the 'Japanese Encephalitis' which affects the child population. The people's perception about the environment and the incidence of vector borne diseases are very poor. The two major questions arise out of this problem are: They're spatial, economic, and environmental conditions that they have created are at present reacting on them. The substantial evidences that were collected for the above variables and the scientific methods applied to verify them. Secondly the perceptual habitat of their own environment in which they create and live and its reactions are unknown to the people of the town.

1.32 Methodology

To analyze the above problem, data relating to both primary and secondary have been gathered from various sources. The secondary data relating to the demographic factors particularly the population density, literacy rate, child population, morbidity and mortality rate, crime rate physical and climatic data, water quality parameters and specific environmental factors that influence the topography such as the location of pig sheds, the mosquito density count and location of public latrines that drains contaminated water on the road side which will affect the quality of life in Ariyalur Town were gathered from various sources of the Town panchayat and District administration of Ariyalur. Apart
from the above all the locations of Registered Medical Practitioners (RMPs') were gathered though field investigation method and transferred all the points on a map. The secondary information was used to substantiate the problem and depict the Ariyalur town to its present shape of adverse environmental quality when compared to other towns in Tamil Nadu. To identify the major environmental hazardous zones and also the disease ecological zones in Ariyalur and surrounding, the Indian Remote Sensing Digital Data (IRS 1C) has been acquired from NRSA. The data were subjected to various digital image analysis techniques using ENVI 4.0 to map the recent built-up areas, huts, water bodies, stagnant water areas, improper drainage, Pig shed, vegetation cover, Agricultural areas and barren surface.

To study the peoples' perception and attitudes towards the environment in which they live, a primary schedule has been prepared with 50 related questions were designed to measure the attitude and it was distributed among 386 samples which are spread over in 18 wards which is 2 per cent of sample population and it varied depending on the individual population of the ward (sample distribution is described in chapter 4). The sampling method in the study area was the random sample method based on the basic assumption that in general the environmental condition is uniformly bad in shape and the field investigation method before the collection of primary data was undertaken. The questions were directly related to measure the parameters of the environmental quality of the life and also to correlate with the healthy city indicator approach. The questions include apart from the name of respondent, age, sex, number of dependents, socio-economic characters, housing type, persons living with the respondent, living area (in
square feet), details about the waste disposal site distance, source and quantity of wastes per week, perception about the wastes, common health problems, types of health services sought, environmental problem arising out of waste disposal, respondents’ attitude towards the unhygienic, water logging, disease prone, wet land, pig and cattle nuisance, family details as far as the health care is concerned and so on.

1.33 Techniques of analysis

To study the People's perception about the spatial-environmental problems at gross-root level, the Factor Analytic Model has been used, to identify broad dimensions and to search for a simple factor structure; Factor Analysis is a dimension reduction method. To study the health care user behavior at the grass-root level, factor analysis has been used. It is a dimension reduction method and has the ability to reduce a large data set down to a smaller number of factors. The aim of this analysis is to define new variables or factors that adequately and clearly describe the original set of variables. The need is to search for a simple factor structure whereby each original variable loads high on one factor or low on the second. The second higher-level technique of Cluster Analysis with Dendrogram, a classification method was implied to group the distinct group of samples based on the similarity.