Factors Contributing to the Occurrence of Emerging Infectious Diseases

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Emerging infectious diseases (EIDs) have been receiving increasing attention for more than two decades. Such attention has resulted from observations of increasing resistance of microorganisms to the usual antibiotics, the identification of formerly unknown disease agents and the diseases they cause, and the realization that the concept of globalization includes global exposure to disease agents formerly confined to small, endemic, or remote areas. Sadly, in the fall of 2001, the potential for using microbial agents as instruments of terror and destruction became obvious with the incidents of anthrax spread in the United States, mainly through the mail, although chemical and biological agents had already been used in this way in the past century. The relationship between infectious diseases and social, political, and economic change from the earliest times to the present has been well documented. Emerging infectious diseases and their basic causes present a threat to the stability of nations and indeed the world. Reasons for the emergence/reemergence of infectious diseases are complex and interrelated. The global village provides global economic and social opportunities but also opportunities for disease emergence and transmission. Although characteristics of microorganisms such as genetic adaptive changes are important in the emergence of infectious diseases, factors under human control play a large role. Behavioral and lifestyle choices are also a major influence on the emergence and spread of many EIDs and require attention. Factors contributing to the appearance of emerging and reemerging infectious diseases are discussed.

BIOLOGICAL RESEARCH FOR NURSING
Vol. 4, No. 4, April 2003, 258-267
DOI: 10.1177/1099800403251238

Key words: *emerging infectious diseases, bioterrorism, demography, prevention, infectious disease, public policy, bacterial diseases, viral diseases, parasitic diseases*

Emerging infectious diseases (EIDs) have been receiving increasing attention for almost two decades, most particularly since the oft-referenced Institute of Medicine (IOM) report was published in 1992 (Lederberg and others 1992). Such attention has resulted from observations of increasing resistance of microorganisms to the usual antibiotics, the identification of formerly unknown disease agents and the diseases they cause, and the realization that the concept of globalization includes global exposure to disease agents formerly confined to small, endemic, or remote areas (Lashley 2002a; Lederberg and others 1992). Sadly, in the fall of 2001, the potential for using microbial agents as instruments of terror and destruction became obvious with the incidents of anthrax spread in the United States, mainly through the mail, although chemical and biological agents had already been used in this way in the past century. Chavers and others (2002) describe the emergence and reemergence of infectious diseases as occurring, at least in part, because of "changes in the dynamics of human activity within the context of nature, mediated by new technologies" (p 7).

Various authors and historians have documented the relationship between infectious diseases and so-

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cial, political, and economic change from the earliest times to the present. Developed nations have recognized that emerging infectious diseases and their basic causes present a threat to both their own and world stability. This further accentuates the idea of the nonisolation of nations and the connectivity of events. Not all of the changes in practices that influence infectious disease emergence that are described below were seen to have wide-ranging consequences at the time they occurred or were implemented. Thus, even alterations that seem relatively simple at first blush, such as combining duck and pig farming in Hong Kong to improve productivity, may produce unintended disease-related effects—in this case, the recombination of the genes of an avian variety of the influenza A(H5N1) virus to produce a mutant strain that infected humans, with the potential to cause a large influenza pandemic (Centers for Disease Control and Prevention 1998). Prevention of such a spread included the destruction of hundreds of thousands of animals.

This paper will look at factors that contribute to the emergence and reemergence of infectious diseases in broad categories with specific examples. These are summarized in Table 1, and each is considered in further detail below. Emerging infectious diseases may be thought of as the following:

- newly identified diseases caused by a previously known microorganism (e.g., variant Creutzfeldt-Jakob disease [vCJD] and group A *Streptococcus* resulting in toxic shock syndrome);
- newly identified diseases caused by a previously unknown or unrecognized microorganism (e.g., human immunodeficiency virus [HIV]);
- known diseases newly realized to be caused by a previously known microorganism (e.g., peptic ulcer found to result from *Helicobacter pylori* infection);
- diseases and microorganisms found in new geographic areas (e.g., West Nile virus in the Western Hemisphere causing the introduction of encephalitis and cholera into the Americas);
- microorganisms found to be resistant to antimicrobial agents (e.g., vancomycin-resistant enterococci [VRE], multidrug-resistant tuberculosis and methicillin-resistant *Staphylococcus aureus* [MRSA]);
- microorganisms of animals that have extended their host range to newly infect humans (e.g., *Bartonella henslae* causing cat scratch fever and cryptosporidiosis);
- newly identified reservoirs for microorganisms (e.g., the 1966 identification of cattle as reservoir hosts for *Trypanosoma brucei* rhodesiense, the cause of Rhodesian sleeping sickness) (Haydon and others 2003);
- microorganisms that have become more virulent or changed characteristics in other ways—this can occur as a result of microbial evolution and can occur in virtually any organism (e.g., *Escherichia coli* O157:H7);
- known diseases that have markedly increased in incidence (e.g., diphtheria and pertussis, especially in nations with deteriorating public health infrastructure) (Lashley and Durham 2002; Lederberg and others 1992).

In some cases, identifying the cause of certain EIDs may await the development of appropriate diagnostic technology such as the molecular methods now being applied to tuberculosis (Yang 2003). It is anticipated that various cancers and chronic illnesses will ultimately be shown to have a microbial contribution (Kuo and Campbell 2003; Lashley 2002b, 2002d).

Demographic Factors, Population Characteristics, and Living Conditions

Demographic factors contribute to the emergence and reemergence of infectious diseases in a variety of ways, and these are highly interrelated. The world population continues to increase, with a high proportion of very young persons and an increasing proportion of elderly persons. The proportion of elderly persons older than age 80 years is increasing in developed countries. Conditions of crowding and close living quarters have long been known to increase chances of acquisition of infectious diseases such as tuberculosis and other airborne communicable diseases. These often are associated with rapid population growth, urbanization, poverty, poor sanitation, poor hygiene, unsafe water and food, and exposure to animal reservoirs and pests. The very young, elderly, and those who are immunosuppressed may be particularly vulnerable. Medical advances have contributed to increasing the

Table 1. Factors Contributing to the Occurrence of Emerging Infectious Diseases

Factor	Example
Demographic factors, population characteristics and living conditions	Tuberculosis (TB), dengue
Sociocultural patterns and human behavior	Cyclosporiasis, cholera, HIV, hepatitis C, Ebola
Travel/recreation	Cryptosporidiosis, Legionnaires' disease, gastrointestinal illnesses
Economic factors/decreased public health infrastructure	TB, dengue, vaccine-preventable diseases
Weather/climate changes	Hantavirus pulmonary syndrome, malaria, dengue, various tick-borne fevers
Advances in health care and technology	Variant Creutzfeldt-Jakob disease (vCJD), HIV
Natural disasters/manmade conflicts	Coccidioidomycosis vaccine-preventable diseases, cholera
Environmental alterations	Rift Valley fever, Venezuelan hemorrhagic fever, Argentine hemorrhagic fever, vCJD, Lyme disease
Antimicrobal resistance/ microbial adaptation	Multidrug-resistant tuberculosis, Methicillin-resistant *Staphylococcus aureus*, Vancomycin-resistant enterococci
International release of microbes	Anthrax, smallpox, plague, tularemia, foot and mouth disease

SOURCE: Cohen and Larson (1996); Chavers and others (2002); Lashley (2002a).

numbers of persons living to an older age, which is associated with immune suppression, and have also resulted in more persons who are living with varying degrees of immune dysfunction due to certain medical therapies. These factors contribute to host susceptibility to microbial pathogens, and the crowding allows easier transmission of organisms from person to person. Malnutrition, also associated with poverty, can result in immunosuppression and susceptibility to infection (Morris and Potter 1997). Poor sanitation, unsafe food and water, and poor hygiene contribute to the emergence of infectious diseases.

Lacking basic clean water to drink or in which to bathe is still a major issue for a substantial portion of the world's population. Waterborne emerging infections may result from the ingestion of contaminated drinking water or through immersion in contaminated water. Infections most frequently resulting from contaminated drinking water are gastrointestinal illnesses. *E. coli* O157:H7 has been reported to have been transmitted from a fecal accident in a water park, for example, and cryptosporidiosis due to the parasite *Cryptosporidium parvum* affected more than 400,000 people in Milwaukee, Wisconsin, in 1993 (MacKenzie and others 1994).

Sociocultural Patterns and Human Behavior

Another major category is that of social customs, cultural practices, and human behavior. This is a very large category, and one might argue that to some degree, it is overarching—for example, war might be considered a consequence of human behavior as well as fitting under the category of manmade conflicts. One recent change is that of eating patterns, especially in developed countries. There is an increased demand for organic, exotic, internationally distributed foods and for out-of-season produce. The latter has resulted in increased importation from some developing countries where the agricultural practices may compromise food safety. An example of this has been the outbreaks of diarrhea and other gastrointestinal manifestations due to *Cyclospora cayetanensis*, which in some U.S. outbreaks resulted from eating raspberries imported out of season from Guatemala (Centers for Disease Control and Prevention 1997). In some instances, eating contaminated organically grown alfalfa sprouts resulted in infection with *E. coli* O157:H7. The widely recognized incidence of an *E. coli* O157:H7 outbreak due to consumption of undercooked fast-food hamburgers in several western states was the first recognition of the virulence of that strain (Mohle-Boetani and others 2001).

An example of an outbreak from consumption of internationally distributed foods was that of a cholera outbreak in Maryland resulting from ingestion of frozen coconut milk imported from Southeast Asia (Centers for Disease Control and Prevention 1991). Other food-related behavior changes are a higher reliance on convenience foods from fast-food restaurants and take-out facilities in supermarkets, as well as situ-

ations of partial food preparation where, for example, melons are sliced and microbes on the outer surface have the potential to contaminate the interior portion. *Salmonella* serotype sonnei and serotype Poona have been transmitted in this way (Centers for Disease Control and Prevention 2002b). There is also a greater prevalence of food served at salad bars or buffets, allowing greater temperature variation and/or contamination. As developed countries become more multicultural as well as adventurous in food tastes, various food practices may become popular throughout the population, some of which pose health risks. For example, habits of eating raw or lightly cooked foods of animal origin such as ceviche, sushi, sashimi, or raw ground beef may result in a variety of illnesses (Lashley 2002a).

Another change has been that of more child care outside the home in developed countries, often in congregate settings such as day care centers. This creates conditions of closer contact than would probably be experienced inside the home. It also increases the number of people to which any individual is exposed and enhances the opportunities for the spread of airborne infections and those spread because of inadequate handwashing, especially in situations of diaper handling. It also exposes more people to potentially infected food handlers. Increased sexual freedom has accelerated the spread of HIV infection throughout the world. For many, behavior can be a major factor in increasing exposure to EIDs but often is difficult to modulate. For example, HIV in adults is mainly spread through unprotected sex and injectable IV drug use, both of which could be virtually ended by different behavioral and lifestyle choices. Likewise, the body art practices of piercing body parts and tattooing promote transmission of hepatitis C and HIV. The death ritual practices surrounding the funerals of those who died of Ebola hemorrhagic fever among certain African peoples has contributed to the spread of the Ebola virus to participants (Fahey 2002).

Travel and Recreation

More and more people are traveling both for business and for pleasure. Travel and recreational pursuits can expose people to emerging infectious diseases they might not ordinarily encounter. Virtually any destination can be reached in less than 36 hours, allowing unprecedented potential for the global spread of microbes. Increasingly, destinations for leisure travel are from developed to developing countries. In such instances, the traveler may be exposed to endemic infections for the country they are visiting, may become infected themselves, and can also transport the microbe back either on their body or via their luggage or even souvenirs (Lashley 2002e). An example of the latter is given by Smith (1995) in which a girl became infected with cutaneous anthrax through a souvenir camel-hair saddle brought from Pakistan. Furthermore, adventurous pursuits such as spelunking, eating unusual foods, seeking sexual adventures, or adopting the indigenous cultural practices provide the opportunity for contact with organisms travelers would not usually encounter, especially zoonoses (Lashley 2002e). Cryptosporidiosis may be acquired from contaminated swimming pools, and gnathostomosis, caused by a nematode, has been acquired by travelers in Mexico through eating ceviche in which the fish was cooked only by marinating it in citrus juice (Rojas-Molina and others 1999). Cruise ships have had outbreaks not only of gastrointestinal diseases but also of influenza and Legionnaires' disease (Lashley 2002e). In the fall of 2002, Norovirus (formerly called "Norwalk-like virus") infections became particularly troublesome.

Migrants and immigrants may also be thought of as a type of traveler for reasons other than recreation. Those migrating because of disasters or war are at high risk for emerging infectious diseases because they are often stressed, undernourished, and exposed to crowded and unsanitary living conditions without shelter from animals and disease vectors. Migrants also bring their endemic diseases to their new locale. Cases of malaria acquired in the United States have been postulated to result from the bite of an infective *Anopheles* mosquito that acquired *Plasmodium vivax* through biting a person already infected with malaria and then transmitting it to another person (Centers for Disease Control and Prevention 2002a). Thus, areas for higher risk for this sort of transmission are those with higher concentrations of persons who have migrated from malaria-endemic countries.

Economic Factors

Economic shifts (sometimes due to politics) may also contribute to disease in other ways than those al-

ready mentioned such as impaired public health infrastructure. When it was thought that infectious diseases had been "conquered" in the United States, public health surveillance, reporting, and preventive resources for infectious diseases were shifted to other areas. Breakdowns in these important structures do not allow rapid recognition of a pattern of infectious disease outbreaks and proper concomitant communication. When attention, including monetary support of such public health programs, diminished, few personnel were dedicated to certain surveillance and infectious disease activities in many states. Diminished budgets also limited the necessary follow-up activities once a case had been identified (Berkelman and others 1994). Economic issues can affect such basic programs as immunization.

Dengue had largely been kept in check in the Americas by a strong public health program aimed at eradication of the mosquito vector. This program was discontinued in the early 1970s, and by the 1980s, major epidemics had been reported. Other factors also contributed to the resurgence of dengue. Changes in weather and even slight global warming favor dengue vectors and the expansion of their range. Urbanization provides environments favorable for mosquito breeding. Environmental concerns have also led to restrictions on the use of the insecticides that were originally used for vector control, allowing proliferation of mosquitoes and disease expansion (Gubler 1998).

Weather and Climate Changes

Changes in weather patterns, jet stream changes, global warming, and other types of climactic changes can affect infectious diseases. An example is the El Niño southern oscillation (ENSO), a cyclical, recurring oceanic/atmospheric disruption that resulted in increased precipitation and vegetation in the southwestern United States in 1993. One of the results of this increased vegetation was increased food and shelter for small rodents. This led to an increase in their population. One outcome was the first recognized outbreak of hantavirus pulmonary syndrome (HPS) in the southwestern United States (Engelthaler and others 1999). HPS is due to the Sin Nombre hantavirus, and certain mice carry the virus. The virus is transmitted to humans with exposure to the excreta of the mice through inhalation, skin contact, or possibly through ingestion (Groom and Cheek 2002). ENSO is thought also to have other effects such as droughts and, as a consequence, fires, which change crop production and may decrease food sources, leading to impaired nutrition. The increase in average global temperatures, warmer weather, and receding freezing zones that have been experienced over the past few years have resulted in expanded ranges for and increases in insect populations that can carry microbes for diseases such as malaria and dengue fever. Thus, mosquito carriers of the organisms causing these diseases are being seen in other areas as well. These changes also have resulted in vegetation changes. For example, increased vegetation in higher altitudes provides sustenance for insects and animals not usually found in those areas but which can then establish themselves there, possibly bringing disease-causing microorganisms with them. An example is the shift in distribution of tick-borne fevers in Sweden.

Advances in Health Care and Technology

Advances in health care and related technology also may have unintended consequences. Organ and tissue transplantation may be associated with immunosuppression, making the affected person more susceptible to infectious diseases. Moreover, the donor tissue may be infected with a transmissible agent. An example of this is the acquisition of Creutzfeldt-Jakob disease from both corneal and dura mater transplants. Another example is the transmission of West Nile virus through blood transfusion (Centers for Disease Control and Prevention 2002d). Immunosuppressive drugs used to treat cancer, arthritis, and other diseases make hosts more susceptible to opportunistic and other infections. Better therapy and longer lives for those with primary and secondary immunodeficiency diseases also increases the opportunity for opportunistic infections to arise. Increased catheter use and the use of semipermanent openings in the body for therapeutic reasons also may result in increased infection. The widespread and sometimes inappropriate use of antimicrobial therapy can lead to the development of antimicrobial resistance, leading to increased incidence and frequency of diseases such as multidrug-resistant tuberculosis, chloroquine-resistant malaria, and drug-resistant *Streptococcus pneumoniae*, some-

times called pneumococcus, which is the most frequent cause of otitis media, pneumonia, meningitis, and sinusitis in the United States. Using pooled plasma concentrates to treat persons with hemophilia unintentionally resulted in the ability of an HIV-contaminated blood donation from one donor to be transmitted to many recipients.

Even the increased use of animals in research and for vaccine production has resulted in an emerging infectious disease outbreak, although limited in scope. In 1989, numerous monkeys were imported to the United States from the Philippines, specifically to a primate facility in Reston, Virginia. Some were soon noted to be ill, and eventually it was discovered that they were infected with a virus now known as Ebola-Reston. Fortunately, unlike other strains of the Ebola virus, this one did not have a predilection for humans (although some of their handlers had serologic evidence of infection with Ebola-Reston without symptoms) and was able to be contained via quarantine and destruction of the infected animals (Centers for Disease Control and Prevention 1990). It is feared that some Ebola strain might evolve to be spread by airborne transmission.

Natural Disasters and Manmade Conflicts

Natural disasters such as earthquakes, floods, and famine and manmade conflicts such as wars, civil conflicts, and political unrest may have similar consequences. Earthquakes may lead to conditions described above such as crowding, inadequate and/or contaminated food supplies and malnutrition, unsafe water, poor sanitation, stress, exposure, and aerolization of microorganisms in dust. For example, an outbreak of coccidioidomycosis (a fungal infection affecting the respiratory tract) followed the 1994 Ventura County, California, earthquake, which exposed a broader population to increased levels of windblown dust contaminated with *Coccidioides immitis*, which is endemic in that area (Centers for Disease Control and Prevention 1994). Wars, civil conflicts, and political unrest may also lead to unsafe food and water, crowding, stress, poor sanitation, famine, malnutrition, sexually transmitted disease outbreaks, and migration of certain population groups, both exposing that population to other diseases and exposing other populations to the migrants' endemic diseases.

Breakdown in public health systems may also result in the appearance of vaccine-preventable diseases such as diphtheria and polio. Beyond this, health care workers may be seen in some countries torn by civil conflict as representing the government and be targeted by rebel forces for those reasons. An example was in Nicaragua when the "contra" rebels attacked government health workers and clinics, and expansion of malaria was part of the result (Chavers and others 2002; Garfield and others 1987). Infectious diseases have also played a historical role in conflict and wars. Peters (2001) reports on studies that indicate that the Aztecs were unable to stop the Spaniards from taking Mexico City, not because the Spaniards were better soldiers but because the Aztecs were devastated by smallpox, which had been introduced into their susceptible population by the Spaniards and had run rampant. Social consequences often follow large pandemics, including turmoil; panic; stigmatization of sufferers, their families, and subgroups blamed for the disease; religious revivals; rampant rumors; and economic consequences (Peters 2001).

Environmental Alterations

Alterations in the environment both for agricultural and other purposes may result in the emergence of infectious diseases. Irrigation projects and the building of dams can alter water levels, affecting the mosquito populations. For example, construction of the Aswan Dam in Egypt was intended to slow the Nile River, prevent annual Nile flooding, and create a large lake. The floodlands formed in this way, however, provided an opportunity for the proliferation of mosquitoes that carried Rift Valley fever, a zoonotic disease of animals such as camels and cattle usually found in sub-Saharan Africa. It was believed that the 1977-1978 epidemic began with an outbreak of Rift Valley fever among livestock in northern Sudan, and infected mosquitoes with increased breeding opportunities found human hosts. In all, more than 20,000 people were infected. In 1997-1998, a large outbreak occurred in Kenya following heavy rain and flooding, illustrating the effects of a natural disaster on the occurrence of emerging infectious diseases (Woods and others 2002; Garrett 1994).

Agricultural practices can also have unintended effects. The decision to change grassland to the cultivation of maize in a part of Argentina is an example of environmental alteration with the intention of bettering the lot of the people that had unintended consequences. In this case, the maize crop favored a particular rodent that was the natural host for Junin virus, which causes Argentine hemorrhagic fever. Human cases of this fever appeared as the maize cultivation increased (Morse 1995). Another agricultural practice was that of increasingly using recycled rendered ruminant tissues in animal feed as a cheaper source of protein. This practice coincided with endemic scrapie in sheep in the early 1980s, and it is believed to be responsible for the outbreak of bovine spongiform encephalopathy (BSE) seen in British cattle and associated with the development in humans. These events have had severe economic and political consequences and resulted in widespread slaughter of ruminants in Great Britain. The first known case of vCJD has now been recognized in the United States in a woman born in Great Britain (Centers for Disease Control and Prevention 2002c).

The clearing of a forested area in Venezuela in 1989 was believed to stir up dust contaminated with cotton rat excreta, leading to outbreaks of Venezuelan hemorrhagic fever (Morse 1995). In the United States, forested areas have been cleared for suburban development. The trend for building homes near wooded areas brings humans into closer contact with disease-bearing vectors. An example of this is Lyme disease, caused by *Borrelia burgdorferi*, which is transmitted by a particular tick that lives on forest animals such as deer, which tend to dwell at the edge of forested areas. Thus, clearing the land and allowing people to live close to these areas brings the animals, the vectors, and humans into close contact with each other (Cohen and Larson 1996; Lashley 2002b; Meegan 1979).

Antimicrobial Resistance

Although the development and use of myriad antimicrobial agents has had many benefits, antimicrobial resistance is a growing problem. This results from both human and nonhuman sources. Livestock producers generally have supported the use of antibiotics in animal feed and water to prevent illness and thereby promote growth, theoretically by preventing illness. One effect has been the emergence of antibiotic-resistant bacteria that can infect humans such as enterococci and *Salmonella*. Proposed bans on this use illustrate the interplay between political and economic issues and health (Lashley 2002c). Such bans can be effective. For example, in Denmark in 1999, chicken and pig farmers and cattle ranchers only gave antibiotics to animals for therapeutic reasons. Results there have included decreased spread of bacterial strains resistant to antibiotics among both the animals and humans. However, some animal food producers continue to resist such restrictions, saying that results would be decreased productivity and increased illness in their animals as well as increased feed costs because more feed would be necessary for weight gain of the animals (Stephenson 2002).

Another source of resistant microorganisms results from the overuse of antimicrobials often for inappropriate treatment reasons such as viral infections. Another problem results when antibiotics are prescribed for the treatment of infection with organisms that are not susceptible to that antibiotic. Often, health care providers allow themselves to be pressured into prescribing antibiotics merely to please the patient, whether or not they believe such a prescription is warranted. Thus, education for both patients and providers is needed. Multidrug-resistant tuberculosis (MDR-TB) is a growing global health problem. After a period of relative quiescence, MDR-TB emerged as a problem in developed countries in the late 1980s, but beginning in 1993, decreasing TB rates in the United States shifted attention away from it (Lashley 1995). In 2000, about 3.2% of the 8.7 million new TB cases were multidrug resistant (at least resistant to both isoniazid and rifampin). These strains are unevenly distributed, and it is estimated that 70% of the MDR-TB cases worldwide are concentrated in 10 countries, several of which are in Eastern Europe (Dye and others 2002).

Intentional Release of Microorganisms

The deliberate release of microorganisms (usually pathogens) in the context of bioterrorism or biological warfare (biowar) has received considerable recent attention since the anthrax attack that occurred in the United States in the fall of 2001. The potential for this type of event had been previously identified, and in

2000, the Centers for Disease Control and Prevention (CDC) released a list of organisms believed to have a high potential for use in this way. These are shown in Table 2. Category A agents represent the greatest threat to national security because they can be easily disseminated or transmitted person to person; cause high mortality, with potential for major public health impact; might cause public panic and social disruption; and require special action for public health preparedness. Category B agents are the second highest priority and include those that are moderately easy to disseminate, cause moderate morbidity and low mortality, require specific enhancements of the CDC's diagnostic capacity and enhanced disease surveillance, and possess the ability to cause illness but require fewer public health preparations. Category C agents include pathogens that could be engineered for mass dissemination because of availability, ease of production and dissemination, and potential for high morbidity and mortality and major health impact. They are considered possible emerging public health threats (Centers for Disease Control and Prevention 2000).

Various plans were developed at different levels but, when reexamined after the anthrax attacks, were found not to be adequate. Furthermore, there was confusion in providing accurate and timely information about those attacks when they occurred. In fact, a recent *New York Times* article titled "At the Health Department, the Messengers Still Stumble" (Altman 2002) calls attention to the still critical lack of effective and accurate information and communication with regard to the possibility of an infectious disease outbreak, as well as confusion about what agencies were to take leadership roles. Many first-line health care providers realized that their disaster plans needed revision to be effective. Besides the morbidity and mortality that could result from the deliberate release of certain microorganisms, there is also a potential for social disruption, including riots, violence, and panic among the public.

The potential for the use of microorganisms as bioterror weapons in the United States was realized graphically when a large community outbreak of salmonellosis was identified in the Dalles, Oregon, in 1984. In this instance, law enforcement and public health investigations pinpointed the source of the organism as a laboratory operated by a religious cult, the Rajneesh. It was eventually revealed that this group had intentionally seeded salad bars with the organism to influence voter turnout in an election. This incident pointed up the vulnerability of developed-world societies to bioterror attacks (Perrotta 2002; Török and others 1997). It should be noted that such attacks do not necessarily have to be acute and immediate. Such attacks could take a more chronic course and include diseases of animals or plants that could affect eco-

Table 2. Critical Biological Agents that Could Present a Threat to National Security

- Category A
  - Category A agents include
    - Variola major (smallpox)
    - *Bacillus anthracis* (anthrax)
    - *Yersinia pestis* (plague)
    - *Clostridium botulinum* toxin (botulism)
    - *Francisella tularensis* (tularaemia)
    - Filoviruses
    - Ebola hemorrhagic fever
    - Marburg hemorrhagic fever
    - Arenaviruses
    - Lassa (Lassa fever)
    - Junin (Argentine hemorrhagic fever) and related viruses
- Category B
  - Category B agents include
    - *Coxiella burnetti* (Q fever)
    - *Brucella* species (brucellosis)
    - *Burkholderia mallei* (glanders)
    - Alphaviruses
    - Venezuelan encephalomyelitis
    - Eastern and western equine encephalomyelitis
    - Ricin toxin from *Ricinus communis* (castor beans)
    - Epsilon toxin of *Clostridium perfringens*
    - *Staphylococcus* enterotoxin B
    - A subset of list B agents includes pathogens that are food- or waterborne. These pathogens include but are not limited to
      - *Salmonella* species
      - *Shigella dysenteriae*
      - *Escherichia coli* O157:H7
      - *Vibrio cholerae*
      - *Cryptosporidium parvum*
  - Category C
    - Category C agents include
      - Nipah virus
      - Hantaviruses
      - Tick-borne hemorrhagic fever viruses
      - Tick-borne encephalitis viruses
      - Yellow fever
      - Multidrug-resistant tuberculosis

SOURCE: Centers for Disease Control and Prevention (2000).

nomic stability. For example, chemical agents such as dioxin have been found to contaminate the food supply unintentionally via chickens that were fed contaminated feed, as occurred in Belgium. Presumably, agents such as those causing chronic wasting disease in animals or foot and mouth disease could be used to cause deliberate contamination, with economic, social, and medical consequences. In another example of the interrelatedness of events, the relatively new antiterrorism measure signed by President Bush allows the security screening of persons working with certain microorganisms and limits several classes of individuals such as felons from possessing certain microorganisms (Malakoff and Enserink 2001). The reestablishment of the smallpox vaccination in the United States for at least selected at-risk groups remains a hotly debated issue at the time of this writing.

Summary

Reasons for the emergence/reemergence of infectious diseases are complex and interrelated. The global village, which provides global economic and social opportunities, also provides opportunities for disease emergence and transmission (Ostroff and Kozarsky 1998). Although characteristics of microorganisms such as genetic adaptive changes are important in the emergence of infectious diseases, factors under human control play a large role. Behavioral and lifestyle choices are a major influence on the emergence and spread of many EIDs. Some of these suggest ways that health care providers can intervene. An example is that of antimicrobial resistance related to the behavior of both patients and health care providers with regard to the inappropriate use of antibiotics for conditions not requiring antibiotic therapy. The role of microbes in various cancers and chronic illnesses such as that of *Chlamydia pneumoniae* and cardiovascular disease is still at early stages of discovery but offers the potential for different prevention approaches. Effectively addressing threats from emerging infectious diseases requires cooperation and communication among a large variety of professionals, including those with expertise in animal disease, ecology, behavioral science, epidemiology, basic science, public health, medicine, and nursing. We must meet this new challenge.

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