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Geography, ecology and emerging infectious diseases

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Abstract

Emerging infectious diseases are the focus of increased attention and even alarm in the scholarly and popular literature. The emergence of new diseases and the resurgence of older and previously recognized infectious diseases both in developing and developed country poses challenges for understanding the ecological web of causation, including social, economic, environmental and biological components. This paper is a synthesis of the major characteristics of emerging diseases, in an interdisciplinary context. Political ecology is one framework for analysis that is promising in developing a modified ecology of disease. © 2000 Elsevier Science Ltd. All rights reserved.

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Introduction

An important principle of disease ecology is that population, society and both the physical and biological environments are in dynamic equilibrium. Significant enough stress on this equilibrium can produce cascading effects on any of the aforementioned components. The human-environment relationship, if disturbed enough by major changes in land use, migration, population pressure, or other stressors can show significant maladaptation, as manifested by the appearance or diffusion of new diseases. Much historical work has demonstrated the effects on both Europe and the Americas of the early widespread contact of the European explorers (e.g., Crosby, 1972, 1986; McNeill, 1976; Whitmore, 1991; Denevan, 1992).

Other more contemporary manifestations of disequilibrium include the tremendous increase in the incidence of schistosomiasis following the construction of the Aswan Dam, and the increase in schistosomiasis, malaria and other infectious diseases following the Volta River project in Africa. Examples from other continents include increases in malaria following land clearance for rubber plantations in Malaysia, increases in vectored diseases with the construction of transportation routes in Brazil, and the appearance of Lyme disease in the United States following the reforestation of peri-urban areas in the northeast. The reforestation occurred as previously agricultural areas were brought into residential and even commercial usage, thus increasing the proximity of humans and deer. Deer are important in the transmission of Lyme disease, serving as the main link between the rodent reservoirs of Lyme disease and humans. The increased proximity also increased the contact between people and deer ticks. Since deer are edge dwellers, transmission of disease between the animal reservoir and humans via the deer ticks increased by changes in land use patterns.

Despite the human toll taken by the AIDS pandemic, the major lesson to be learned from the pandemic is that the assumption that infectious diseases

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are a phenomenon of the past, largely restricted as major health threats to developing countries, and that "international health" consists of the study of problem of developing countries, are all erroneous. HIV/AIDS is prototypical of emerging and resurgent infectious diseases, which the medical and public health communities now acknowledge to be a hitherto unappreciated reality and a severe threat to worldwide public health. Many geographers have analyzed the spatial and ecological patterns and issues of HIV/AIDS (e.g., Shannon and Pyle, 1989; Shannon et al., 1990; Gould, 1993).

Human ecology and emerging infectious diseases

The social sciences consider scales from the individual to the global. Human ecology is the study of how individuals and groups interact with one another. This is best appreciated within the context of the natural environment as well. Disease ecology, so basic to medical geography and epidemiology, is also a powerful approach to understanding disease emergence and resurgence (May, 1958; Meade, 1976). Many changes that are relevant to understanding emerging and resurgent diseases are due to political and economic power at a variety of scales, ranging from the transnational down to the household and individual levels. Some, or even much of this power is influenced by which groups control decisions over land use. This, in turn, influences the relationships of people and the environment. This is a basic principle of political ecology which has received some attention in the geography of health and disease (Mayer, 1996), and has been used increasingly in understanding the consequences of human–environment interactions. The political ecologic approach is used at the end of this paper as an interpretative framework for disease emergence.

The emergence and resurgence of infectious diseases is as much a matter of social, ecological and geographical change as it is of smaller scale molecular or microbiological phenomena. Indeed, the meaning of disease causation changes when considering it in social and ecological contexts. The germ theory of disease and the doctrine of specific etiology concentrated much attention on the smaller scale, microscopic and submicroscopic scales of disease. Yet, causation can also be expanded to larger scales, and though not refuting the germ theory, by so doing, it adds to our understanding of disease causation.

That there was complacency over the supposed conquest of infectious diseases is, in part, understandable. Improvements in sanitation and nutrition in developed countries in the nineteenth century, the development of antimicrobials and antibiotics by the mid-twentieth century, and the proliferation of vaccines by the mid to late twentieth century led to a spirit of optimism. This diverted funding and training to chronic, apparently non-infectious diseases in most developed countries. The World Health Organization embraced the idea that there could be "Health for All by the Year 2000". This assumed that most nations would already have undergone the "health transition" whereby infectious diseases are displaced by non-infectious diseases as the major causes of mortality and morbidity (Omran, 1971; Garrett, 1996). Moreover, the "Health for All" slogan presupposes that it is possible to eliminate disease as part of the human experience. This is clearly impossible, and estimates are that the human life span is approximately 120 years maximum. Disease has always been present in society and it will remain part of all societies in the future. More salient issues are what types of diseases will be prevalent where, and for how long, and which social and economic groups will bear the burden of which types of disease. The statement in 1969 that it is "time to close the book on infectious diseases, declare the war on pestilence won, and shift national resources to such chronic problems and heart disease" came from none other than the Surgeon General of the United States. Yet, as Morse (1993a, p. 23) argues, "The lesson of AIDS demonstrates that infectious diseases are not a vestige of our premodern past; instead, like disease in general, they are the price we pay for living in the organic world". The general significance of HIV/AIDS was not realized when it first appeared in the Western World. It is interesting in retrospect to note that one of the earliest reports of AIDS (Marx, 1983) termed it a new disease, but did not set it within any context of a general context of "new infectious diseases". This is certainly understandable, since only in retrospect can we realize that the appearance of HIV/AIDS would presage other diseases to come. AIDS was seen in isolation, rather than as an early manifestation of the reappearance of then controlled infectious diseases, or the initial appearance of new infectious diseases. AIDS was the first emerging disease of major threat to public health that was recognized in contemporary history, and its initial emergence was not enough to establish any concern over or identification of a pattern.

With the destruction of complacency comes uncertainty, and it is this uncertainty that we now face as our assumption of the conquest of major infectious diseases is negated. Originally termed "emerging infectious diseases", the new concentration on "emerging and resurgent infectious diseases" and their effects on society have been receiving increased attention worldwide (Garrett, 1994). A clinical focus is important for treatment, and both surveillance and containment are crucial public health measures. However, the disease ecological approach is essential for understanding the emergence of new diseases, the re-emergence of older ones, and their mutual potential for rapid diffusion. Emerging diseases have received only limited attention from geographers, yet they reflect the changing structure of world society, including the globalization of societies, capital, and biotic entities (e.g., Cliff and Haggett, 1995).

The Institute of Medicine of the US National Academy of Sciences convened a meeting in 1992 to develop an understanding of the nature of emerging diseases. The panel examined the causes of disease emergence, surveillance for their detection, and strategies for their containment (Lederberg and Oaks, 1992). It is ironic that the year after the Institute of Medicine released its report, three of the diseases that were considered had significant impact in the United States (Berkelman, 1994). These included an outbreak of *Escherichia coli* 0157:H7 that causes severe diarrhea, and particularly in children, the severe renal complication of hemolytic-uremic syndrome (HUS). This killed several children and was traced to contaminated hamburgers served by one fast food outlet in the Pacific northwest. A second disease was cryptosporidiosis, which caused 420,000 cases of severe gastroenteritis in the Milwaukee area and the hospitalization of 4400 people. It also caused over a dozen deaths, almost all of which were in immunocompromised individuals. The third disease was a new variant of a Hantaan virus, in the Four Corners area of New Mexico, Colorado, Utah and Arizona. This species eventually became labeled the "sin nombre" (without a name) virus. Several local physicians noted similar severe respiratory symptoms, leading to ARDS (acute respiratory distress syndrome) in several temporally and spatially clustered Navajo patients, which alerted them to the possibility that a cluster of an unknown disease had emerged. Both the Epidemiology Intelligence Service of the CDCP, and the State of Utah's Health Department were mobilized for rapid epidemiologic investigation. Tissue samples of the dead patients were used for molecular typing.

In 1994, the Centers for Disease Control and Prevention published a report which was a prevention strategy for infectious diseases for the United States (Centers for Disease Control, 1994), and this document gave official recognition to the necessity of acknowledging that infectious diseases are a major threat to public health. Prevention must be of vital concern to public health agencies. An interagency conference on emerging and re-emerging infectious diseases was concerned to a greater degree with international surveillance and prevention (Report of the NSTC Committee, 1994).

The definitions of "emerging and resurgent diseases" may, by now, be intuitively meaningful, yet many of the formal definitions are flawed. For example, according to the Institute of Medicine's report (Lederberg and Oaks, 1992, p. 34) "Emerging infectious diseases are clinically distinct conditions whose incidence in humans has increased". This fits the criteria of any epidemic. The basic definition of an epidemic is when the incidence of a disease, and particularly of an infectious disease, is much greater than expected under usual conditions. Much more helpful is Morse's (1993b) specification of emerging viruses, which can be expanded to other pathogens: "We may use the term 'emerging viruses' to refer to viruses that either have newly appeared in the population or are rapidly expanding their range, with a corresponding increase in cases of disease (p. 10)". This echoes many other definitions, and leads to the generalization that major social and geographical trends, such as greater national and international connectivity, mobility, social interaction patterns, land use change, and changing cultural ecologies make it likely that new or previously unrecognized diseases will be discovered. Older ones, once thought to be extinct, or not major public health problems, may reappear (Wilson, 1994). One of the major challenges of research in emerging diseases is the meticulous documentation of empirical examples of human-biotic-interactions and their relationships to infectious diseases.

Another aspect in the definition of emergence is also troublesome. What may be an emerging disease in one society may have been present, at low or high levels, in other societies, for varying lengths in time. For example, the northward movement of dengue fever makes it a disease that is emerging in the United States. However, it is hardly newly emerging in the tropical countries of Latin America and the Caribbean, where it has been endemic for decades. Conversely, the appearance of chronic diseases such as ischemic heart disease and cancers in developing countries may reflect emergence to the populations of those countries, but these diseases have been highly endemic in developed countries for centuries. Thus, there is a distinction between those diseases that are introduced into new areas through diffusion and those that arise de novo.

Microbial traffic

There are several ways in which new pathogens can appear in a human population in a new region. Many of these are encompassed in the concept of "viral traffic", as conceived by Morse (1993b). The concept is not applicable only to newly emerging diseases in the contemporary era. It may be applied retrospectively to phenomena as diverse as the appearance of syphilis in new areas during the period of the conquistadors and the transspecies transfer of viral and other pathogens, such as trypanosomiasis, yellow fever, and, as is very likely, AIDS.

Though originally developed in the context of viruses (Morse is a virologist), the term "traffic" has broader implications and is more appropriately labeled "microbial traffic", of which viruses are only one type of pathogen. The concept of "traffic" inherently has geographical implications, for it implies movement and interaction, and certainly should not be limited to viruses, though these pathogens pose the most daunting threats to human health.

The appearance of new pathogens in populations can therefore be due to the following factors:

1. Cross-species transfer.
2. Spatial diffusion.
3. Pathogenic evolution, or change in the structure and immunogenicity of earlier pathogens.
4. The new description of a pathogen that had been present in humans for years, but which is "newly recognized".
5. Changes in the human–environment relationship. Morse did not mention this important component and it is inherently geographical.

Cross species transfer

Of these mechanisms, cross-species transfer and spatial diffusion appear to be most important. The pathogens responsible for a multitude of infectious diseases can be transferred to and from humans and other mammals. These include influenza, which can be highly prevalent in swine and avian populations; yellow fever, which is present in South American and African monkeys, and, quite likely, HIV. There are two forms of HIV in Africa. HIV-1 is found mostly in East Africa, and is clinically more serious than its West African variant, HIV-2. RNA fingerprinting techniques show remarkable homologies between HIV-2 and the simian immunodeficiency virus (SIV) in mangabee monkeys. Considering this evidence, it is quite reasonable to conclude that there has been a cross-species transfer of the pathogen, most likely from the mangabees to humans. The RNA techniques are so specific that misidentification of viral species is nearly impossible and SIV and HIV-2 differ from one another only minutely in their nucleotide sequence. The mechanisms of cross-species transfer are more a matter of speculation than of concrete proof.

Another example of cross-species transfer is that of bovine spongiform encephalopathy (BSE) which is caused by a prion, and the development of new variant Creutzfeldt–Jacob disease (nvCJD). Prions lack nucleic acids, and are essentially protein templates for their own reproduction. In the popular press, this is known as "mad cow disease" and there is at least one popular book that gives a fine description of prions and the logic in concluding that BSE caused nvCJD (Rhodes, 1997). BSE first came to the attention of the popular press in April 1996, when there was a statistically meaningful temporal cluster of this very rare degenerative neurological disease in the UK. There is a consensus, but not a universal agreement among scientists, that the appearance of nvCJD was due to the consumption of infected beef. Most of the cases have been in the UK, and banning British beef from the EU countries became a major political issue.

In December, 1997, the US government banned the import of British beef and sheep products. As of 1994, no nvCJD cases had been detected in the United States. However, because of the high mortality and disability associated with the disease, and the weight of the evidence linking BSE with nvCJD, it seems reasonable to have imposed an embargo on importation.

Recent concerns over some of the tropical hemorrhagic fevers serve to illustrate the potential importance of cross-species transfer. For example, the recent outbreak of Ebola hemorrhagic fever in May, 1995 in Kikwit, Zaire (now named The Congo) posed a serious question and remained a mystery: why did the disease, which had been recognized and described two decades earlier, make a sudden reappearance? This reappearance was as deadly as its original appearance in the same area of the world. The mode of transmission seemed to be clear, since the highest risk groups for transmission were either health care workers who had had documented contact with the secretions of patients, family members who had contact with infectives either prior to the onset of symptoms, prior to hospitalization, or family caretakers. There were and are many mysteries that surround this disease. Why did it make its appearance in Kikwit when it did? What social and human–environment interactions provided the conditions that were appropriate for its development and spread? It is equally mysterious that there is no known natural reservoir for the Ebola Virus. In the 1996 outbreak of Ebola-Zaire in Gabon, almost all of the affected people shared the same dead chimpanzee for food. Chimpanzees in this region are predators of soota-mangabeys. This was the single epidemiological factor that united these cases. Research is still ongoing and there is no definitive or singular animal reservoir that has been identified for Ebola. Teams of zoologists and entomologists were dispatched by numerous agencies from several countries shortly after the outbreak in Zaire waned to try to identify definitive hosts, yet few definite conclusions have been learned from this. The interesting footnote to this epidemic was described earlier, where the common risk factor in the 1996 outbreak of Ebola in Gabon was the consumption of meat from apparently infected monkeys.

Spatial diffusion

Spatial diffusion has, of course, been of tremendous interest to geographers and epidemiologists for centuries. Recent changes in travel patterns have altered the human ecology of infectious disease. A well-known characteristic of contemporary society is the increasing speed with which individuals and transportation vehicles traverse the earth. This is illustrated by the diffusion of new influenza strains, as discussed previously. One estimate is that approximately 1 million people travel internationally each day, and 1 million people travel from developed to developing countries (and vice versa) per week (Garrett, 1996). Thus, if somebody contracts a disease on one continent, it could be transmitted to the population on another continent by the next day.

The rates and patterns of diffusion depend on the mode of transmission. With respiratory viruses, such as influenza, where viral replication takes place on the epithelial cells of the respiratory tract, and then the virus is transmitted via the airborne route, diffusion is rapid. The particular diffusion patterns are determined largely by understanding the origins and destinations of human travellers. Where spatial interaction is more intense, the likelihood of spatial diffusion is greater. This is particularly significant for rapidly diffusing diseases with high attack rates such as influenza. Travel and migration have been established as the main reason for the diffusion of HIV/AIDS, but the spread of AIDS has been much slower than that of influenza, since transmission is more difficult, and requires participation in specific behaviors (Quinn, 1995). Moreover, while influenza, and most other respiratory diseases have short latency periods that are frequently a matter of a few days, the latency period for AIDS can be over six months.

Pathogenic evolution

Pathogens can mutate easily to produce new strains, to which people lack immunity. The main reason for the ease of mutation is that these pathogens are small and have relatively simple genetic (RNA and DNA) structures. Minor changes in the amino acid sequences of these nucleotides produce organisms that can cause severe disease in susceptible populations. Because of the simplicity of their DNA or RNA sequences, viruses are particularly subject to mutation, with potentially major consequences for human health. Recently developed techniques in molecular biology allow the specific identification of the DNA and RNA sequences. While much mutation may develop due to antimicrobial resistance, as discussed subsequently, some mutations are purely random, yet they pose major threats to health. Minor changes in the structure of the genetic material thwart specific immune responses. As with most phenomena that are repetitive, minor "mistakes" may have major ramifications. Recurrent events occasionally have random results, and pathogenic replications are no exception. Viruses, and to a lesser extent, larger organisms such as bacteria are particularly prone to random mutations because of the sheer simplicity of their genetic structures.

Genetic shift and genetic drift are responsible for the regular and almost predictable emergence of new strains of influenza, thought by most infectious disease experts to originate frequently in China because of the chain of contagion from ducks to domesticated swine (Kida et al., 1988; Betts, 1996). Genetic changes occur within the swine population that are then communicated both to the avian and human populations, resulting in new outbreaks of influenza among susceptible, non-immune humans. Since immunity is very specific for a particular configuration of the surface antigens on the influenza virus, anybody who has not been vaccinated against a particular strain, or who has not gained immunity through actual exposure to the specific viral strain, is highly susceptible to each new variant of influenza.

The geographical implications of genetic change are important. If changes, however minor, in the genetic structure of a microbe occur randomly, they also occur in random places. However, these newly mutated pathogens travel with the people who carry them. Thus, the potential for spread of random occurrences is great, particularly when transportation is readily available and human spatial interaction is common. The significance of this will be further illustrated when antimicrobial resistance is discussed subsequently.

This mechanism of transfer may either be due to viral evolution, or to new interactions between human activities and disease pathogens. The former is important, particularly in the case of viruses. In summary, as Morse (1993a, p. 27) writes, "the seemingly insoluble problem of viral origins thus reduced to a more manageable... question of viral traffic, and attacking the problem includes better understanding and appreciating the viruses that already exist in nature, including some viruses not yet discovered".

How does a recently mutated virus or other pathogen become established in human populations? The answer is based in the disease ecological principle that for an infectious disease to occur, there must be coincidence in time and space of agent and host. Thus, humans must come into contact with infectious agents that have either newly evolved, or have been introduced to new areas. Either one of these should be considered to be an element of viral traffic.

Newly recognized diseases

Newly recognized pathogens do not present a major conceptual problem. They are unrecognized for several reasons. This is either because the affected population lacks the technological capacity to identify the pathogen or the conceptual framework to correctly attribute a syndrome to a specific disease. One example of this is Legionnaire's disease (legionellosis) which was thought to have constituted a new form of pneumonia when it struck the American Legion convention in Philadelphia in 1976. It was subsequently realized, however, based on serologic tests of previous blood samples from other outbreaks of mysterious pneumonias, that Legionnaire's disease was not a new disease at all, but was a newly recognized disease.

One of the reasons for the new recognition of a disease stems from the difference between a syndrome and a disease. A syndrome consists of a cluster of symptoms (and even the word "symptom" implies something subjective) without having any notion of the underlying causal relationships. A disease is a more systematic biological concept of cause and effect: a set of symptoms that are subjective, signs that are objective, and an assumption of a unifactorial or multifactorial cause or set of causes. Since syndromes and even diseases can resemble one another to the point of appearing, on the surface, as being identical, an apparently emergent disease may simply be newly recognized. The difference between new recognition and actual emergence may even have implications for treatment or therapy.

Another reason that previously unrecognized diseases become recognized for the first time is that the systems of disease surveillance and reporting in the United States and elsewhere are inadequate. It makes recognition and communication of that recognition all that much more difficult (Lederberg and Oaks, 1992; Centers for Disease Control and Prevention, 1994). Both the Institute of Medicine and the Centers for Disease Control and Prevention have emphasized the need for increasing the resources, using existing and new technologies, to monitor the development of new diseases and to spread that information rapidly. While surveillance systems are being developed for new diseases, their efficacy in reporting and controlling new diseases is largely untested.

Changes in the human–environment relationship

A basic question in disease ecology is how changing human–environment relations and social activities can result in fundamental alterations in the interaction between people, the biological environment, and the broader social and economic context. For example, a new dam built in a tropical area in which malaria and other vectored diseases are present might be expected to cause an increase in the prevalence of vectored diseases. If the affected upstream water is endemic for schistosomiasis, onchocerciasis and water-borne diseases, the formation of a lake will similarly increase the prevalence of those diseases. This is particularly so in the absence of significant changes in human behavior toward the water and its immediate proximity.

One of the most elegant schemata for understanding the whole ecology of disease emergence is contained in the report by Lederberg and Oaks (1992). Economic and social causes of disease emergence — changes in land use, human occupation and activity, urbanization — are integrated with biological factors in emergence such as mutation, genetic factors, and changes in the zoonotic pool. These then affect both human and animal hosts, as well as vectors. Knowledge of patterns of human movement and transportation are essential in understanding patterns of emergence and all of these are integrated into the particular forms of social organization in society. The patterns are complex, and the ecology of the intersecting elements is difficult to understand or represent in any simple scheme.

This is the case with Lyme disease, caused by the spirochete, *Borrelia burgdorferi*. The story of this bacterial disease is familiar and has been described elsewhere on numerous occasions. When clusters of the disease were first discovered in and around Old Lyme, CT, and when the agent was identified, some authorities suggested that it was a new disease. However, it had been present for many years in Europe and Scandinavia, and was labeled as erythema chronicum migrans, because of its characteristic ringlike rash, which expands radially.

Lyme disease is the most prevalent vectored disease in the United States. The chain of events that have led to the emergence and recognition of Lyme disease in New England is complex. To understand it, one must understand the population, settlement, and transportation geographies of these areas, both at present and historically; the political economy of land development; the natural ecology of the areas, and their regional entomologies and zoogeographies. Following European colonization, forests were cleared by the colonial settlers for agricultural land use in the 18th and 19th centuries. Cronon (1983) has demonstrated that both the European colonials and the Amerindians both prior to and contemporaneous with the Europeans had left their imprint on the landscape, to the point that it is meaningless to refer to the forest as "virgin".

After the development of commercial agriculture in New England, the 19th century was a period of westward agricultural displacement because of the competitive pressures for residential land use. Supply and demand increased land values, and agriculture simply could not compete with other uses. In addition, with the westward movement of population, and with the development of commercial freight transportation, there was more of a demand for agricultural land farther to the west. Advances in transportation technology made the development of suburban communities possible at relatively great distances from Central Business Districts. These communities were principally commuter communities for central cities. More recently, these communities have experienced further population growth. Much of this growth has been on the outskirts of the already developed suburbs, and has required deforestation and land development for tract housing. The forest surrounding the newer suburban communities tends to be second growth forest This has created habitats that are conducive to deer, and they abound in areas proximal to newer residential developments. This is significant since the vectors of East Coast Lyme disease are deer ticks which are transported by white tailed deer as well as by certain avian species (Smith et al., 1996).

There is a lively debate among entomologists over whether there is any species differentiation between the deer ticks in the northeastern and southeastern United States. Rich et al. (1995) have used molecular sequencing techniques and conclude that it is the diffusion of what used to be called the "northern deer tick" (*Ixodes dammini*) rather than the "southern deer tick" *(Ixodes scapularis*) which transmits Lyme disease in the South. Indeed, they conclude that *I. dammini* have diffused to the south and question the existence of *I. scapularis*.

The ecological conditions of suburbanization and reforestation, with the concurrent existence of deer and the deer ticks, are favorable for the transmission of Lyme disease. Detailed epidemiologic studies established the rapidity of Lyme disease's becoming a highly prevalent disease both on island off the New England coast and on the mainland (e.g., Lastavica et al., 1989; Coyle, 1993; Ginsberg, 1993). Though Lyme disease is fairly well understood by bacteriologists, entomologists and zoogeographers, it has not been studied in depth by social scientists or medical geographers, who can synthesize both the biological and social causes and effects of Lyme disease.

The real estate industry and land developers have been inextricably involved in the complex nature of land use change. An unintended consequence of real estate development has been an increasing incidence and prevalence of Lyme disease. Of course, the real estate industry also acts in response to popular demands for spacious housing on large lots. The real estate industry, though deeply involved in the social creation of Lyme disease, has not had any nefarious intentions of propagating Lyme disease. Indeed, a testable hypothesis is that people may take the probability of developing Lyme disease into consideration in their residential choices.

Consistent with the major lesson of disease ecology, wherein agent and host must come into contact at the same time, the incidence and prevalence of Lyme disease have increased. It would, however, be reductionism to identify only the pathogen, or the disease cycle, as the "cause" of Lyme disease, though this may be the case in a purely biological sense. True understanding of this and other diseases, however, is rarely restricted to pure biology, and it is very obvious how transportation, land development, land developers and population pressures are as much causes of Lyme disease as are the spirochetes which cause Lyme disease in a more purely biological sense.

Antimicrobial resistance

The development of antimicrobial-resistant agents is as serious a threat, and perhaps more of a threat, to the population in developed countries than are some of the more exotic agents mentioned above. Tuberculosis is the infectious disease that is responsible for the greatest number of deaths worldwide, yet most of these deaths are in developing countries that lack the resources for adequate drug treatment. In the United States and elsewhere, the development of multidrug-resistant TB (MDRTB) threatens efforts to minimize the impact of this disease. Though the prevalence of TB has been declining in the United States in recent years, certain pockets of population are particularly susceptible to some very serious forms of the disease. There are a limited number of antimicrobials available in the treatment of TB, yet the intersection of itinerant populations, homelessness, poverty and migration provide a challenge for TB control. Drug protocols in patents whose susceptibility to active TB requires the use of a minimum of two medications and up to four medications on a daily basis for at least six months provides a formidable challenge. If they do not complete their medication regimens, the environment is creative for the selective breeding of drug resistant organisms. Should the individual develop a form of TB that is then resistant to known drugs, this airborne disease may be easily communicated to others, and it is a sobering scenario that the medical community may then lack the appropriate antimicrobials for treatment and prophylaxis of TB.

The origins of the resistant forms of TB are social and are not merely medical. In countries where poverty and homelessness do not present the severe problems that they do in the United States, drug resistant TB is not a major concern. MDRTB is mostly a problem of the large Eastern and midwestern urban areas: areas where the social challenges of poverty are particularly severe. It is quite reasonable to expect, though, that MDRTB will not remain confined to the eastern US and will become a severe problem for the inner city urban populations of the whole country. Multiple drug resistant TB, which is most prevalent in homeless and poor populations, is thus caused just as much by underlying social conditions as it is by the bacillus itself. One recent study, for example, found that nearly 50% of those people enrolled in a tuberculosis treatment program in New York City adhered to the program and many people dropped out and even disappeared into the vortex of impoverishment and homelessness (Pablos-Mendez et al., 1997). In these same neighborhoods, conditions of powerlessness, homelessness, social deprivation, and inadequate funding of public health infrastructures also have a negative impact on local health. This is as important in understanding the emergence of MDRTB as is the comprehension of the smaller scale biological processes which are of great importance in the pathogenesis of drug resistant TB.

The social bases of MDRTB raise some vexing ethical issues, for there have been many examples of individuals who have been detained against their wills to complete their TB treatments. Detention has been justified by the argument that the interests of society in minimizing the spread of MDRTB are more important than individual autonomy and freedom in extreme circumstances. Patient autonomy, which has been taken as one of the presumptions of medical ethics in the United States, is less important than collective well-being, when it is perceived that the interests of the public would be sufficiently threatened by adhering to individual autonomy.

The ease of transportation is as important in the spread of resistant organisms as in the diffusion of new pathogens. If a resistant organism remains localized, then its effects will also remain localized. However, transportation facilitates the movement of resistant organisms. This develops both from prescribing practices and biological processes such as mutation, but the diffusion itself is from personal travel. Two examples are helpful. Bifani et al. (1996) used DNA sequencing techniques to trace the diffusion of a particular genotype of *Mycobacterium tuberculosis* from New York City to several other states. The diffusion was obviously the result of migration, transportation, or a combination of the two. The significance of this finding was not lost on the authors: "The result of… molecular processes, coupled with dismantling of TB control programs and contemporary social trends [e.g., migration and transportation — added by author] has been dissemination of a cohort of bacteria throughout the most populous city in the United States". The findings of this study also demonstrate that the spread was not limited to New York City alone.

Another example is that, for nearly a decade, the fluouroquinolones appeared to be effective treatments for gonorrhea (caused by *Neisseria gonorrhea*, or more popularly, by gonococci). In the 1990s, however, resistance to the quinolones developed in Asia, principally in the Philippines, and subsequently appeared in Hawaii, Washington State and several other states in the United States. This could only have occurred through travel and migration. The result is that more complicated and more costly drug regimens are required to treat gonorrhea at present. Now, fluoroquinolone resistance has been reported in many other countries (Knapp et al., 1997).

Other organisms have developed degrees of resistance to even newly developed drug protocols. Of great concern are hospital-acquired (nosocomial) infections. Methicillin resistant *Staphylococcus aureus* (MRSA) has been of great concern in institutional settings, since the presence of this organism occurs periodically in epidemic proportions within hospitals. Moreover, time–space clusters of MRSA are pronounced. There are few medications available to treat this frequently lethal bacterium. It is transmitted principally via the nares of hospital workers and of patients and visitors. It tends to concentrate in larger hospitals and in intensive care units, and the most effective strategy for dealing with an epidemic of MRSA is complete isolation of carriers. Vancomycin is usually the only effective antimicrobials against MRSA, yet vancomycin-resistant staphylococci have recently appeared in Japanese hospitals and these organisms may be expected to spread.

Of even greater concern is the more recent development of vancomycin-resistant enterococcus (VRE). For these bacteria (*E. faecalis* and *E. faecium*) vancomycin is the only available medication. When enterococci become resistant, there is simply no available antimicrobial treatment for patients, and supportive care is the only alternative. It, too, occurs in clusters within hospitals and nursing homes and in clusters on a broader geographical scale. The case fatality rate is high.

Drug-resistant forms of communicable disease thus constitute major threats in developed countries, and may ultimately prove to be more serious than the newly discovered more "exotic" diseases such as Ebola, Marburg, and Lassa fever. Rapid surveillance and quick isolation of infected individuals is crucial in the case of MDRTB, MRSA, VRE and other drug-resistant organisms. While the development of contemporary molecular methods of microbial typing allow the description and inference of probable patterns of diffusion, their relationship to the control of the diffusion is less obvious. The elegance of DNA and RNA techniques can identify and specify the exact nature of pathogenic mutation, and geographical analysis can then be joined with molecular biology in an overall project of delimiting the patterns and spread of resistance (e.g., Bifani et al., 1996).

Trade and transportation

As we have already seen, trade and transportation constitute potential bases for the introduction of new diseases into new areas. As such, it is a factor in disease emergence. One estimate is that 1 million people traverse national boundaries each day, and every week, 1 million people travel between developed and developing countries (Garrett, 1996). The various regions of the world are increasingly interdependent. Development theory considers interdependency, regardless of the theoretical framework that is espoused. Interdependency can introduce diseases in several specific ways, all related to diffusion. First, humans may serve as vectors themselves. People travelling from one region to another who may be carrying a communicable disease can introduce that disease into a new region with relative ease. This is particularly so for airborne diseases that are readily transmitted, but also holds, though less dramatically, for vectored diseases, sexually transmitted diseases and nonvectored bloodborne diseases.

Second, transportation vehicles can, themselves, serve as mechanical vectors for the diffusion of diseases or disease vectors. It is well known that one of the vectors of dengue fever, *Aedes albopictus*, was introduced into the United States from Asia via automobile tires on ships coming from Asia. The tires were damp or actually contained pools of water, which provided the vectors with ideal conditions for survival and replication. This has potentially serious consequences for the United States, since the possibility exists that dengue will be introduced into even temperate areas of the country once the vector is present.

Other examples abound wherein the transportation vehicle itself serves as a vector for transmission. The introduction of cholera into the Americas in the most recent outbreak was due to a ship from Asia dumping its bilgewater into the ocean off the coast of Peru. The cholera epidemic in the Americas has been spreading rapidly as a result of this. Thus, over 1.4 million cases of cholera have been reported in the Americas, mostly south of Mexico, and at least 10,000 deaths have been recorded. Commercial transportation was therefore responsible for the reintroduction of cholera, but passenger transportation is now implicated in the further diffusion of the disease in the Americas. Sanchez and Taylor (1997) discuss the example of 75 passengers on a flight of 336 passengers developing cholera after flying from Argentina to Los Angeles. This was because contaminated seafood salad was loaded onto the airliner for a meal during a stop in Lima, Peru.

The proliferation of trade and transportation is the result of economics and political factors, and affects regional development, individual firms and corporations, local economies and the broader society. In a general sense, the "cause" of the diseases that are conveyed via transportation modes is not just biological. The continuing drive for local and regional development is one of the anthropogenic causes of disease, particularly in developing countries, where regional and economic growth can be important determinants of human welfare. The movement of raw materials, commodities, may be motive forces behind regional development, but they can also be responsible for the diffusion of emerging diseases.

At all scales, regional interconnectivity is increasing in much of the world. The causes for this interconnection are complex, and are embedded in the contexts of the various societies that are increasingly intermingled. It is exactly this interconnection, the development of a world tied together through transportation and movement of goods and people, which is responsible for the sometimes apocalyptic visions of global epidemics due to emerging diseases. What these visions do underscore is that it is conceivable for new agents to move rapidly across space and it is equally conceivable for emerging agents to have very high prevalence and case-fatality rates. After all, this is a phenomenon that is not new in history. The European "conquest" of the Americas carried with it great mortality, as documented by geographers, historians, and anthropologists. The influenza pandemic of 1918–1919 killed between 20 and 50 million individuals. The numbers are impossible to confirm because of the lack of the technology or infrastructure for surveillance at that time. It is also impossible to confirm virologically exactly what happened in that pandemic, but it was almost certainly due to antigenic shift and genetic mutation of the influenza virus. This is presently being tested in an expedition, led by a medical geographer, to exhume a number of bodies from a cemetery in northern Norway. The site is ideal since the bodies are well preserved. The molecular biologists on the team will be able to use their techniques to specify which strain of influenza resulted in these deaths. The strain of influenza that caused morbidity and mortality in the community can be inferred from this information.

Major genetic shifts have been documented in the latter half of the twentieth century. That there was a major pandemic of influenza in 1918–1919 is itself testimony to the fact that transportation systems and mobility were already well established, for the virus cannot live, much less travel, outside of living cells — principally, of humans. Interaction between the United States and Europe during World War I provided the mobility for the easy transportation of a genetically shifted influenza virus. Close personal contacts in small spaces that troops faced provided the basis for an even more rapid spread of influenza than would have been the case in other settings.

Food and waterborne diseases

One area of great concern is the internationalization and globalization of the food supply. The UN Food and Agricultural Organization estimates that the net value of the global trade of food is about US$270 billion per year. For the purposes of this discussion, foodborne and waterborne diseases will be grouped together, since people consume them both. Both *E. coli* 0157:H7 and cryptosporidiosis occurred because of breakdowns in the local infrastructure for producing and monitoring food and water. In the former case, the outbreak was due to abattoir practices that led to the contamination of the hamburger meat and totally inadequate meat inspection policies. Microbiologic techniques were not used because of the cost, and meat was inspected only on the basis of its overall appearance. Multiple outbreaks of foodborne diseases in the past few years have emphasized the inadequacies of the capabilities to regulate and inspect food quality in the United States. In late 1997, the US Food and Drug Administration approved the irradiation of meat supplies, which should virtually eliminate the threat of *E. coli* 0157:H7, as long as funding is provided, and the infrastructure is appropriately supported and developed.

In the case of cryptosporidiosis in Milwaukee, the metropolitan water filtration was inadequate to protect the population from the protozoan causing cryptosporidiosis (*Cryptosporidium parvum*). In retrospect, cattle were allowed to excrete upstream of one of the major sources of the metropolitan water supply, and contaminated the supply. Neither of these diseases, however, were totally new to the United States, because there had been lower level epidemics of these diseases for years. Unfortunately, the public infrastructure could not detect or contain either of these epidemics. Because of this, *C. parvum* and related pathogens have been designated as "new" (Ortega et al., 1993). The epidemiology and microbiology of cryptosporidiosis and its pathogen have been reviewed in detail recently (Goodgame, 1996; Meinhardt et al. 1996). *C. parvum* is normally found in the gastrointestinal systems of many animals. It is also difficult to filter and is unaffected by chlorination of the water supply.

Another example of the inadequacy of the public health infrastructure to detect and regulate the quality of imported food was the widespread outbreak of gastroenteritis in the United States, which was due to the importation of raspberries from Guatemala. These berries were contaminated with another rare and emerging pathogen, *Cyclospora cayatensis* (Herwaldt and Ackers, 1997). Like cryptosporidia, cyclospora have only recently been recognized to be potentially major causes of contamination (Huang et al., 1993; Ortega et al., 1993). The raspberries which were implicated after painstaking epidemiologic field research were first introduced into the United States from Guatemala in 1988, following their introduction into Guatemala in 1987 for domestic production and international shipment (Herwaldt and Ackers, 1997). On December 22, 1997, the United States instituted a ban on raspberries imported from Guatemala.

The outbreak associated with Guatemalan raspberries illustrates a broader concern with the potential microbial contamination of imported food (Hedberg et al., 1994). The reasons for the internationalization of foodstuffs are complex, and are one example of the broader, yet sometimes ill defined, "global change" in the world. Certainly, the availability of inexpensive labor, and the year-round availability of arable land are factors in the internationalization of food that is imported to the United States and other nations in temperate climates.

Food, though, is, of course, needed for human survival, and the degree to which the American food supply is international is surprising to some. Most American travellers take precautions to avoid contaminated food and whatever when they travel to Latin America and other developing areas. However, much of the produce which is consumed in the United States, depending on the season and the location, is actually produced abroad, and can cause diarrheal disease as easily as foreign travel in relatively unsanitary areas.

The Institute of Medicine devoted a large section of their report on emerging diseases (Lederberg and Oaks, 1992) to the internationalization of the food supply and argued that earlier in the century, produce was grown for the local market and could only remain fresh for a few weeks, but that the introduction of refrigerated overseas transportation carriers made it possible to ship food from distant locations. The report noted emphatically that the existing infrastructure for testing the safety of foods is insufficient to detect many foodborne pathogens. The authors further suggested that the North American Free Trade Agreement might even exacerbate the problem of produce contaminated with bacteria and other pathogens, since the free flow of food from Mexico to the United States and Canada would be greatly facilitated. Mexico is considered to be a high-risk country for diarrheal diseases by travel medicine experts, the World Health Organization, and the Centers for Disease Control and Prevention. Food which Mexico and other countries export does not receive any special sanitary sampling or treatment, and by the time it reaches the consumer, the food may be laden with pathogens, as occurred with raspberries and cyclospora.

The regulation and control of emerging infectious diseases due to the contamination of imported food must be a priority for international policy. The legal infrastructures are highly fragmented. Plotkin and Kimball (1997) provide an excellent overview of existing regulations but conclude that these must be developed further before they are effective. The major need is that regulations must not be fragmented across different agencies in an uncoordinated manner, as they are now.

A waterborne disease that is of great danger to the United States is the new strain of El Tor cholera that was introduced in Peru. It has been diffusing northwards, into the northern parts of Mexico. The disease is caused by a particular vibrio, and noncholera vibria have been observed in the Pacific Ocean as far north as the State of Washington and the Province of British Columbia. The sanitary systems in the United States and Canada are certainly more effective than those found in Latin America, yet it would be unwise to be complacent about the possibility that the current cholera pandemic might spread into the United States and Canada. Cholera has been enormously costly in Latin America, not only in its human toll, but also in the direct costs of controlling cholera and treating patients. Estimates are that by the end of 1993, nearly 1 million people had contracted cholera in Latin America and that it was responsible for at least 8000 deaths. Moreover, the Pan American Health Organization (PAHO), which is one of the regional divisions of the World Health Organization, estimated that the cost would exceed US$200 billion to control cholera in Latin America (CDC, 1994, p. 11.)

Migration, mobility, and disease emergence

Many statements have been made to the fact that society is becoming more mobile, yet this is not entirely valid. True, when considering affluent, developed nations, and the subpopulations in those societies who travel for business and pleasure, there is a great deal of domestic and international movement. However, among the poor, and in less affluent societies, mobility on the scale typified by the generalization that "society" is becoming more mobile, a major question is "which societies and which populations?" Moreover, the underlying reasons for mobility must be considered to understand the effects of mobility on disease emergence and diffusion.

The world should be considered as a continuum of mobility. In traditional societies, mobility is limited. In hunting and gathering groups, mobility is dictated by the seasons, by natural hazards such as drought, and by the periodic movement of the animals to be hunted. The hierarchy of mobility ranges from some populations that are not mobile at all, to members of other affluent societies where intercontinental business and pleasure trips are the norm. Lack of mobility — a kind of permanence in space — tends to favor stability in the spatial distribution of infectious diseases, while highly mobile individuals and the availability of speedy overseas transportation favors the possibility of very rapid international diffusion of new diseases. Similarly, immobile societies may even be protected from disease diffusion due to lack or minimization of contact with other geographically remote social groups. It is an overgeneralization to argue that the world is uniformly facing increasing mobility, which predisposes most populations to the rapid influx of new disease agents.

It is also crucial to consider the reasons for mobility, and the political, social, and settlement characteristics at the origin and destination of migrants. Migration implies a more permanent movement than does travel, though population geographers and demographers classify migration into a typology which includes forced vs. voluntary migration, periodic vs. permanent or semipermanent migration, and other typologies of migration. Forced migration due to political or religious persecution, natural hazards such as drought, or war, in which many refugees end up in densely settled and unhygienic refugee settlements, clearly favors the diffusion of many infectious. Voluntary migration more typical of affluent societies entails little change in disease risk and disease diffusion. Thus, it is very important to be specific about the type of mobility that is considered.

Of less significance in terms of pure numbers of affected individuals, but of great conceptual importance has been the phenomenon of "airport malaria". In this apparent anomaly, some who live within several kilometers of international airports have contracted malaria. These individuals have not been in areas where malaria is endemic, and may have even not left their home countries for any travel. Such outbreaks have happened in the past few years around the Geneva airport in Switzerland, Newark Airport, Heathrow and Detroit Metropolitan Airport. Experimental data indicate that anophelines may survive a flight from a tropical country in the wheel wells of aircraft, and then fly into the areas surrounding the airports. This is the only way that those affected by "airport malaria" could possibly have contracted the disease. Should this occur in areas where anopheline replication is easy due to climatic and ecological factors, the potential exists to introduce malaria into previously non-endemic areas. A recent report on the Internet-based ProMED, which is an effort financed by the Federation of American Scientists, to serve as a forum for the rapid reporting of disease outbreaks, documents a case of malaria acquired indigenously in the Toronto area. The patient had not been out of the country, nor had she been near a major international airport, as had "airport malaria" patients. The only putative source of contagion was that an anopheline in the Toronto area had taken a blood meal from an infected individual and had transmitted the disease in the usual manner.

This kind of phenomenon indicates that vectored transmission can be a potential threat even in areas that are free of a particular disease. This is particularly the case with tropical countries where climatic conditions are conducive to vector survival and multiplication. One fascinating example is that yellow fever is confined to tropical Africa and Latin America, yet it has apparently never been present in Asia, which has the correct habitats for vector survival, and potentially a highly susceptible population, lacking any immunity due to no previous exposure. Why has yellow fever not diffused to Asia? This remains an unanswered question.

Two examples, however, do indicate the possibility of vector transportation with major public health consequences. Dengue was probably introduced to the Americas from Africa because of the slave trade. It had been endemic in Africa (Morse, 1995). It has since become a major problem and is epidemic in Latin America and the Caribbean. It is almost certain that the movement took place because of worldwide shipping patterns.

Global climate change and infectious diseases

Obviously, much attention in the scientific and policy communities has been devoted to the dual problems of global warming and ozone depletion. Global warming will undoubtedly affect human health by increasing the latitudes at which the vectors for malaria, dengue fever and vectored encephalitides can survive. Thus, a reasonable prediction is that these diseases will be seen in more temperate areas than they are currently endemic. Indeed, dengue has been moving northwards in the Caribbean and has reached epidemic proportions in the Caribbean islands. Parts of Mexico in which dengue was not seen are now experiencing outbreaks of dengue, and in 1996, several cases of locally acquired dengue occurred for the first time in many years in the United States. Dengue serves to illustrate the generalization that there will be latitudinal movement of vectors for a number of infectious diseases, as suggested by the Intergovernmental Panel on Climate Change (1995). Many vectored diseases were identified as having significant potential for diffusion, but none is more notable than malaria. This disease, which was nearly eradicated in the 1960s, now results in 300–400 million new infections per year and the World Health Organization (1995) estimates that the population at risk of developing malaria will increase to 2.5 billion people with scenarios of moderate temperature change.

An indirect effect of climate change is on the human immune system itself. Ozone depletion, which, fortunately, is greatest over Antarctica, results in the absorption of ultraviolet radiation, and, of particular interest, of ultraviolet B radiation. Halocarbons and other greenhouse gasses contribute to this depletion. There is great consensus that human absorption of UV-B radiation affects our immune response by altering the effects of the skin's Langerhans cells, and therefore compromises our cell-mediated immunity, and particularly, our suppressor T-cells (Bentham, 1994; Intergovernmental Panel on Climate Change, 1995). The relationship between ultraviolet radiation and immunity is an area of active research. The effects of ultraviolet B radiation on the immune system is without controversy, though the dose-response relationships, particularly with very low levels of exposure, is not firmly established. In summary, ozone depletion, leading to immunosuppression, will surely compromise our immune systems' abilities to respond to pathogenic challenge, and, as Bentham (1994) notes, it is fortunate that the greatest ozone depletion, until now, has been in relatively unpopulated areas such as Antarctica. There is no assurance that this will be the case in the future.

A political ecologic interpretation of emerging infectious diseases

The political ecology of disease is a promising if as yet underdeveloped approach to understanding disease dynamics and it is potentially useful in a social interpretation of emerging and resurgent diseases. It combines the elements of traditional disease ecology with the concepts of political economy that have been very productive in explaining a whole variety of human projects (Mayer, 1996). Political ecology emphasizes the unintended human and natural consequences of individual, corporate and governmental projects, and demonstrates aptly that disease has its "human-made" components as well as its natural components. Bryant (1992, p. 13) succinctly summarizes political ecology: "broadly... political ecology may be defined as the attempt to understand the political sources, conditions and ramifications of environmental change". Political ecology has been most widely applied to land development and management and combines elements of cultural ecology with political economy (Blaikie and Brookfield, 1987). In the future, applying its underlying concepts to specific diseases and populations may test its potential. At its deepest, political ecology can alter the concepts of the causality of disease from a purely biomedical concept to one that also incorporates the unintended aspects of human action. Unfortunately, however, the most recent work on political ecology (a whole book), argues that there are two issues on which political ecologists appear to agree. As the authors write: "the environmental problems facing the Third World are not simply a reflection of policy or market failures... but rather are a manifestation of broader political and economic forces. Those forces are associated with the worldwide spread of capitalism (Bryant and Bailey, 1997, p. 3)". The authors continue that the second area of agreement "is the need for far-reaching changes to local, regional and global political-economic processes (Bryant and Bailey, 1997, p. 3)". Essentially the authors argue that political ecologists agree that there is a need for fundamental changes to the structures of society. This is overly restrictive, since those who have dominated political ecology only in the context of social change have cast a useful framework for interpretation, and the utility of this approach has been therefore narrowed.

A third area of implicit agreement is that political ecology considers only the Third World. However, political ecology can be a useful and a powerful method of explanation in countries like the United States, and in the absence of any implicit need to promote fundamental changes in social and economic structure. Thus, my enthusiasm over political ecology is that it can explain relationships of phenomena, and that such explanation need not occur in a Third World setting. Political ecology can help to clarify the dynamics of Lyme disease in New England just as well as it can be used as a tool of change in Nigeria.

As discussed previously, it is strongly influenced by land developers who, in pursuit of profit, obviously respond favorably to individual desires for large private homes with private lots, facilitated by the availability of transportation for access to employment centers and other amenities. Political ecology therefore has possibilities — but a largely untested promise — for facilitating a deeper understanding of the interaction between population, environment, power, and disease (Mayer, 1996).

Most political ecology has involved critical and usually Marxist concepts of political economy, yet, as Staniland (1985) has established, political economy is itself a loosely defined term. Peet and Thrift (1989) affirm the diversity of definitions of political economy and then argue in favor of using the term in the context of critical social science. The only commonality between neoclassical political economy and Marxist or post-Marxist political economy is that political economy emphasizes the relations between politics and power on the one hand and on profit and revenues on the other hand. The approaches are so disparate that it is difficult to develop a definition beyond that. As stated in *The Dictionary of Human Geography* (Johnston et al., 1994), two concepts of political economy have remained pivotal since the initial use of the terms by Ricardo and others (p. 446):

> first, production and accumulation; and second, distribution of the 'surplus' so produced. It is the focus on distribution that really accounts for the political part of political economy; for questions of apportioning the surplus among the classes of society necessarily pushes inquiry beyond the purely economic, and into the spheres of the social and political.

Echoing the argument that it is difficult to find a universally accepted definition of political economy that, nonetheless, is a term used so widely that Milton Friedman and the free market economists at The University of Chicago used it in the 1960s, *The Dictionary of Human Geography* continues (p. 447):

> Admittedly, it is difficult to find a common thread among the many uses of political economy within geography but if it exists it is that in all practices the political and the economic are irrevocably linked; a sentiment not that distant from that proposed by the originators of the term.

This is not the place for an extensive review and critique of either political economy in general or of political economy and health. An excellent review of the diversity of concepts of the former is provided by Staniland (1985) Two reviews of the latter are by Brenner (1995) and Reich (1994).

As mentioned previously, Bryant (1992) provides a convenient summary of most of the major concepts of political ecology, while Peet and Watts (1996) develop a basis for a "poststructuralist" political ecology, which they label "liberation ecologies," which has an unabashed political agenda. Rochelau et al. (1996) apply feminist perspectives to political ecology, and vice versa. In none of these works are health and disease even mentioned. Using an interpretive framework developed in the context of advocating social change provides a challenge for the sociomedical interpretation of disease.

If new understanding is to come, it will arise from the fact that many diseases, and their emergence, result directly from the unintentional consequences of human action. For example, if ebola hemorrhagic fever may be taken as one prototype of an emerging disease, there are only two things that are clear about the disease. One is that it is poorly understood, and the other is that it has a very high case fatality rate. While the viral basis of the disease has been identified, its human and political ecologies are enigmatic and remain mysteries despite intense attempts at identifying how the virus moves from an enzootic into one that affects. Sometimes groups with limited contact with the rest of the world populate an area such as an isolated valley, and a disease may therefore remain restricted to that valley. Kuru, for example, is a degenerative neurological disease that was restricted to one valley in New Guinea. An ethnic group called the Fore populates this valley. Gajdusek and colleagues described this disease (Gajdusek and Zigas, 1957; Zigas and Gajdusek, 1957), A prion was eventually suggested to be the causal agent. Prusiner won the Nobel Prize for Medicine and Physiology in 1997 because of his work on prions that began with his research on kuru (e.g., Prusiner, 1987). Ritual cannibalism was thought to be the mechanism of contagion, which explains the puzzling observation that morbidity and mortality were restricted almost entirely to women. Since cannibalism has ended in the area, no new cases of kuru have been described. When it was first discovered, kuru was a disease that should be regarded as "emerging" in the sense that it had not yet been identified or even recognized by those other than the Fore, yet the proviso must be added again, "recognized by whom?" Kuru was not emerging for the Fore; the evidence was clear through oral histories that it had been present for generations. Kuru was thus the result not only of isolation, but also of cultural practices.

In other cases, as human activities expand the range of human action to include new portions of tropical rainforest, the potential for diseases hitherto unknown or very rare in the human population to appear in the population is high. Species jumps are common, and are not particularly exotic. Influenza is present in avian populations; psittacosis is primarily a disease of psittacine birds that have become fond pets in the western world, and hantavirus pulmonary syndrome has its reservoir in rodent populations.

Conclusion

The world is undergoing rapid change as human–environment relations evolve, global interdependency increases, and previously stable equilibria are disrupted. One of the consequences of these global changes is that infectious diseases, once thought to be on the wane, are still very much a factor both within developed and developing countries. The complacency with which much of the medical community viewed infectious diseases until the 1980s is understandable, for smallpox had been eliminated, tuberculosis was well on the way to being a minor problem in the United States, and many infectious diseases in the tropics appeared to be on the wane. However, infectious diseases are a cause for concern in some places, and for alarm in other places. HIV has devastated much of sub-Saharan Africa; drug-resistant tuberculosis continues to increase in the United States, particularly among the urban poor and homeless, and hospital acquired infections are increasing. Several of these have extremely high case-fatality rates, since they are responsive to no known antibiotics. Over the long term, disruption of the ecosystem, and its fragile equilibrium with humans, continues to take its toll.

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