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THE ANTHROPOLOGY OF INFECTIOUS DISEASE

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INTRODUCTION

Diseases caused by infectious agents have profoundly affected both human history and biology. In demographic terms, infectious diseases—including both great epidemics, such as plague and smallpox, which have devastated human populations from ancient to modern times, and less dramatic, unnamed viral and bacterial infections causing high infant mortality—have likely claimed more lives than all wars, noninfectious diseases, and natural disasters taken together. In the face of such attack by microscopic invaders, human populations have been forced to adapt to infectious agents on the levels of both genes and culture. As agents of natural selection, infectious diseases have played a major role in the evolution of the human species. Infectious diseases have also been a prime mover in cultural transformation, as societies have responded to the social, economic, political, and psychological disruption engendered by acute epidemics (e.g. measles, influenza) and chronic, debilitating infectious diseases (e.g. malaria, schistosomiasis). Today, the global epidemic of acquired immune deficiency syndrome (AIDS) provides a salient example of the processes underlying infectious-disease-related cultural transformations. As many of the examples cited in this review illustrate, human groups have often unwittingly facilitated the spread of infectious

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diseases through culturally coded patterns of behavior or through changes in the crucial relationships among infectious disease agents, their human and animal hosts, and the environments in which the host-agent interaction takes place.

Thus, infectious diseases provide a rich area for anthropological research, with contributions to be made from all of anthropology's subdisciplines. Indeed, because the study of infectious disease is an intrinsically biocultural endeavor, the "anthropology of infectious disease" described here must be a holistic one, in which traditional subdisciplinary boundaries are irrelevant. Infectious disease problems are both biological and cultural, historical and contemporary, theoretical and practical. Because the relevant research requires the synthesizing theoretical framework of general anthropology, it cannot be subsumed by medical anthropology. Note the range of anthropological and public health literature cited in this review.

Simply defined, infectious diseases are those caused by biological agents ranging from microscopic, intracellular viruses to large, structurally complex helminthic parasites (see 33 for a classification of infectious disease agents, including viruses, bacteria, fungi, parasites, and several classes of intermediate forms, as well as their routes of transmission). The variety and complexity of infectious agents—in terms of their biological characteristics, their reproductive strategies, and their modes of transmission—are impressive (35). The classification of this tremendous diversity forms part of the subject of the World Health Organization's (WHO's) *International Classification of Diseases*, now in its ninth revision (224). These disease categories provide a standard mode of scientific discourse in biomedicine, where "diseases" are considered as clinical entities with pathological underpinnings, while "illnesses" are more closely linked to a patient's perceptions and behaviors. As is generally recognized by medical anthropologists, however, biomedicine is only one type of culturally constructed medical system (100, 101).

It is important to note that infection with a specific agent does not necessarily result in disease. This progression depends upon a number of intervening variables, including the pathogenicity of the agent, the route of transmission of the agent to the host, and the nature and strength of the host's response (23, 193). All of these factors, in turn, are affected by the natural and social environments in which the agent and host are juxtaposed; in some cases, the environment may promote the transmission of the agent to the host, while in other cases it may limit or even prevent such transmission. Critical characteristics of the environment result largely from sociopolitical influences; thus, many infectious diseases, such as tuberculosis, are rightly considered "social diseases" (57, 217).

The American Anthropological Association's Working Group on Anthropology and Infectious Disease defined the anthropological field of infectious disease as the "broad area which emphasizes the interactions between sociocultural, biological, and ecological variables relating to the etiology and prevalence of infectious disease" (26:7). This review uses the same definition, examining anthropological works on infectious disease (including those by scholars in related disciplines whose methods or theoretical frameworks are anthropological in nature) and classifying them for heuristic purposes according to their primarily biological, ecological, or sociocultural orientation.

BIOLOGICAL APPROACHES

Microevolutionary Studies

From an evolutionary perspective, infectious diseases have probably been the primary agent of natural selection over the past 5000 years, eliminating human hosts who were more susceptible to disease and sparing those who were more resistant. Individual biological factors that conferred protection from a specific disease could eventually be selected for in the human populations living where the disease was endemic. Thus, as first suggested by Haldane (102), humans adapted to infectious disease at a most basic level—the level of the gene (5, 6).

Over the past 40 years, anthropologists and human geneticists have been testing the hypothesis that specific genotypes may confer immunity or resistance to infection. Such hypotheses have also been suggested to help explain relatively common genetic conditions that may be adaptive in one context and maladaptive in another. Allison (4) was the first to suggest that the heterozygous condition known as sickle-cell trait (i.e. inheritance of the gene for the common form of hemoglobin from one parent and the sickling hemoglobin S from the other) appeared with greater frequency in regions of Africa where life-threatening *Plasmodium falciparum* malaria was present. This association led Allison to hypothesize that hemoglobin S, when present in the heterozygous state, conferred resistance to death from malaria. Although this hypothesis has been a prominent textbook example for two decades, the statistical correlation between malaria prevalences and sickle-cell gene frequencies in West Africa has only recently been systematically confirmed (70). Moreover, while there is significantly higher malaria mortality among children who are heterozygous sicklers than among homozygous normals, differences in parasite densities among individuals of the two genotype groups have not been determined (159).

In a classic anthropological work that followed Allison's, Livingstone (158) related the widespread distribution of the sickle-cell trait in West Africa to specific factors of cultural evolution: namely, the introduction of iron tools and subsequent swidden agriculture. He argued that the diffusion of the new technology led to increased sedentism, horticultural production, and deforestation, effectively increasing the available breeding grounds for *Anopheles gambiae*, the major mosquito vector. These changes allowed falciparum malaria to become established as an endemic disease among settled, West African agricultural societies and as a selective agent for the sickle-cell allele (158, 160). Through analysis of data from 60 African communities, Wiesenfeld (221) demonstrated that populations most reliant on root and tree crops (the Malaysian agricultural complex) created the most malarious environments; this would lead to greater selective advantage for heterozygous individuals, who enjoy protection from malaria death yet are not at risk of death from sickle-cell anemia (the condition of homozygous sicklers).

More recently, other hemoglobin abnormalities have been identified (161) that appear to confer resistance to malaria, including glucose-6-phosphate-dehydrogenase (G6PD) deficiency, thalassemia, and hemoglobins Hb^C, Hb^E, and Hb^F. Similarly, it has been argued that the Duffy blood group negative genotype, characteristic of most African and US blacks, provides a high level of protection from *Plasmodium vivax*, a more benign strain of malaria (164). In an examination of fava bean consumption and its relation to malaria in the G6PD-deficiency-endemic, circum-Mediterranean area, Katz & Schall (136) have suggested that the combination of nonexpressed gene and consumption of fava beans (the "gene-bean interaction") may protect heterozygous females from malaria death. This may be viewed as an excellent example of the "coevolution" of genes and cultural traits, which, in combination, offer substantial protection from disease (135), although in this case, G6PD-deficient males may suffer potentially fatal hemolytic crises of favism (32).

Other studies tentatively linking infectious diseases to genetic traits and cultural factors have recently emerged. For example, Blangero (18) studied the relationship among helminthic zoonoses, the P2 allele of the P blood group system (which is hypothesized to confer resistance to these zoonoses), and subsistence practices involving animal husbandry. He has shown that high frequencies of the P2 allele occur in populations manifesting heavy dependence on and contact with domesticated livestock. In a different context, Meindl (174) has hypothesized that, for European populations with a long history of pulmonary tuberculosis and high frequencies of cystic fibrosis, carriers of the recessive gene for cystic fibrosis may have increased resistance to tuberculosis.

Conversely, anthropologists helped to demonstrate that the hepatitis B surface antigen (HBsAg) was not part of the genetic endowment transmitted from parents to offspring. Rather, the clustering of the antigen observed in families was due to both horizontal (i.e. person to person) and vertical (i.e. mother to infant) infectious transmission (20–22)—a finding made, in part, through participant observation of family life in New Hebrides (51, 52). These discoveries played a role in the successful development of a hepatitis B vaccine.

Macroevolutionary Studies

Macroevolutionary studies of infectious disease attempt to reconstruct epidemiological patterns of disease transmission among prehistoric and historic human populations. The broad aims of this research are two-fold: (*a*) to establish the antiquity and evolution of various infectious diseases in human populations through examination of prehistoric osteological and, in some cases, soft-tissue evidence; and (*b*) to contextualize these findings to the physical and cultural circumstances of the human populations involved.

Paleopathology has contributed significantly to the understanding of the prevalence and spread of infectious diseases in human populations. Simply defined, paleopathology is the study of disease in prehistoric populations through examination of skeletal and tissue remains, coprolites, and when available, works of art (1, 130). Because some infectious diseases leave their marks on the human skeleton and flesh, examination of these remains has allowed researchers to describe the disease patterns of prehistoric populations and to establish relative chronologies.

Paleopathological reconstructions utilizing skeletal and tissue remains have been attempted for infectious diseases including tuberculosis (34, 181), leprosy (179), and American (203) and African trypanosomiasis (151). Studies of the kidneys of Egyptian mummies have yielded evidence of schistosomiasis (191); and coprolite studies, utilizing dried fecal remains found in or near prehistoric camps and shelters, have provided valuable insights on the epidemiology of intestinal helminthiases in prehistoric populations (40, 69, 191, 201, 205, 206).

Paleopathology has had a particularly decisive role in the debate over the antiquity and origin of syphilis in the Old and New Worlds. Using osteological evidence, paleopathologists have argued that human venereal syphilis originated in the Americas and was transported to Europe and then to other human habitats by European colonists and explorers, including, as Crosby (45, 46) has argued, Christopher Columbus's crew. This conclusion is based on abundant evidence of syphlitic skeletal material from pre-Columbian remains discovered in the New World (43, 93, 94, 179, 181, 200, 222) and the distinct absence of pre-Columbian, Old World skeletal material with any of the treponemal stigmata (223). Nevertheless, other reconstructions of the history of syphilis based on contemporary and historical knowledge of the treponemal diseases have been put forward (39, 99, 119–122); these have been well summarized by McNeill (172) and Wood (223).

In addition, paleoepidemiological reconstruction of infectious disease patterns in prehistoric and early historic human populations has been undertaken through ethnographic analogy—that is, examination of disease patterns in contemporary isolated hunter-gatherer populations followed by extrapolation of these findings into the past. First suggested by Dunn (58) and Polunin (196), this approach has been advocated subsequently by a number of scholars

(16, 17, 40, 95, 185). Basing their theses largely on serological evidence collected from contemporary hunter-gatherer groups, they hypothesize that, because of their small numbers, mobility, and relative isolation from other groups, ancient hunter-gatherers were relatively free from the acute, epidemic infectious diseases that later took their toll on more advanced agrarian societies. Many acute infectious diseases require large numbers of susceptible individuals to support their chains of transmission, which are characterized by brief and rapid stages of infection. In early food-foraging groups, populations of no more than 200–300 persons would not have been large enough to sustain such a chain of transmission; if introduced, these acute infections would have run their courses and then died out. From the standpoint of natural selection, pathogens that live in a long-term commensal relationship with the host (e.g. the agents of typhoid, amoebic dysentery, trachoma) and those that persist for periods of time outside the final host or vector (e.g. the agent of schistosomiasis) would have been favored, and infections like measles, which spreads rapidly and immunizes a majority of the population in one epidemic, would have been rare or absent.

A number of scholars (5, 40, 55, 56, 82, 171, 195) have gone beyond this original proposition to describe the coevolution of human culture and infectious disease, basing their arguments largely on knowledge of population size and density and their impact on infection. Humans made a rapid cultural transition from small, isolated groups of hunter-gatherers to small, scattered villages of farmers, to large, preindustrial and then industrial cities, marked by aggregates of people living in close proximity. This cultural transition profoundly affected the nature of infectious disease patterns by (*a*) changing the degree of contact between humans and animals, either directly or via arthropod vectors, and (*b*) altering the size of human aggregations and the communications and movement within and between them. Thus, the contagious epidemic diseases, which would not have had a large enough population base to affect hunter-gatherers or even small farming villages, would eventually decimate populations in urban centers.

Likewise, the clearing of land for cultivation, the domestication of animals, the increase in sedentism, and the concomitant problems of human and animal waste removal, all of which occurred during the agricultural revolution of the Neolithic and Mesolithic periods, provided ideal conditions for many of the helminthic and protozoal parasites (5). The health consequences of this transition from food foraging to food production have been topics of considerable attention, as seen in the important collection *Paleopathology at the Origins of Agriculture* (42). Twelve of the eighteen case studies in this collection report substantial increases in infection rates from the time of early hunter-gatherers to early farmers (41). Research from both the Old and New Worlds shows a repeated pattern of decreased stature, higher infant mortality, and increased physiological stresses indicative of malnutrition, characteristic of populations during the Neolithic revolution. Such a pattern indicates the strong synergistic relation between chronic malnutrition and infectious disease morbidity and mortality (207). It should be noted, however, that the intensification of agricultural systems, whether in the past or present, shows no direct linkage with increased infectious disease rates (41, 112).

In addition, a number of scholars, primarily medical historians, have examined the effect of infectious diseases on civilizations during historical periods (for numerous examples of these works, see 24). Utilizing texts and other primary and secondary sources, they have chronicled the impact of such infectious diseases as the plague (53), typhus (226), cholera (202), malaria (105), and smallpox (115), for better and for worse, upon state-level societies and populations. In the most comprehensive treatment of this theme, McNeill (172) argues that epidemics have played an active role in the expansion of empires throughout history, as state-level societies introduce endemic childhood diseases into smaller and simpler societies, causing massive population losses and subsequent socioeconomic disorganization. The depopulation of North and South American Indian societies by epidemic infections brought from Europe by colonizers and from Africa by slaves (8, 91, 138, 149, 186, 187) provides a salient example of McNeill's point: Infectious diseases accelerated the conquest, subjugation, and acculturation of tribes and chiefdoms.

McNeill's model requires the recognition that a universal aspect of history has been the "confluence of disease pools." Owing to rapid transportation, we now live in a single epidemiological world system—despite striking differences in the distribution of disease and death between the poor societies of the Third World and affluent nations, an important theme in a number of recent analyses (14, 171). Kunitz (150) and McKeown (170) have also concluded that socioeconomic change has had a greater impact on improvement of health and diminution of infectious diseases than has the introduction of (and innovation in) clinical medicine.

ECOLOGICAL APPROACHES

Theoretical Models

Most anthropological research on infectious disease has been ecological, focusing on the interaction between agent and host within a given ecosystem. Disease ecology, as the discipline is often called (33), owes much to the pioneering work of the medical geographer May, who in his classic volume *The Ecology of Human Disease* (167) formalized the role of the environment—both physical and sociocultural—in the study of infectious disease problems. May constructed a model that treated physical environment, disease pathogens, human hosts, and the cultural practices employed by these hosts as separate factors in an interactive process. In this view, disease expresses a temporary maladjustment between human hosts and their environment. Using examples from his own research in Asia, May demonstrated how transmission of malaria in North Vietnam and hookworm in China were affected by specific environmental and cultural patterns. In the North Vietnamese case, he showed how lowland housing types, which were transplanted without modification to the highlands, were responsible for the higher rates of malaria among lowland-to-highland migrant populations, whose ground-level dwellings exposed them to low-flying mosquito vectors. Native hill peoples, on the other hand, had adjusted to the malaria threat by constructing stilted houses with living quarters above the mosquito's 10-foot flight ceiling. Likewise, in China, May showed how rates of hookworm infection depended upon the environments within which individuals worked: While rice growers who worked in fields of mud mixed with nightsoil (raw human feces) were usually and often seriously infected, silkworm farmers who spent their days on ladders tending to mulberry leaves were not.

Following May's lead, a number of scholars delineated models of the interactions among infectious disease agents, human hosts, and the environment. Audy (10, 11) whose major work focused on the roles of human behavioral and environmental factors in the transmission of scrub typhus (9), broadened his approach to disease etiology by incorporating the notion of "insults" into his model. Insults were defined as physical, chemical, infectious, psychological, or social stimuli that adversely affected an individual's or population's adjustment to the environment. Audy viewed both health and disease as states in an individual's dynamic relations with the environment: Measuring either one depended upon identifying the multiple positive and negative insults and their cumulative effects. Moreover, exposure to a pathogen was a necessary but not sufficient cause of disease; the progression from exposure to disease depended in part on the health of the exposed person, which, given an individual's vulnerability to a complex of insults, was never a constant.

Audy introduced the concept of insults in an attempt to overcome the limitations of a pathogen-specific approach to disease. Dunn (68) developed the even broader concept of "causal assemblages"—complexes of environmental, host-biological, and host-behavioral factors that must be considered when studying disease etiology or attempting to control disease spread. In his early work with Malaysian aboriginal groups, Dunn (59, 61) showed how both environmental factors (e.g. altitude, temperature, soil type, presence of scavenging animals) and human behavioral factors (e.g. subsistence strategies, housing types, community mobility) significantly affected rates of parasitic infection. He later demonstrated the important implications of this model in the design of effective disease control programs (60, 62–64, 66).

In a radical departure that she has labeled the "political ecology of disease," Turshen (217) has argued that "bourgeois empiricist" models of disease causality, such as those described above, are little more than accretions to the basic epidemiological triad of agent, host, and environment—a model that is inadequate because it fails to consider the ultimate causes of disease, which she holds are economic, social, and political. In her own study of infectious disease and related health problems in Tanzania, Turshen argues that the continued focus on the former triad is the ultimate cause of scholarly failures to elucidate why epidemics occur at certain historical moments or why eradication of a specific infection does not ensure prevention of illness. She favors a Marxist construction of the causes of poor health, which focuses on modes and factors of production and changing social relations seen from the perspective of colonialist and neocolonialist history. This approach has also been influential in medical geography (131), as well as in the development of "critical medical anthropology" (211).

Research Examples in Disease Ecology

Much of the recent empirical work in disease ecology has been, in fact, political-economic, if not explicitly Marxist in orientation, in that it focuses on the untoward consequences of ecologically ill-advised development schemes. It concerns the so-called "developo-genic" diseases, the consequence of environmental disruptions caused by large-scale, internationally sponsored projects (123). Dubos (54, 55) was among the first to note that all technological innovation, whether industrial, agricultural, or medical, upset the balance of nature; the sensible goal was thus not to maintain the balance of nature but to change it to the benefit of as many plant and animal species (including humans) as possible.

Unfortunately, many of the development schemes of the past and present have been neither balanced nor beneficial. As Hughes & Hunter (123) point out in their comprehensive review of development projects and disease in Africa, few of the projects initiated on that continent over the past two centuries have been undertaken within a preconceived ecological framework. They include in their survey programs of agricultural, industrial, and infrastructural change, as well as resulting population relocations, all undertaken in the name of progress. As they note, development projects of dam construction, land reclamation, road construction, and resettlement in Third World countries have probably done more to spread infectious diseases such as trypanosomiasis, schistosomiasis, and malaria than any other single factor.

The life-threatening blood fluke infection schistosomiasis (bilharziasis) provides a trenchant example of the unforeseen health consequences of ecological disruption caused by development schemes. As Heyneman (110,

111) notes, schistosomiasis is probably the fastest spreading and most dangerous parasitic infection now known. The rapid spread of this disease is almost entirely due to programs of water resource development involving the construction of high dams, man-made lakes and reservoirs, and irrigation canals (50, 110, 111, 208). These waterways have provided an ecological "free zone" for the snails that are the intermediate host of the schistosomal parasites. As the snail population has spread throughout Africa and parts of the Middle East, Asia, South America, and the Caribbean, so have schistosomiasis infections, which are acquired when larval parasites, released in the water from snail vectors, penetrate immersed human skin. Today, 200–300 million people worldwide are estimated to be infected (134), and new "epidemics" of the disease occur following the expansion of waterways in areas of the world where the parasite and vector live. For example, Kloos and coworkers (140, 141, 144, 145, 147) have described the expanding distribution of schistosome-transmitting snail populations and escalating rates of human infection following government-sponsored creation of large, irrigated farming estates in the Awash Valley of Ethiopia. In neighboring Sudan, the disease cycle was established within a few years of the start of the Gezira scheme, a large-scale, irrigated cotton project south of Khartoum (83, 98, 147), which was also responsible for an increased prevalence of malaria in this region (98). In Nigeria, the prevalence of schistosomiasis soared following construction of a low-earth dam providing perennial access to a large body of infective water—an increase that was likely to continue, researchers predicted, given government plans to build more dams in the area (198).

Subtler ecological changes may also be associated with increases in infectious disease. For example, Chapin & Wasserstrom (37) have shown how increased pesticide use in the intensive production of cotton in both Central America and India resulted in a serious resurgence of malaria because of the rapid evolution of insecticide-resistant strains of *Anopheles* mosquitoes. Similarly, the severe epidemic of typhoid fever in Mexico in 1972–73 was the result of overuse of the powerful antibiotic chloramphenicol for ailments such as the common cold; this change in disease ecology brought about rapid selection for chloramphenicol-resistant strains of the typhoid fever bacterium (218).

SOCIOCULTURAL APPROACHES

Human Behavior and Infectious Disease Transmission

THEORETICAL MODELS As we have argued elsewhere (33), any anthropological study that hopes to shed light on the etiology and transmission of infectious disease must ultimately adopt both a macrosociological perspective—of the kind advocated by Turshen (217) and exemplified in much of the work on disease ecology and development—and a microsociological perspective. We have defined the latter as the study of the individual manifestations of culturally prescribed behavioral patterns, which are seen as risk factors (or, in some cases, limiting factors) for the contraction of infection (33).

The critical links between human behavior and infectious disease transmission have been recognized for more than a century, when, during an epidemic of cholera in London, differential rates of infection were linked by early epidemiological investigators to varying drinking patterns of factory workers (212). Since then, numerous anthropologists and other behavioral scientists (3, 60, 62, 64–67, 109, 176, 184, 195, 204, 210) have noted the importance of understanding culturally prescribed and proscribed behavioral practices and their effect on the transmission of infectious disease agents.

The impetus for this orientation in anthropology owes much to the pioneering work of Alland (3), who used evolutionary theory to examine how cultural behaviors could enhance human hygiene and health. Utilizing concepts from mathematical modeling, Alland used the term "minimax" to refer to cultural practices that minimize the risk of disease and maximize the health and welfare of the group.

However, as both Roundy (204) and Dunn (60, 62, 64) have suggested, not all human behavior is adaptive in the evolutionary sense, since many culturally prescribed patterns of behavior actually promote infectious disease spread. Roundy (204) has called such disease-promoting patterns of behavior "hazards." In his model, human behavior can affect disease transmission in four areas: (*a*) exposure to the agent, (*b*) shedding of the disease agent from an infected human host, (*c*) creation of man-made habitats in which the transmission cycle can be completed, and (*d*) diffusion of the transmission system from one place to another.

Dunn's (60, 62, 64) model of health-promoting and health-demoting behaviors is perhaps more useful on a methodological level. Dunn classifies all health-related behaviors along two axes: deliberate vs nondeliberate and health-promoting or maintaining vs health-demoting. He conceptualizes four major categories of individual or group health-related behaviors: (*a*) deliberate, consciously health-related behavior that promotes or maintains health; (*b*) deliberate behavior that contributes to ill health or mortality; (*c*) behavior not perceived to be health related that nevertheless enhances or maintains health; and (*d*) behavior not perceived to be health related that contributes to ill health or mortality. He notes that each of these categories of behavior may be further divided along a third axis: the perspectives of "insiders" (the populations at risk) as opposed to "outsiders" (members of the health-care community).

RESEARCH EXAMPLES The role of human behavior in increasing or limiting transmission can be demonstrated for virtually every infectious disease. Dunn (60), for one, has applied his classificatory scheme to the study of behavioral factors in filariasis transmission. In more recent works, he has outlined theoretical and methodological considerations in the study of behavioral risk factors for trachoma (66), human arboviral infections (67), and four of the five parasitic infections (schistosomiasis, filariasis, American and African trypanosomiasis, and malaria) targeted by the United Nations (UN), the World Bank, and WHO for 20-year research and control programs (62, 64).

Nations (184) has recently summarized some of the behavioral factors that affect infectious disease transmission, including dietary customs, child care patterns, religious practices, migration patterns, agricultural techniques, kinship relations, and traditional medical treatments. However, as Nations notes, observational studies of disease-related behaviors—and, more important, anthropological studies that "make sense" of these behaviors in a broader cultural context—are few, considering the tremendous potential for this type of research.

Kuru and cannibalism Perhaps the best-known example of anthropological involvement in an infectious disease problem involves the case of kuru, a neurological degenerative condition found in the remote eastern highlands region of New Guinea among the Fore (157). A multidisciplinary team of anthropologists, neurologists, pathologists, and epidemiologists eventually discerned that this lethal condition was due to an infectious agent—a "slow virus" acquired through behavioral practices associated with cannibalism (124). Anthropologists provided clinicians detailed information regarding subjects' reports of the preparation and consumption of the flesh and organs of deceased relatives (157). Adult women suffered the highest kuru infection rates, since it was their responsibility to prepare corpses for consumption. As Lindenbaum (157) notes, following the imposition of Western law and a subsequent government-monitored ban on cannibalism, disease incidence plummeted, thus indirectly supporting the etiological role of cannibalism in kuru's transmission.

Steadman & Merbs (215), however, have questioned the association between kuru and cannibalism, noting that researchers in the New Guinea highlands never actually witnessed an act of cannibalism. These authors suggest that Fore mortuary practices were more likely the crucial behavioral variable, permitting transmission of the deadly virus via cuts and sores on the hands of the women preparing dead bodies for burial.

Malaria and cultural adaptation Anthropologists interested in cultural adaptations to disease have focused their attention upon malaria, a parasitic infection thought to have killed more people than any other named disease (159). Genetic adaptations to this disease have merited particular interest, and malariologists have recognized the important role of human behavior in malaria control (see the bibliography in 213). Wood (223) summarizes many of the studies of cultural practices, most of them nondeliberate, that may limit transmission in areas where malaria is endemic. These include the use of alkaline laundry soaps that destroy mosquito breeding sites, clothing styles that serve as mechanical barriers to biting insects, the use of malodorous traditional pesticides and insect repellents, and seasonal migrations away from mosquito vectors. Empirical evidence for the efficacy of such practices is generally lacking, however. Brown (27) has also argued that the combination of nucleated settlement pattern and inverse transhumance (flock movement to high elevations in summer) served to reduce exposure to malaria in Sardinia and to explain its social epidemiological distribution. These and other traditional behaviors based on the folk theory of miasma probably had preventive effects. Behavioral adaptations to malaria in other cultural contexts include fava bean consumption in the Mediterranean (135, 136), traditional medicines in Nigeria (75, 76), and the use of thick blankets and netting in Africa (163).

Echinococcosis and companion dogs Echinococcosis (hydatid disease) is a life-threatening parasitic infection transmitted from domesticated livestock to dogs to humans. Hence, it occurs in areas of the world where humans, dogs, and livestock (primarily sheep) live in close association. The Turkana of Kenya and the neighboring tribes of southwestern Ethiopia are highly infected. Medical anthropologists and geographers (89, 90, 92) working in this region have provided rich reports of the interactions between humans and their dogs. Of particular interest from the standpoint of echinococcosis transmission are the women's "nurse dogs," which are specially trained to lick and clean children who have just defecated; in so doing, these nurse dogs disseminate infective parasitic eggs throughout the domestic environment and to their young charges. In addition, potentially infective dog feces are highly valued among the Turkana as a traditional medicinal and cosmetic substance, which is used to dress wounds, ward off evil spirits, and protect women's skin from the damaging effects of their heavy layered necklaces (90). Unfortunately, the Turkana and other highly infected tribes in this region do not associate their often lethal disease with dogs, dog feces, or the hydatid cysts they observe in their livestock (92); this situation makes preventive cultural adaptations to the disease less likely.

Schistosomiasis and water contact Schistosomiasis is a water-based parasitic disease in that water plays a major role in the developmental life cycle of the parasite and in its transmission to humans. Because of the importance of water contact in schistosomiasis transmission, WHO (225) has advocated and supported numerous water-contact studies throughout the world. The most extensive single investigation of water-contact behavior was carried out in Egypt, where Farooq and associates (77–80) performed elaborate observational studies of the daily social, occupational, and religious uses of water in a Nile Delta village. They noted that schistosomiasis was more prevalent among Muslims than among Christians, presumably owing to the frequent Islamic practice of *wudu,* or ritual ablution before prayer. Since then, a number of other investigators in Africa have studied how individuals became infected through water-contact activities (47, 72, 84, 142, 143, 146, 192). Much less attention has been paid to ways individuals infect water through urination and defecation into waterways. Cheesmond & Fenwick (38) showed that excretory behaviors in an area of the Gezira, Sudan, served to diminish the chances of schistosomiasis transmission. Namely, they observed that excretory episodes occurred in sites far removed from bodies of water, privacy being a more important consideration than proximity to water for purposes of ablution.

Sexually transmitted diseases (STDs) and labor migration The crucial role of human behavioral factors in the dissemination of sexually transmitted diseases (STDs) has been known for hundreds of years and is a reason why these conditions were dubbed "social diseases." However, the need for social scientific studies of the behaviors placing individuals at risk from STDs—and of the sociocultural determinants and consequences of those behaviors—has only been recognized recently. This need has been made more urgent by the appearance of AIDS during the past decade (13, 81, 97, 127, 176). Prior to the recognition of AIDS as a widespread problem in sub-Saharan Africa, a number of behaviorally oriented researchers working in that region (7, 15, 49, 173, 197, 219) noted the roles of rural-to-urban migration and prostitution in the transmission of STDs, primarily gonorrhea. The typical pattern of transmission included the following components: Young men from rural tribal areas—areas plagued by political upheaval, unemployment, rapid modernization, and the uneven distribution of economic opportunities—migrate to cities, where they make up the clientele of prostitutes operating from bars, brothels, dance-halls, and the street. These prostitutes, who face the same economic pressures as the males and are mostly young (aged 15–30), rural-born, uneducated, unmarried (often as the result of abandonment by nonreturning migrant husbands), and highly mobile, constitute the major reservoir of sexually transmitted infection. The risk of STD transmission is even further increased when men migrate to isolated labor camps and mines where, characteristically, a small number of prostitutes have sexual relations with a large number of men (155). Upon accumulating sufficient wealth, these men return to their natal towns and villages, where they infect their regular sex partners, usually their wives, who may be rendered infertile as a result of STD-induced reproductive pathology. This triad of migration, prostitution, and STD has been recognized in other areas of the nonindustrialized world as well (106, 133, 175, 183, 199). It is impossible to overemphasize the impact of this cycle of STD transmission on the serious sociomedical problem of infertility in these populations (169).

AIDS and sexual behavior The above-described pattern of STD transmission is also responsible in large part for the rapid spread of AIDS in sub-Saharan Africa and is a primary reason why the epidemiological profile of AIDS in Africa is radically different from that in the United States (81, 97, 155). In Africa (*a*) the infected population comprises primarily heterosexuals, (*b*) prostitution plays a dominant role in the transmission of the human immunodeficiency virus (HIV), and (*c*) the epidemiology of the disease is largely explained by economic influences on male labor migration patterns (155). In the United States, on the other hand, early cases of the disease were reported almost exclusively among gay and bisexual men in New York City and San Francisco (48). Since the early 1970s, these urban epicenters had already had a high prevalence of STDs among gay and bisexual populations, especially among the more sexually active men in the so-called "fast lane" (97, 148). When AIDS appeared in the United States in the early 1980s, an initial reaction to the epidemic in the gay community was denial; the severity of the AIDS epidemic was deemphasized in the interest of preserving the sexual values and institutions that represented the successful political struggles of gay liberation (97, 209). Among these institutions, bathhouses (and the sexual behaviors they encouraged) particularly facilitated the transmission of STDs, including HIV, in urban gay centers (209). By the mid-1980s, however, many gay and bisexual men began to modify their sexual behavior, especially by reducing the number of casual partners (36); the extent of this behavioral change toward "safe sex" is remarkable.

Ethnomedical Beliefs Regarding Etiology, Diagnosis, and Cure

RESEARCH NEEDS Although behavioral studies of the kind cited above can provide useful information on infectious disease transmission, they are nevertheless limited in their utility if they do not proceed beyond the observational level. As Dunn (62:503) has cautioned in his discussion of schistosomiasis and water contact, "A further series of studies . . . will be needed in each situation to specify why people behave as they do, where and when . . . Any effort to change human behavior must rest on such studies." Dunn's call for anthropological studies that answer the all-important "why" question—by identifying the social, cultural, and psychological correlates of human behavior relating to infectious disease, including indigenous beliefs about etiology, diagnosis, and cure—has been reiterated by a number of other anthropologists (33, 97, 109, 184).

Nation's (184) recent survey of the literature revealed that ethnomedical studies of lay recognition, etiology, and treatment of infectious diseases are even rarer than behavioral studies, in part because of the entrenched belief in the biomedical community that indigenous beliefs and practices are irrelevant to the problem at hand. Yet, information of this sort is of the utmost importance in ensuring the success of public health efforts.

RESEARCH EXAMPLES The need for such information becomes clear in the literature on ethnomedicine and infectious disease, a number of examples of which are included here.

Diarrhea and folk beliefs In her study of indigenous beliefs surrounding infant diarrhea in northeastern Brazil, Nations (184) argues that traditional "folk beliefs," disdained by the epidemiologists and biomedical practitioners working in this area, could not be more relevant to controlling this widespread problem. These beliefs, she demonstrates, are intimately tied to epidemiological issues, such as (*a*) underreporting of infant mortality, (*b*) detection of morbidity and establishment of accurate attack rates, (*c*) identification of high-risk populations, (*d*) identification of behavioral risk factors, and (*e*) generation of testable analytical epidemiological hypotheses. These issues are apart from that raised by frustrated physicians, of why more children with severe diarrhea and dehydration are not brought to physicians sooner, when the chances of saving them are greater. Nations concludes that the beliefs of poor Brazilian mothers regarding the recognition, etiology, and treatment of childhood diarrheal illnesses are the key to this problem.

Another example of the importance of ethnomedical beliefs for the successful treatment of an infectious disease is provided by the work of Kendall and coworkers (137) in Honduras. They showed that diarrhea thought to be caused by the folk illness *empacho* was consistently *not* treated with oral rehydration therapy, since *empacho* was thought to warrant a purgative cure.

Dracunculiasis and contaminated water Dracunculiasis (guinea worm disease) is a parasitic disease characterized by the presence of long adult worms in subcutaneous tissues, usually of the leg. When infected individuals step into waterways, the female worms vomit their eggs into the water via small ulcerations on the infected individual's skin (114). If water fleas, the intermediate host of the parasite, are present they become parasitized and transmit disease to humans, who ingest them while drinking. Dracunculiasis is, in fact, the only infectious disease that could be completely eliminated if all populations living where the parasite is endemic were provided with—and used—safe drinking water (113). Because of the importance of water in the transmission cycle, dracunculiasis has been targeted by a number of international agencies, including the UN, WHO, and the World Bank, as the primary focus of their International Drinking Water Supply and Sanitation Decade (1981–90) (152). However, studies (74, 220) carried out in villages in Ghana and Nigeria—where the disease has been called the "annual festival of agony"—showed that, despite eradication efforts, few individuals thought the disease was preventable or were aware of the mode of transmission of the parasite through contaminated drinking water. Rather, the disease was attributed to heredity, transmission through soil or blood, person-to-person contact, or even the god of smallpox (2). In addition, efforts to prevent secondary infections in dracunculiasis ulcers, a significant cause of absenteeism in schools and agricultural settings throughout West Africa (126, 188), were hampered by local methods of treatment, some of which exacerbated the dracunculiasis wounds or prevented healing (73, 74).

African trypanosomiasis and brush removal Another example of the need for ethnomedical studies revolves around African trypanosomiasis, or "sleeping sickness." In the 1930s and 1940s, the British colonial government attempted to rid the tribal Hausa peoples of northern Nigeria of the often fatal disease through efforts by biomedical personnel to explain the nature of the disease, its transport by flies, and the necessity of controlling it by slashing brush near streams to eliminate fly breeding areas. But, as Miner (178) explains, the Hausa refused to believe that brush was related to the illness, which they attributed to spirit possession. The control program was eventually carried out by force, and the Hausa were convinced to slash the brush once a year, thereby virtually eliminating the disease. But, when asked later why they cut the brush, the Hausa replied that they were forced to do so, and many people wanted to discontinue the practice. In short, the biomedical connection among brush, flies, and sleeping sickness never successfully replaced the Hausa's indigenous beliefs about the etiology of the illness.

Malaria and traditional medicines and foods Other researchers working among the Hausa have examined traditional means by which they have coped with malaria. Etkin & Ross (75, 76) have identified 31 antimalarial plant medicines used by either herbal specialists or the general population. Some of these medicinal plants have been shown to change the oxidation-reduction status of red blood cells, a physiological condition known to impede development of the malaria parasite (71). Furthermore, parasitological tests of extracts of these traditional medicines, using a mouse model of malaria, showed that three of the substances were highly effective cures. Similarly, in China, a promising compound, artemisinin, extracted by chemists from a traditional antimalarial treatment (*quing hao,* or "green herb," related to *Artemisia annua),* has recently been identified (139). Such biochemical evaluation of native ethnopharmacopoeias for the effectiveness of antimalarial treatments, which has its historical roots in the discovery of quinine, has gained added significance with the evolution of chloroquine-resistant strains of the disease. In addition, in dietary studies from Liberia, Jackson, who has examined Liberian mothers' folk classification of malaria symptoms (128), has hypothesized that regular cassava consumption may curtail parasite growth and development in humans, because of the minute amounts of lethal cyanide contained in traditional cassava foods (unpublished manuscript).

Trachoma and ethno-ophthalmological practices Trachoma, the leading cause of preventable blindness in the world, is a bacterial eye disease whose transmission is highly dependent on individual and community hygiene (for a comprehensive review of social factors relating to trachoma transmission, see 165, 166). Medical anthropologists working in rural Egypt where the disease is endemic have examined the behaviors that place individuals at risk of trachoma (153) and described the traditional beliefs and practices surrounding eye disease in general and trachoma in particular (177). Millar & Lane (177) showed that Egyptian villagers had a complex repertoire of "ethno-ophthalmological" practices to treat trachoma, including mineral substances applied to the eyelids, surgical curettage of the inner surfaces of the eyelids with a razor blade, and blood-letting from the temples to let the "bad blood" out of the inflamed eyes. These practices can all be traced to earlier literate medical systems in Egypt, dating back in some cases to Pharaonic times. Lane & Millar argued that decisions to use traditional or biomedical treatment depended more on the individual's status in the family or community than on belief in traditional-vs-biomedical etiologies of the disease (154). As a result, individuals with less social status, particularly adult women and children, were more likely to receive less highly valued traditional remedies—despite their elevated risk of trachoma and (among women) blindness.

Local Responses to Infectious Disease Control Programs

Given the small size of the discipline of anthropology, its contributions to international health and disease control programs have been significant (216). In their early role in such efforts, anthropologists served as cultural interpreters and "troubleshooters," who were brought into programs following negative community responses. Anthropologists demonstrated that public health interventions succeeded first by being acceptable to the public. This was

especially important in international programs, where recognition of differences in community organization, cultural values, and preexisting health beliefs was critical. Paul's edited volume, *Health, Culture, and Community* (189), provided important case studies of community reactions to health programs, most of which involved infectious disease prevention or control.

Thus, part of the early anthropological contribution to infectious disease control programs involved identifying social and cultural "barriers" to local-level acceptance of innovations. For example, a cholera vaccination program in China, following epidemics in the 1940s (117, 118), was hindered by the fact that villagers had their own ideas, both "scientific" and "magico-religious," about the cause of the outbreak; for most villagers, prevention did not involve acceptance of an injection. Similarly, in Bang Chan, Thailand, only a handful of villagers availed themselves of diphtheria immunization, because the channels of communication used by public health workers never reached the majority of the rural populace (103). Heggenhougen & Clements (107) have summarized more recent applied anthropological work on the effective delivery of immunizations. Of particular interest is the "checklist" of reasons for low immunization coverage developed by Brown (25); it includes behavioral attributes of both the participating population and health providers.

Following initial anthropological activity in international health programs, Foster, who had much experience in such work (85–87), warned of the danger of inappropriately blaming "culture" for failures caused instead by the attitudes and behaviors of health care planners and providers (85). This recognition was based in part on Polgar's (194) insightful analysis of "four fallacies" afflicting international public health endeavors: (*a*) the fallacy of empty vessels; (*b*) the fallacy of the separate capsule; (*c*) the fallacy of the single pyramid; and (*d*) the fallacy of interchangeable faces. Such critical questioning of the intellectual premises underlying both biomedicine and the organization of health care probably played a role in the development of "critical medical anthropology." The tradition of ethnography applied to the critical analysis of international health programs is best exemplified by the recent work of Justice in Nepal (132).

Theoretically, the ultimate goal of infectious disease control programs is the reduction of disease transmission to the point where the disease organism becomes eradicated. Such an outcome has been achieved for only one disease—smallpox—through a coordinated, global effort completed in 1978 (116). This remarkable accomplishment of international public health involved minimal anthropological expertise—namely, Morinis's assessment of the flow of smallpox case-detection information in rural markets in India (180). Toward the end of the eradication effort, Foster & Deria (88) developed a culturally acceptable method of case isolation among Somalian pastoralists by adapting a traditional technique used for sick camels.

Yet, control programs aimed at reduction of a single disease identified by outsiders can meet with resistance from local populations. Various programs to eliminate hookworm (63, 85, 87, 125) and malaria (105) appeared, from the people's point of view, too concentrated on a seemingly minor health problem. In the tea plantations of Ceylon, the Rockefeller Foundation's 6-year program to eliminate hookworm through treatment and installation of pit latrines was a failure. Far from being grateful to public health workers, tea pickers actively opposed the program because of its dull routine and focus on what they deemed an unimportant problem (190). Likewise, a malaria control program using insecticide spraying in Surinam met resistance from local populations; reasons for the reluctance ranged from fear of the insecticide and its effects on animals and local gods to disbelief about the relationship between mosquitoes and malaria (12). More recently, MacCormack (163), who has worked in malaria control activities in Africa, has encouraged the treatment of traditional sleeping nets with residual insecticides.

In addition to direct participation in malaria control programs, some anthropologists have focused on the demographic, economic, and cultural effects of successful malaria control in such locations as Mexico (108), Sardinia (29), Sudan (98), and Sri Lanka (31). Brown (28) has described this approach as the anthropology *of* disease control, since these researchers view health improvements as the result of outside influences on social and cultural change. This approach contrasts with the application of anthropological knowledge *in* disease control programs. An example of the latter approach is provided by the work of Gordon (96), who examined the causes and local perceptions of the vector-borne disease dengue fever in an urban area of the Dominican Republic. As part of a mixed-strategy intervention program, Gordon's survey demonstrated significant changes in people's explanatory models of dengue, although such changes were not accompanied by a reduction of sources for the mosquito vector, *Aedes aegypti*.

Widespread medical anthropological interest in primary health care (PHC) (19)—including such key strategies as oral rehydration therapy (44)—is, in fact, aimed primarily at the reduction of infectious disease morbidity and mortality. Because PHC requires more community participation and adaptation of culturally acceptable and affordable health technologies than did the older, vertically oriented disease control strategies, this is an area where anthropological research contributions will be especially critical.

CONCLUSION: THE IMPORTANCE AND LEGITIMACY OF INFECTIOUS DISEASE RESEARCH IN MEDICAL ANTHROPOLOGY

Anthropological studies of infectious diseases comprise an impressive literature characterized by a broad range of theoretical paradigms and research

methodologies. We have examined this rich body of research, categorizing it according to three basic orientations—biological, ecological, and sociocultural. Note that research related to the interaction of humans and infectious disease agents is not limited to medical anthropology. Indeed, this subject requires discussion of classic research questions in biological anthropology, archaeology, cultural ecology, ethnomedicine, and applied anthropology in international health. A focus on infectious disease requires us to bridge the gap between the cultural and biological subfields and to return to a holistic perspective.

Nevertheless, there are four reasons why medical anthropologists in particular should pay increased attention to infectious disease research. First, infectious diseases have acted throughout human history as important agents of selection for both biological and behavioral characteristics of the species. Second, the distribution of infectious diseases is significantly influenced by human actions that affect ecology, since infectious agents make up an important part of that ecology. As such, culturally coded behaviors provide critical clues for understanding the social epidemiology and potential control of such diseases. Third, infectious diseases represent the most important cause of suffering and death in societies traditionally studied by anthropologists. The origins of this suffering must be analyzed from both micro- and macrosociological perspectives, including the political-economic one. And, finally, applied medical anthropologists must be equipped to work within the biomedical paradigm if they hope to be effective in improving infectious disease control programs or health care delivery. This does not imply, however, that they should be limited to that paradigm.

In recent years, many medical anthropologists have abandoned the research directions described in this review. Concepts such as adaptation to disease, while still prominent in teaching texts (168), are receiving less than adequate attention from researchers. Even worse, the charge has been made that medical anthropologists who utilize biomedical categories (e.g. the diseases described above or epidemiological concepts) have been "coopted" by the intellectual hegemony of Western biomedicine. This accusation by critical medical anthropologists has three basic elements: 1. that because all reality—including the processes of sickness and health—is socially constructed, biomedicine is predicated upon culturally limited assumptions about fundamental categories like "causation" and "disease"; 2. that diseases are only the proximate causes of human suffering, since the ultimate etiologies involve political and economic inequality (the so-called "political economy of health"); and 3. that the institution of biomedicine itself functions to maintain social inequalities. These criticisms, which are not altogether new, have merit; but they do not contradict the basic findings of the literature described here, which does not advocate an unquestioning acceptance of biomedicine.

In fact, anthropological research in infectious disease reemphasizes the long-standing claim of medical anthropology that culture "manufactures" disease in two ways. First, societies actively change their ecology so as to increase or decrease the risk of particular diseases. Second, culture provides a theoretical system for understanding—and attempting to manipulate through medicine—the diseases that cause human suffering and death. As students and interpreters of societies and cultures, anthropologists cannot afford to ignore the infectious diseases, because coping with them is a universal aspect of the human experience.

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