BIOLOGY, ECOLOGY AND HEALTH

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Contents

Summary

Many of the factors that influence the health of an organism, such as genetic factors, are inherent or "internal". External factors of the physical environment (climate, toxins, etc.) play an increasingly important role. The other "external" factors that impinge upon human health include biotic interactions, especially man's involvement in animal and vector-borne disease cycles such as plague, malaria and yellow fever, as well as the more recent "newly emerging/resurging" diseases such as Lassa and the South American Hemorragic Fevers, Dengue and Dengue Hemorrhagic Fever and related arboviral infections and others. This paper discusses some of the biologic and human features of such disease cycles and how they may change in time and place through human transport, domestication, and modification of ecosystems and biodiversity. It considers adaptations such as vector and parasite resistance to pesticides and anti-parasitic (e.g., anti-malarial) drugs, as well as behavioral modifications that influence the frequency and intensity of transmissions of some of these diseases; and especially the role of man through overpopulation, exploitation of natural resources, and environmental modifications that favor the spread and intensity of these diseases by enhancing the growth of vector populations and increasing their contact with humans.

1. Introduction

Considering the biological nature of man as one of the approximately 4000 known species of mammals, it is hard to imagine how anything impacting on his health and/or well-being would not, directly or indirectly, be termed a biological determinant. In a broad sense, the characteristics (or ranges) of physiological and functional values that determine what we refer to as "normal" and "abnormal" (pathological) are direct measures of an individual's biological state at a point in time. Similarly, external conditions or actions that may be either "deleterious" or "beneficial" to an individual's or a community's health are usually measured by indirect biological functions (e.g., quality of food, water and shelter, safety, etc).

Certain biological determinants (e.g., genetics, nutrition, etc.) are so fundamental in their relation to health that they are treated as individual areas of investigation and understanding, both in other chapters of this work and elsewhere. At the same time, multiple factors (determinants) are usually integrated in their relation to health so that the pragmatic approach generally considers their impact on specific groups of individuals (as in pediatrics or gerontology, etc.); or on discrete organ systems (cardiovascular, skeletal, pulmonary, etc.); or with reference to types of diseases (chronic non-infectious or acute infectious). In practice, therefore, most of these approaches to understanding biological determinants of health must be integrated as health, or lack thereof, is seldom due to any one factor.

The determinants mentioned above could be called "internal biologic determinants" in that they are part and parcel of each human individual, and in that they deal largely with the "inner" workings of each person's genetic individuality. A second set of factors might be called environmental/ecological determinants and are "external biologic". Marston Bates, an entomologist famous for his work on Yellow Fever and malaria, referred to these as "skin-in" and "skin-out" biology (Bates, 1960). This approach attempts to include factors/determinants much more broadly than is generally considered under the rubric of "environmental health". Environmental health *generally* focuses on aspects dealing with water and sanitation, possibly nutrition, and physiological responses to heat/cold, responses to environmental pollution and other physio-chemical aspects of the environment. In some instances it might include control of soil parasitic infections or control of vector-borne infections (arthropod, rodent, snail), but, if so, it seldom treats the interrelations between vector, host and parasite, or the evolution and ecological aspects of the disease cycles involved. A generation ago this ecologic approach was well described in the volume edited by Jacques May (1961) entitled *Studies in Disease Ecology* and that of Rene Dubos, *Man Adapting* (1965), both reviewing the ecology, at that time, of certain vector-borne diseases (malaria, filariasis, schistosomiasis, dengue, etc,), other parasitic diseases (e.g. hydatidosis/echinococcosis) as well as other communicable diseases such as smallpox and measles.

In this paper we will look at the evolution and ongoing changes in the transmission cycles of a number of vector-borne diseases and their "inter-species" relations by examining:

2. **Evolutionary adaptations** between certain hosts, parasites and their vectors;
3. **Patterns of migration**, human, vectors, pathogens and resistance;
4. **Domestication of livestock and human cohabitation**;
5. **Ecological modifications** and the impact of biodiversity on transmission control of vector-borne diseases.

2. Evolutionary Adaptations

Potential Adaptations
- morphologic
- physio-genetic
- behavioral

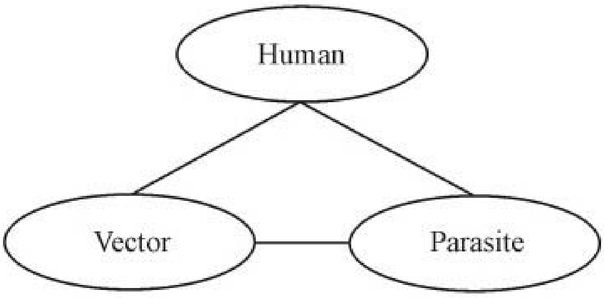

Figure 1: Diagrammatic representation of a vector-borne disease cycle

Figure 1 illustrates a simple, diagrammatic representation of a vector-borne disease cycle, linking: 1) the human "host", 2) the vector, and 3) the pathogen (virus, parasite, etc.) Additional, "secondary" hosts and vectors are possible, complicating but not changing the basic components and their relationships. Each of these three components undergoes changes over time influencing the spread and intensity of the disease as well as the efficacy of measures used to control the disease. Some of these changes (e.g. those that may result in *morphological changes* resulting in speciation or development of new strains) occur over long periods of time and are not generally detectable in the few hundred years of human observation available to us. However, the number of "species complexes" or sets of "sibling species" identified among arthropod vectors (e.g. *Anopheles gambiae*, the major malaria vector in Africa), as well as the numerous species of *Plasmodium* and *Leishmania* and the abundant strains of arboviruses (e.g. dengue) attest that this evolutionary process is dynamic, especially at the *physio-genetic level* where it is much more rapid and more easily observed. For example, over the past 50 years the development of parasite resistance to drugs (e.g. anti-malarials) as well as vector resistance to insecticides are not only well known but pose major obstacles to efforts to control the disease(s) in question, especially malaria. The evolution of the morphologically similar, but genetically distinct "sibling species" mentioned above is also reflected in the divergent vectorial competence and/or vectorial capacity of these closely related species, as well as their different responses to insecticides. Although man and other mammalian hosts develop an individually acquired immunity to various pathogens, this protection is not equivalent to the rapid and widespread insect and pathogen resistance to insecticides and drugs respectively. In various locations man demonstrates defense mechanisms such as sickle cell (HbS) and other hemoglobinoses providing some protection against malaria, but these are not recent acquisitions. In general, adaptations resulting in morphologic change are slow throughout the man-vector-parasite relationship, but probably slowest in the host (i.e., human). On the other hand, physio-genetic adaptations may occur most quickly in the vector and parasite components.

The level at which the human host is most labile is the behavioral. Through urbanization and agricultural pursuits and exploitation of natural resources (e.g. mining, deforestation, etc.) man has managed to modify the face of the earth at an increasingly rapid rate, not only through increasing population levels but also to satisfy *per capita* demands. To a great extent this "cultural evolution" (which appears to be a human trademark) has provided certain vectors with increased suitable habitats. The spread of malaria in the Amazonian basin following on the heels of resource extraction and demands for agricultural expansion is one of the best examples of the past 40 years. In the Peruvian Amazon, areas with 3% of the national population have >50% of the malaria reported in the country: and it is mostly falciparum malaria, the most dangerous form. Deforestation has resulted in producing habitats most suitable for *An. darlingi*, the most effective malaria vector in South America. Elsewhere, malaria vectors such as *An. stephensi* have adapted to urban conditions, as has *Aedes aegypti*, the major vector of dengue (and yellow fever) wherever it occurs. Vector behavioral changes in biting and breeding habits often respond rapidly to human environmental changes, resulting in increased vector populations and more intensive man-vector contacts, resulting in increased disease transmission.

Thus, although evolutionary changes at the morphologic level may be slow on all components (vectors-parasites-humans) of vector-borne disease cycles, and vectors and parasites may evolve more rapidly at the physio-genetic level, human behavioral (= environmental) changes certainly provide the opportunities and conditions for concurrent vector and parasite adaptations resulting in the spread and intensity of disease transmission. The development of resistance to drugs and insecticides also hinders currently available control measures.

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Biographical Sketch

Andrew A. Arata, Ph.D. (b. 1932, New Orleans, LA, USA), until his retirement in 1999 was Senior Tropical Disease Specialist with USAID's Environmental Health and the earlier Vector Biology and Control projects in Arlington, VA. He held concurrent positions as Clinical Professor of International Health and Adjunct Professor of Tropical Medicine, Tulane School of Public Health and Tropical Medicine. He has over 35 years’ experience consulting, managing projects, teaching and conducting research in tropical diseases and vector control. From 1968 to 1985, he was Scientist/Ecologist for WHO and PAHO in Geneva, Venezuela and Mexico. Dr. Arata is a biologist by training, receiving his doctorate from the University of Florida (USA) in 1962. He continues serving as a consultant to USAID and World Bank projects involving vector-borne diseases and their control.