DISEASE IN HUMAN EVOLUTION: THE RE-EMERGENCE OF INFECTIOUS DISEASE IN THE THIRD EPIDEMIOLOGICAL TRANSITION

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For millions of years, humans and their ancestors suffered from diseases -- both the kind caused by infectious pathogens (e.g., bacteria, viruses, parasites) and the kind caused by our own bodies as they age and degenerate. Over this long period, humans constantly created new ways of living and eating, and actual physical or genetic changes evolved to minimize the effects of these diseases. From the point of view of a bacteria or virus, however, any shift in the physical makeup or behavior of its human host represents not only an obstacle but also a challenge to be overcome. As a result, new diseases emerged with each major change in the human way of life.

For nearly four million years, humans lived in widely dispersed, nomadic, small populations that minimized the effect of infectious diseases. With the agricultural revolution about 10,000 years ago, increasing sedentism and larger population groupings resulted in the first epidemiological transition in which infectious and nutritional diseases increased. Within the last century, with the advent of public health measures, improved nutrition and medicine, some populations in developed nations underwent a second epidemiological transition. During this transition, infectious diseases declined and non-infectious, chronic diseases, and degenerative conditions increased. Today, with the increasing use of antibiotics, we are facing a third epidemiological transition, a reemergence of infectious disease, with pathogens that are antibiotic-resistant and have the potential to be transmitted on a global scale. Populations that experienced and those that never experienced the second epidemiological transition are both increasingly exposed to antibiotic-resistant pathogens.

"Emerging" pathogens are seen as new diseases, discovered when they have an impact on our adaptation or survival. Even when we take a more holistic ecological perspective, it is often limited to a position that considers emerging disease as the result of environmental changes that are only relevant to the present situation as it affects humans here and now. This article argues that the emergence of new diseases has been the human pattern since the origin of the hominids and accelerated with the shift to agriculture 10,000 years ago.

Paleolithic Baseline

For most of their 4,000,000 years of evolutionary history, human populations lived in small, sparsely settled groups. Population size and density remained low throughout the Paleolithic. Fertility and mortality rates in small gathering-hunting populations would have to have been balanced for the population size to remain small.

Demographic factors creating this stability are still a matter of discussion. Some demographers argue that gatherer-hunters were at their maximum natural fertility, balanced by high mortality. Armelagos, Goodman and Jacobs (1991) argue, however, that gatherer-hunters maintained a stable population with controlled moderate fertility balanced by moderate mortality.

The demographic changes following the Neolithic may provide insights into the case for population stability controlled by moderate fertility and mortality during the Paleolithic. Following the Neolithic revolution, a dramatic increase in population size and density occurred. It was thought that the Neolithic economy generated food surpluses that led to a better nourished and healthier population with a reduced rate of mortality. Since populations were at their natural maximum fertility, there would have been a rapid increase in population size.

The empirical evidence suggests an alternative scenario in the shift from gathering and hunting to agriculture. The picture suggests a much bleaker picture of health. Instead of experiencing improved health, there is evidence of a substantial increase in infectious and nutritional disease (Cohen and Armelagos 1984). A paradox emerges if the traditionally accepted models of Paleolithic fertility and mortality are correct. How can a population experiencing maximum fertility during the Paleolithic respond with exponential growth in population when their health is deteriorating?

A consideration of the disease ecology of contemporary gatherer-hunters provides insights into the types of disease that probably affected our gatherer-hunter ancestors. Polgar (1964) suggests that gatherer-hunters had two types of disease to contend with in their adaptation to their environment. One class of disease would be those organisms that had adapted to prehominid ancestors and persisted with them as they evolved into hominids. Head and body lice (Pediculus humanus), pinworms, yaws, and possibly malaria would be included in this group. Cockburn (1967) adds to this list most of the internal protozoa found in modern humans and such bacteria as salmonella, typhi, and staphylococci.

The second class of diseases are the zoonotic, which have non-human animals as their primary host and only incidentally infect humans. Humans can be infected by zoonoses through insect bites, by preparation and consumption of contaminated flesh, and from wounds inflicted by animals. Sleeping sickness, tetanus, scrub typhus, relapsing fever, trichinosis, tularemia, avian or ichthyic tuberculosis, leptospirosis, and schistosomiasis are among the zoonotic diseases that could have afflicted earlier gatherer-hunters (Cockburn 1971).

Although early human populations were too small to support endemic (constantly present) pathogens, they maintained some kind of relationships with the vectors that would later serve to perpetuate such human host-specific diseases as yellow fever and louse-borne relapsing fever. Certain lice were ectoparasites as early as the Oligocene, and the prehumans of the early Pliocene probably suffered from malaria, since the Anopheles (mosquito) necessary for transmission of the disease evolved by the Miocene era. Frank Livingstone, an anthropological epidemiologist, dismisses, however, the potential of malaria in early hominids except in isolated incidences because of the small population size and an adaptation to the savanna, an environment that would not have included the mosquitoes that carry the malaria plasmodium.

The range of the earliest hominids was probably restricted to the tropical savanna. This would have limited the pathogens that were potential disease agents. During the course of human evolution, the habitat expanded gradually into the temperate and eventually the tundra zones. Hominids, according to epidemiologist Frank Lambrecht, would have avoided large areas of the African landscape because of tsetse flies and thus avoided the trypanosomes they carried. He also argues that the evolution of the human species and its expansion into new ecological niches would have led to a change in the pattern of trypanosome infection. While this list of diseases that may have plagued our gathering-hunting ancestors is informative, those diseases that would have been absent are also of interest. The contagious community diseases such as influenza, measles, mumps, and smallpox would have been missing. There probably would have been few viruses infecting these early hominids, although Cockburn (1967) disagrees and suggests that the viral diseases found in non-human primates would have been easily transmitted to hominids.

The First Epidemiological Transition:

Disease in Agricultural Populations

The reliance on primary food production (agriculture) increased the incidence and the impact of disease. Sedentism, an important feature of agricultural adaptation, conceivably increased parasitic disease spread by contact with human waste. In gathering-hunting groups, the frequent movement of the base camp and frequent forays away from the base camp by men and women would decrease their contact with human wastes. In sedentary populations, the proximity of habitation area and waste deposit sites to the water supply is a source of contamination. While sedentarism did occur prior to the Neolithic period in those areas with abundant resources, once there was the shift to agriculture, sedentary living was necessary.

The domestication of animals provided a steady supply of vectors and greater exposure to zoonotic diseases. The zoonotic infections most likely increased because of domesticated animals, such as goats, sheep, cattle, pigs, and fowl, as well as the unwanted domestic animals such as rodents and sparrows, which developed (Polgar 1964) permanent habitats in and around human dwellings. Products of domesticated animals such as milk, hair, and skin, as well as the dust raised by the animals, could transmit anthrax, Q fever, brucellosis, and tuberculosis. Breaking the sod during cultivation exposed workers to insect bites and diseases such as scrub typhus. Frank Livingstone showed that slash-and-burn agriculture in west Africa exposed populations to Anopheles gambiae, a mosquito which is the vector for Plasmodium falciparum, which causes malaria. Agricultural practices also create pools of water, expanding the potential breeding sites for mosquitos. The combination of disruptive environmental farming practices and the presence of domestic animals also increased human contact with arthropod (insect) vectors carrying yellow fever, trypanosomiasis, and filariasis, which then developed a preference for human blood. Some disease vectors developed dependent relationships with human habitats, the best example of which is Aedes aegypti (vector for yellow fever and dengue), which breeds in stagnant pools of water in open containers. Various agricultural practices increased contact with non-vector parasites. Irrigation brought contact with schistosomal cercariae, and the use of feces as fertilizer caused infection from intestinal flukes (Cockburn 1971).

The shift to agriculture led to a change in ecology; this resulted in diseases not frequently encountered by forager populations. The shift from a varied, well-balanced diet to one which contained fewer types of food sometimes resulted in dietary deficiencies. Food was stored in large quantities and widely distributed, probably resulting in outbreaks of food poisoning. Intensive agricultural practices among the prehistoric Nubians resulted in iron deficiency anemia as did the reliance on cereal grain, weaning practices, and parasitic infestation. The combination of a complex society, increasing divisions of class, epidemic disease, and dietary insufficiencies no doubt added mental stress to the list of illnesses.

Disease in Urban Populations

The development of urban centers is a recent development in human history. In the Near East, cities as large as 50,000 people were established by 3000 BC. In the New World, large urban settlements were in existence by AD 600. Settlements of this size increase the already difficult problem of removing human wastes and delivering uncontaminated water to the people. Cholera, which is transmitted by contaminated water, was a potential problem. Diseases such as typhus (carried by lice) and the plague bacillus (transmitted by fleas or by the respiratory route) could be spread from person to person. Viral diseases such as measles, mumps, chicken pox, and smallpox could be spread in a similar fashion. Due to urbanization, populations for the first time were large enough to maintain disease in an endemic form. Aidan Cockburn, a paleopathologist, estimated that populations of one million would be necessary to maintain measles as an endemic disease. What was an endemic disease in one population could be the source of a serious epidemic (affecting a large number of people at the same time) disease in another group. Cross-continental trade and travel resulted in intense epidemics (McNeill 1976). The Black Death, resulting from a new pathogen, took its toll in Europe in the 1300s; this epidemic eliminated at least a quarter of the European population (approximately 25 million people).

The period of urban development can also be characterized by the exploration and expansion of populations into new areas that resulted in the introduction of novel diseases to groups that had little resistance to them (McNeill 1976). For example, the exploration of the New World may have been the source of the treponemal infection (syphilis) that was transmitted to the Old World. This New World infection was endemic and not sexually transmitted. When it was introduced into the Old World, a different mode of disease transmission occurred. The sexual transmission of the treponeme created a different environment for the pathogen, and it resulted in a more severe and acute infection. Furthermore, crowding in the urban centers, changes in sexual practices, such as prostitution, and an increase in sexual promiscuity may have been factors in the venereal transmission of the pathogen.

The process of industrialization, which began a little over 200 years ago, led to an even greater environmental and social transformation. City dwellers were forced to contend with industrial wastes and polluted water and air. Slums that arose in industrial cities became focal points for poverty and the spread of disease. Epidemics of smallpox, typhus, typhoid, diphtheria, measles, and yellow fever in urban settings were well documented. Tuberculosis and respiratory diseases such as pneumonia and bronchitis were even more serious problems, with harsh working situations and crowded living conditions. Urban population centers, with their extremely high mortality, were not able to maintain their population bases by the reproductive capacity of those living in the city. Mortality outstripped fertility, requiring immigration to maintain the size of the population.

The Second Epidemiological Transition: The Rise of Chronic and Degenerative Disease

The second epidemiological transition refers to the shift from acute infectious diseases to chronic non-infectious, degenerative diseases. The increasing prevalence of these chronic diseases is related to an increase in longevity. Cultural advances results in a larger percentage of individuals reaching the oldest age segment of the population. In addition, the technological advances that characterize the second epidemiological transition resulted in an increase in environmental degradation. An interesting characteristic of many of the chronic diseases is their particular prevalence and 'epidemic'-like occurrence in transitional societies, or in those populations undergoing the shift from developing to developed modes of production. In developing countries, many of the chronic diseases associated with the epidemiological transition appear first in members of the upper socioeconomic strata, because of their access to Western products and practices.

With increasing developments in technology, medicine, and science, the germ theory of disease causation developed. While there is some controversy about the role that medicine has played in the decline of some of the infectious diseases, a better understanding of the source of infectious disease exists, and this admittedly has resulted in increasing control over many infectious diseases. The development of immunization resulted in the control of many infections and recently was the primary factor in the eradication of smallpox. In the developed nations, a number of other communicable diseases have diminished in importance. The decrease in infectious disease and the subsequent reduction in infant mortality has resulted in greater life expectancy at birth. In addition, there has been an increase in longevity for adults and this has resulted in an increase in chronic and degenerative diseases.

Many of the diseases of the second epidemiological transition share common etiological factors related to human adaptation, including diet, activity level, mental stress, behavioral practices, and environmental pollution. For example, the industrialization and commercialization of food often results in malnutrition, especially for those societies in "transition" from subsistence forms of food provision to agribusiness. The economic capacity to purchase food that meets nutritional requirements is often not possible. Obesity and high intakes of refined carbohydrates are related to the increasing incidence of heart disease and diabetes. Obesity is considered to be a common form of malnutrition in developed countries and is a direct result of an increasingly sedentary lifestyle in conjunction with steady or increasing caloric intakes.

A unique characteristic of the chronic diseases is their relatively recent appearance in human history as a major cause of morbidity. This is indicative of a strong environmental factor in disease etiology. While biological factors such as genetics are no doubt important in determining who is most likely to succumb to which disease, genetics alone cannot explain the rapid increase in chronic disease. While some of our current chronic diseases such as osteoarthritis were prevalent in early human populations, other more serious degenerative conditions such as cardiovascular disease and carcinoma were much rarer.

The Third Epidemiological Transition

Today, human populations are moving into the third epidemiological transition. There is a reemergence of infectious diseases with multiple antibiotic resistance. Furthermore, this emergence of diseases has a potential for global impact. In a sense, the contemporary transition does not eliminate the possible co-existence of infectious diseases typical of the first epidemiological transition (some 10,000 years ago) in our own time; the World Health Organization (WHO) reports that of the 50,000,000 deaths each year, 17,500,000 are the result of infectious and parasitic disease. WHO reports that 1.7 million have tuberculosis and 30 million people are infected with HIV.

The emergence of infectious disease has been one of the most interesting evolutionary stories of the last decade, and has captured the interest of scientists and the public. The popular media, with the publication of books such as The Hot Zone and movies such as Outbreak, has captured the public' s fascination with emerging diseases as threats to human survival. There is genuine scientific concern about the problem. David Satcher (Director of the Centers for Disease Control in Atlanta, GA) lists 22 diseases that have emerged in the last 22 years, including Rotovirus, Ebola virus, Legionella pneumophila (Legionnaire s Disease), Hantaan Virus (Korean hemorrhagic fever), HTLV I, Staphylococcus toxin, Escherichia coli 0157:h7, HTLV II, HIV, Human Herpes Virus 6, Hepatitis C, and Hantavirus isolates.

The emergence of disease is the result of an interaction of social, demographic, and environmental changes in a global ecology and in the adaptation and genetics of the microbe, influenced by international commerce and travel, technological change, breakdown of public health measures, and microbial adaptation. Ecological changes such as agricultural development projects, dams, deforestation, floods, droughts and climatic changes have resulted in the emergence of diseases such as Argentine hemorrhagic fever, Korean hemorrhagic fever (Hantaan) and Hantavirus pulmonary syndrome. Human demographic behavior has been a factor in the spread of dengue fever, and the source for the introduction and spread of HIV and other sexually transmitted diseases.

The engine that is driving the reemergence of many of the diseases is ecological change that brings humans into contact with pathogens. Except for the Brazilian pururic fever, which may represent a new strain of Haemophilus influenzae, biotype aegyptius, most of the emerging diseases are of cultural origin. The development of antibiotic resistance in any pathogen is the result of medical and agricultural practices. The indiscriminate and inappropriate use of antibiotics in medicine has resulted in hospitals that are the source of multi-drug resistant strains of bacteria that infect a large number of patients. Agricultural use in which animal feed is supplemented with sub-therapeutic doses of antibiotics has risen dramatically in the last half century. In 1954, 500,000 pounds of antibiotics were produced in the United States; today, 40,000,000 pounds are produced annually.

Conclusion

Recently, much attention has focused on the detrimental effects of industrialization on the international environment, including water, land, and atmosphere. Massive industrial production of commodities has caused pollution. Increasingly there is concern over the health implications of contaminated water supplies, over-use of pesticides in commercialized agriculture, atmospheric chemicals, and the future effects of a depleted ozone layer on human health and food production. At no other time in human history have the changes in the environment been more rapid or so extreme. Increasing incidence of cancer among young people and the increase in respiratory disease has been implicated in these environmental changes.

Anthropogenic impact from technology has been the pattern since Neolithic times. Within the last 300 years, transportation has played a major role in disease patterns by bringing larger segments of humans into contact with the pathogens at an accelerated rate. The emergence of disease in the New World upon contact with Europeans was a consequence of large sailing ships that became a major mode of transportation. Now it is possible for a pathogen to move between continents within a matter of hours. We live in a time where there exists a virtual viral superhighway, bringing people into contact with pathogens that affect our adaptation. The present pattern reflects an evolutionary trend that can be traced to the beginning of primary food production. The scale has changed. The rates of emerging disease and their impact can now affect large segments of the world population at an ever increasing rate, and we need to be increasingly aware of the implications for today s human populations around the globe.

For further reading

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