# Background

## *The Concept of Emergence*

Emerging infectious diseases are diseases of infectious origin whose incidence in humans has increased within the past two decades or threatens to increase in the near future.[1] Many factors, or combinations of factors, can contribute to disease emergence (Table 1). New infectious diseases may emerge from genetic changes in existing organisms; known diseases may spread to new geographic areas and populations; and previously unknown infections may appear in humans living or working in changing ecologic conditions that increase their exposure to insect vectors, animal reservoirs, or environmental sources of novel pathogens. Reemergence may occur because of the development of antimicrobial resistance in existing infections (e.g., gonorrhea, malaria, pneumococcal disease) or breakdowns in public health measures for previously controlled infections (e.g., cholera, tuberculosis [TB], pertussis).

## *The Problem*

In the United States and elsewhere, infectious diseases increasingly threaten public health and contribute significantly to the escalating costs of health care. As society, technology, and the environment change, pathogens evolve or spread, and the spectrum of infectious diseases expands. Emerging infectious diseases such as acquired immunodeficiency syndrome (AIDS) and TB vividly illustrate that no nation can be complacent regarding human vulnerability to the microorganisms with which we share our environment.

Although many serious infectious diseases are largely or completely preventable, current approaches to health care, which neglect public health, hamper our ability to control them effectively. For too long, health policy in the United States has been treatment-driven rather than prevention-oriented, reactive rather than proactive, and complacent rather than anticipatory and vigilant.[1] As a result, the public health infrastructure of this country is poorly prepared to confront the emerging disease problems of a rapidly changing world (Figure 1). Examples of these problems are increasingly common and include diseases due to drug-resistant pathogens, such as *Neisseria gonorrhoeae*, staphylococci, *Streptococcus pneumoniae*, and enterococci; vector-borne or zoonotic diseases, such as hantavirus disease, Lyme disease, arboviral encephalitides, and rabies; foodborne and waterborne illnesses, such as those caused by *Escherichia coli* O157:H7, *Salmonella*, and *Cryptosporidium*; diseases in special settings, such as diarrhea, otitis media, and respiratory illnesses in child care facilities; vaccine-preventable diseases, such as measles, polio, pertussis, and diphtheria in unimmunized populations; and the increasingly commonplace imported infections, such as cholera and malaria.

As the United States moves towards comprehensive health care reform, it is crucial that emerging infectious disease threats be addressed and that the basic tenets of prevention-oriented public health policy form an integral component of plans for health care reform.

Timely recognition of emerging infections requires early warning systems to detect new infectious diseases before they become public health crises. Prompt detection of these new threats depends on careful monitoring by modern surveillance systems and a thorough understanding of trends in incidence and distribution of known infectious agents. However, existing systems to monitor these trends domestically and internationally are inadequate. For example, the true

Table 1. Factors in Emergence*

| Categories | Specific Examples |
|---|---|
| Societal events | Economic impoverishment; war or civil conflict; population growth and migration; urban decay |
| Health care | New medical devices; organ or tissue transplantation; drugs causing immunosuppression; widespread use of antibiotics |
| Food production | Globalization of food supplies; changes in food processing and packaging |
| Human behavior | Sexual behavior; drug use; travel; diet; outdoor recreation; use of child care facilities |
| Environmental changes | Deforestation/reforestation; changes in water ecosystems; flood/drought; famine; global warming |
| Public health infrastructure | Curtailment or reduction in prevention programs; inadequate communicable disease surveillance; lack of trained personnel (epidemiologists, laboratory scientists, vector and rodent control specialists) |
| Microbial adaptation and change | Changes in virulence and toxin production; development of drug resistance; microbes as cofactors in chronic diseases |

*Adapted from reference 1.

magnitude of the antimicrobial drug resistance crisis is unknown because of the absence of systematic monitoring. Because international surveillance is severely limited, early detection of infections that are imported from abroad is often delayed. Also lacking is an effective laboratory-based surveillance system for the early detection of exotic microbial agents that might be used for biological warfare or terrorist activities.

National surveillance for most reportable infectious diseases in the United States depends heavily upon voluntary collaboration between the Centers for Disease Control and Prevention (CDC) and state and local health departments, which in turn depend on physician-initiated reporting of a limited number of specific, recognized infectious diseases. Reporting is generally incomplete.

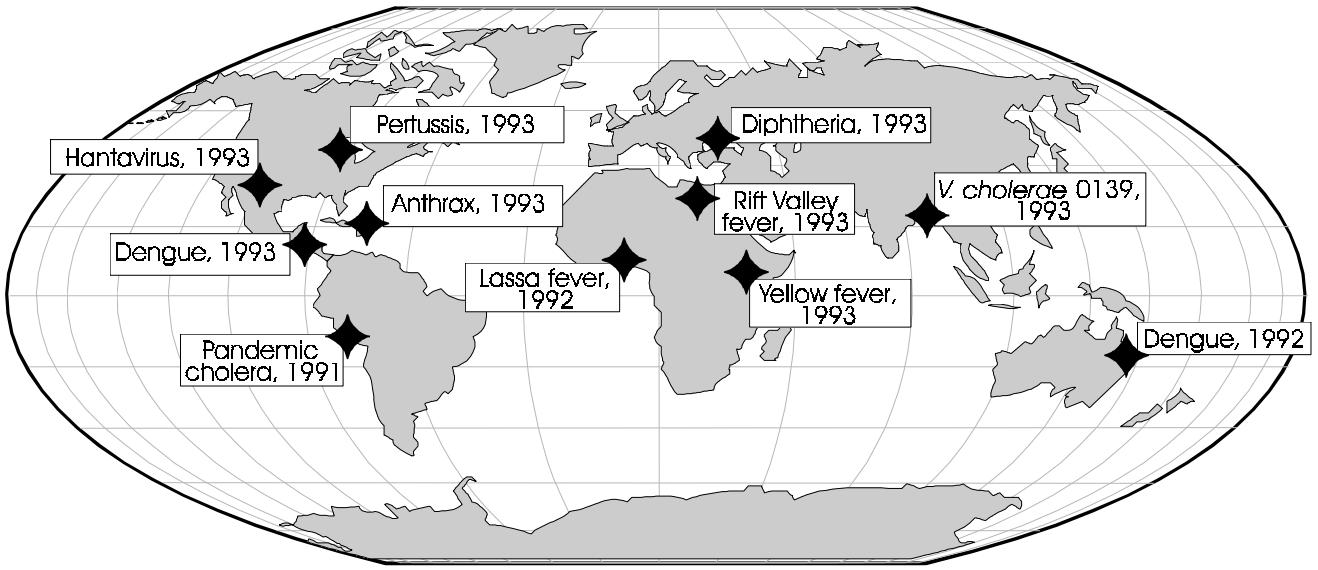
Results of a recent survey by the Council of State and Territorial Epidemiologists (CSTE) illustrate the inadequacy of existing infectious disease surveillance by documenting the limited number of professional positions dedicated to infectious disease surveillance in most states. For example, in 12 of the 50 states surveyed, no professional position is dedicated to surveillance of foodborne and waterborne diseases. Moreover, a small number of diseases command a large proportion of the limited resources. Although more than $40 million in federal funds are provided to states for infectious disease surveillance, more than 95 percent of these funds are limited to surveillance of diseases in four categories (TB, human immunodeficiency virus [HIV]/AIDS, sexually transmitted diseases [STDs], and selected vaccine-preventable diseases).[6]

No federal resources are provided to state and local health departments to support the national notifiable disease system. In addition, the ability of state public health laboratories to support surveillance and control of infectious diseases has diminished, and critical health department services, such as insect vector and rodent control programs, have been dismantled in many states.

In addition to comprehensive and innovative surveillance systems, effective preparation for emerging infectious diseases requires professional expertise, laboratory support, and research capability. These foundations support the infrastructure needed to address the ongoing, but often changing, threats from emerging infections. Despite the continued emergence of such threats, support for applied research and control efforts has declined over the past decade for most infectious diseases.

As highlighted in three recent reports by expert committees convened by the National Academy of Science's Institute of Medicine (IOM), the ability of the U.S. public health system and our health professionals

Figure 1. Examples of Emerging and Resurgent Infectious Diseases in the 1990s



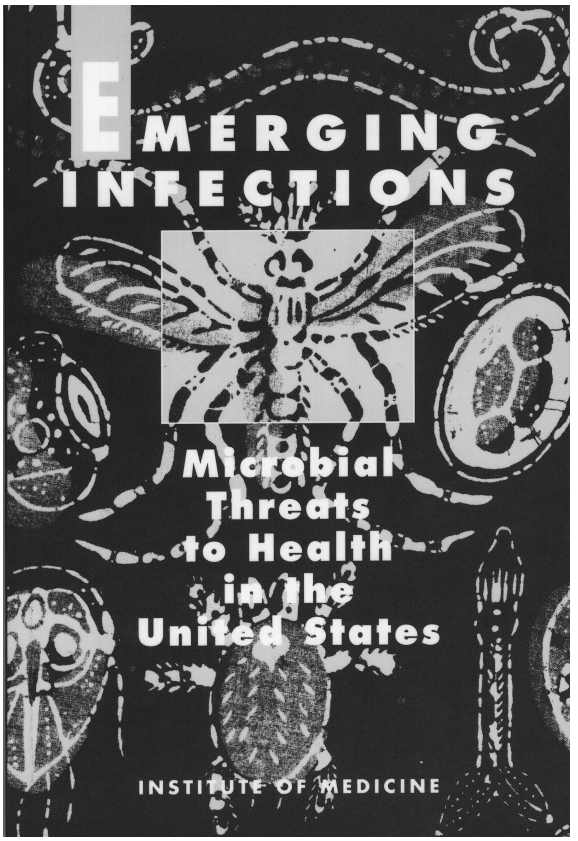
to deal with emerging infectious disease problems is in jeopardy.[1,7,8]

The earliest of these reports, "The U.S. Capacity to Address Tropical Infectious Disease Problems,"[7] published in 1987, documented our poor state of readiness to recognize, treat, or control infectious disease threats emanating from the tropics—regions which have yielded microbial threats such as Lassa fever and Ebola viruses, chloroquine-resistant malaria, and penicillin-resistant gonorrhea.

The second report, "The Future of Public Health," published in 1988, concluded that the U.S. public health system is in disarray. It emphasized that the United States approach to public health has too often been crisis driven or reactive, rather than proactive, an approach that is costly because it blocks our ability to institute cost-saving preventive strategies.[8]

The third IOM report, "Emerging Infections, Microbial Threats to Health in the United States," published in 1992, emphasized the ongoing threat to domestic and global health from emerging infectious diseases and noted that increased vigilance is needed to overcome years of complacency (Figure 2).[1] The report provided specific recommendations for CDC, the National Institutes of Health (NIH), the Food and Drug Administration (FDA), the Department of Defense (DOD), and other federal and state agencies for addressing microbial threats to health in the United States and elsewhere. This report emphasized a critical leadership role for CDC in a national and global effort to prevent and control emerging infectious diseases.

Figure 2. Institute of Medicine report, "Emerging Infections: Microbial Threats to Health in the United States," National Academy Press, 1992




## The Burden of Infectious Diseases

Infectious diseases remain the leading cause of death worldwide.[9,10] Reduction in mortality from many infectious diseases has been described as the single most significant public health achievement of the past century.[11] Unfortunately, historical successes in treating and controlling some of these diseases left many health policymakers with the false perception that the threat to public health from infectious agents had all but disappeared. The resulting public health complacency has been costly in both human and economic terms.[12]

Emerging infections contribute substantially to the ongoing burden of infectious diseases on the American public. Childhood ear infections, the leading cause of visits to pediatricians, increased 150% between 1975 and 1990.[13] Infectious diseases account for 25% of all visits to physicians each year, and antimicrobial agents are the second most frequently prescribed class of drugs.[10,14]

Infectious agents may be causing diseases previously considered noninfectious (Table 2). *Helicobacter pylori* infections, for example, have a well established association with peptic ulcer disease;[15] sexually transmitted human papillomavirus is associated with cervical cancer;[16] and hepatitis C virus is now recognized as a leading cause of chronic liver disease and cirrhosis in the United States with an estimated 150,000 new infections per year.[17] *Chlamydia* infections have long been implicated in infertility and more recently have been tentatively associated with coronary artery disease.[18] Rodentborne hantaviruses may play a role in hypertensive renal disease.[19] Other chronic diseases with possible viral origins include Sjögren syndrome, multiple sclerosis, Alzheimer disease, Kawasaki disease, and juvenile onset diabetes mellitus.[10]

Direct and indirect costs of infectious diseases are staggering. The annual treatment of non-AIDS STDs, for instance, costs $5 billion, and intestinal infections result in almost $30 billion in combined direct costs and lost productivity each year.[10] Annual direct medical costs due to nosocomial infections reached $4.5 billion in 1992,[20-21] and the National Foundation for Infectious Diseases estimates that yearly expenditures incurred from antimicrobial resistance approach $4 billion and are increasing.

Estimated costs for some infectious agents are equally staggering. For example, influenza produces direct medical costs approaching $5 billion and lost productivity costs of almost $12 billion per year.[10] *Salmonella* and *Campylobacter* infections each

produce $1 billion in economic losses yearly. Hepatitis B virus infection costs over $720 million each year, while other important emerging pathogens, such as rotavirus and *Giardia lamblia,* result in annual costs (direct and indirect) of $200-400 million and $120 million, respectively. [20]

These illustrative costs, combined with dollars spent on HIV-related illness, exceed $120 billion. These figures and other measures, however, most likely underestimate the impact of infectious diseases. The International Classification of Diseases (ICD-9) places many infectious diseases in non-infectious categories (such as the classification of endocarditis among cardiovascular diseases and the classification of meningitis and middle ear infections among diseases of the nervous system and sense organs, respectively). Clearly, infectious diseases contribute significantly to economic losses and days of disability in the United States.

## *Important Examples of Emerging Infectious Disease Threats*

Emerging infectious diseases that threaten U.S. public health originate from both domestic and international sources.[22] Toxic shock syndrome (TSS) and Lyme disease illustrate how new technology or products (super-absorbent tampons) and changing ecology and human demographics (reforestation, increased deer populations, suburban migration) can foster the emergence of new microbial threats.[23,24]

Other societal changes, such as the expanding use of child care facilities, have contributed to the emergence of infectious diseases that threaten children and staff in child care centers as well as the children's household contacts. Recent examples of infectious disease threats related to child care include *E. coli* O157:H7 infection, shigellosis, giardiasis, cryptosporidiosis, hepatitis A, and rotavirus infection.[25]

Also, despite new standards of health care delivery within modern, well-equipped clinical facilities, hospital-acquired infections affected an estimated 2 million persons in 1992 alone.[21] The staff and employees of clinical facilities are also at risk for infections that can be occupationally acquired, such as TB and hepatitis B. Moreover, an increasing percentage of our population is elderly, and a growing number of persons are immunosuppressed because of HIV infection, organ transplantation, or cancer chemotherapy. These populations are at increased risk for emerging infections, and their medical management is complex and costly. Specifically, these populations are highly susceptible to opportunistic infections, and an ever-expanding array of such infections is being seen in patients with AIDS and other forms of immunosuppression. The identification of certain opportunistic pathogens in immunosuppressed populations has led to the recognition of these agents in persons with normal immunity; this happened with *Cryptosporidium* and is currently occurring with *Rochalimaea* species and microsporidia.[26-31]

Changes in dietary habits, food processing and packaging, and globalization of the food supply are contributing to an increase in illnesses due to foodborne

Table 2. Chronic Manifestations of Infectious Diseases, United States

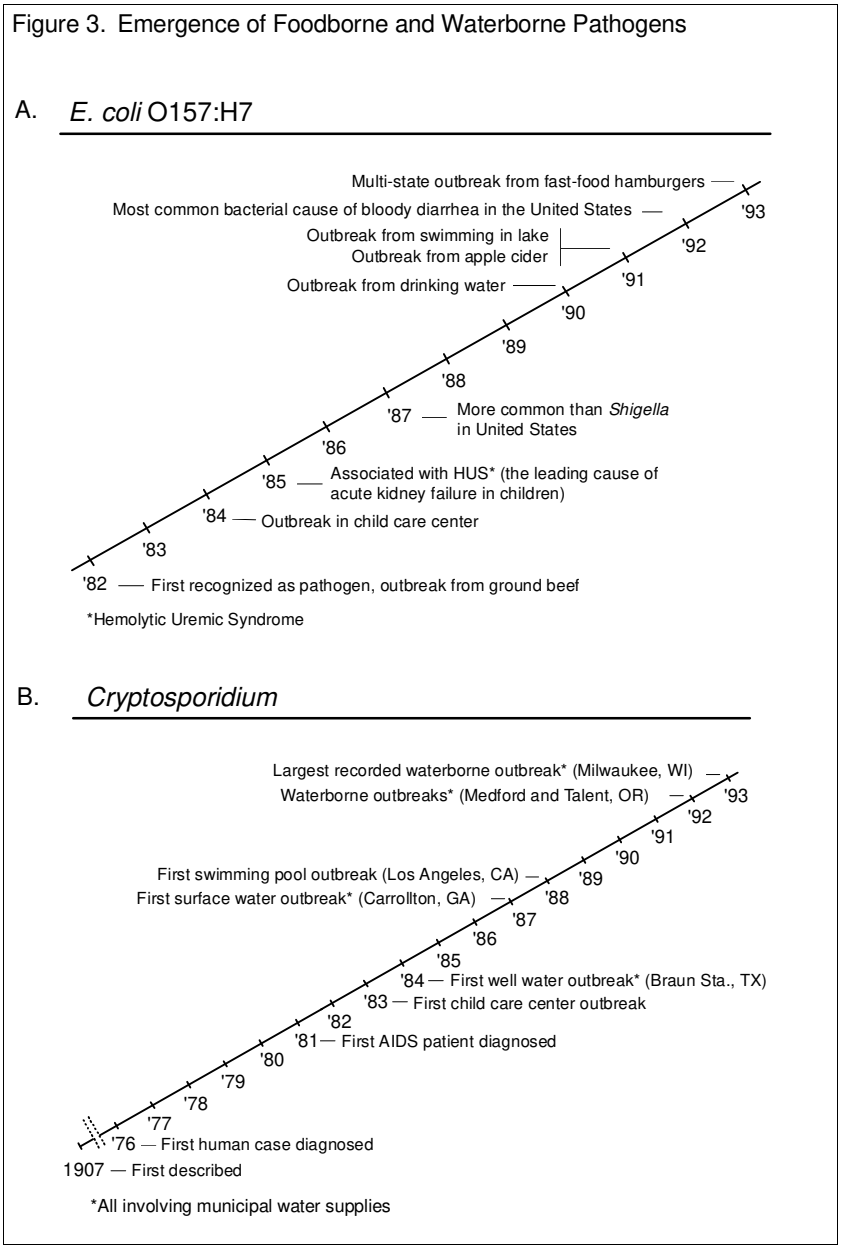
| *Well-Established Association* | | *Reported Association* | |
|---|---|---|---|
| Agent | Disease | Agent | Disease |
| Viruses: | | Viruses: | |
| Cytomegalovirus | Congenital mental retardation | Enteroviruses | Diabetes mellitus |
| Hepatitis B virus | Chronic hepatitis, cirrhosis, hepatic carcinoma | Hantaviruses | Hypertensive renal disease |
| Hepatitis C virus | Chronic hepatitis, cirrhosis | Hepatitis C virus | Hepatic carcinoma |
| Human papillomavirus | Cervical carcinoma, laryngeal papillomatosis | Human papillomavirus | Lung, esophageal, bladder carcinoma |
| Varicella-zoster virus | Post-herpetic neuralgia; congenital mental retardation | | |
| Bacteria: | | Bacteria: | |
| *Borrelia burgdorferi* | Lyme arthritis | *Campylobacter jejuni* | Guillain-Barré syndrome |
| *Chlamydia trachomatis* | Infertility | *C. pneumoniae* | Atherosclerosis |
| Enteric bacteria *(Shigella, Salmonella, Yersinia, Campylobacter)* | Arthritis, Reiter's syndrome | *H. pylori* | Gastric carcinoma |
| *E. coli* O157:H7 | Hemolytic uremic syndrome | | |
| *H. pylori* | Peptic ulcer disease, chronic gastritis | | |
| Parasites: | | | |
| *Toxoplasma gondii* | Congenital mental retardation | | |

infections. Infectious agents continue to contaminate the national food supply, as evidenced by recent outbreaks of serious diarrheal illness associated with the consumption of raw milk, domestic cheese, eggs, and commercial airline food.[32-37] Powdered milk products and infant formula have been contaminated with diarrhea-causing bacteria.[38] Seafood is increasingly implicated as the source of infectious disease outbreaks due to hepatitis A virus, Norwalk virus, *Vibrio* species, and *Clostridium botulinum*[39,40] and is the source of illness associated with marine biotoxins (paralytic, diarrheal, and amnesic shellfish poisoning; scombroid and ciguatera fish poisoning), which often occur during periods of marine algae overgrowth ("algal blooms" or "red tides") in coastal waters in the United States and elsewhere.[41,42]

Other commonly consumed food items contaminated with infectious agents may place large numbers of persons at risk. In early 1993, for example, hamburgers contaminated with the bacterial pathogen *E. coli* O157:H7 and served at a fast-food restaurant chain (at least 93 restaurants were implicated) caused a multi-state outbreak of severe bloody diarrhea (hemorrhagic colitis) and serious renal disease (hemolytic uremic syndrome [HUS]). Data from the ongoing investigation of this outbreak indicate that over 500 children and adults became ill, and four children died (Figure 3A).[43,44]

Increasingly, outbreaks of gastrointestinal illness due to contaminated municipal water—such as the outbreak of cryptosporidiosis in Milwaukee, Wis., in April 1993 that affected hundreds of thousands of people (see Figure 3B; Box, page 12 )—are associated with viral and parasitic infectious agents.[45,46]

Figure 3. Emergence of Foodborne and Waterborne Pathogens




Exposure to certain animals is also placing Americans at risk for emerging infectious diseases. Hantavirus pulmonary syndrome (HPS), first detected in the southwestern United States in 1993, has been linked to exposure to infected rodents in more than a dozen states. More than 50 cases have been detected, and more than half of those infected have died (see Box, page 32).[47-50]

Emerging infectious disease threats from abroad are also increasing. Cholera has recently returned to the Western Hemisphere in epidemic proportions after almost a century's absence (Figure 4). Through October 1993, at least 900,000 cases of infection were detected, and more than 8,000 persons died. The Pan American Health Organization (PAHO) estimates that it will take more than a decade and more than $200 billion to control the current pandemic in Latin America. Although cholera initially reemerged in Peru, the disease has occurred throughout Latin America, and cases have been imported into the United States, where more cases occurred in 1992 than in any other year since cholera surveillance began in 1962.[36,51] Moreover, the *V. cholerae* O1 strain responsible for cholera in Central and South America has been isolated from oysters and oyster-eating fish captured in oyster beds along U.S. Gulf Coast waters.[52] More recently, a newly described toxigenic strain of *V. cholerae*, *V. cholerae* O139, has emerged in southern Asia where it is causing epidemic cholera-like illness and has largely replaced *V. cholerae* O1 strains in many areas. Standard diagnostic tests for cholera are inadequate for this new

### Waterborne Cryptosporidiosis

In the spring of 1993, the outbreak of waterborne cryptosporidiosis in the greater Milwaukee area caused prolonged diarrheal illness in approximately 403,000 persons, 4,400 of whom required hospitalization. Attack rates were as high as 50% in some parts of the city. In the United States, existing surveillance systems are inadequate to rapidly recognize outbreaks of this parasitic infection. Early recognition of *Cryptosporidium* as a cause of widespread diarrheal illness would implicate common sources, such as municipal water supplies, sooner and likely prevent significant numbers of new infections by the early institution of preventive interventions, such as boil water advisories. Future outbreaks of this emerging parasitic infection could be prevented or controlled through improvements in water quality monitoring, use of appropriate diagnostic tests, and surveillance to evaluate the effectiveness of regulations and other control measures.

strain, and neither current vaccines nor prior infection with *V. cholerae* O1 is protective. This new form of cholera is spreading, and an imported case has occurred in a U.S. traveler returning from India.[53]

Similarly, various parasitic diseases, once considered exotic in the United States, are emerging or reemerging as public health threats. Local transmission of malaria, for instance, has been observed since 1986 among Hispanic immigrants and residents of an affluent area of San Diego County, Calif.[54] In North Carolina, severely ill, malaria-infected Southeast Asian refugees have seriously strained the laboratory and health care delivery services at state and local health departments.[55] Elsewhere, such as the metropolitan New York City area, multiple cases of locally acquired neurocysticercosis have been attributed to transmission from immigrant household workers.[56]

These and other examples suggest that the concept of "domestic" as distinct from "international" health is outdated. Such a dichotomous concept is no longer germane to infectious diseases in an era in which commerce, travel, ecologic change, and population shifts are intertwined on a truly global scale.[57,58]

## Antimicrobial Drug Resistance

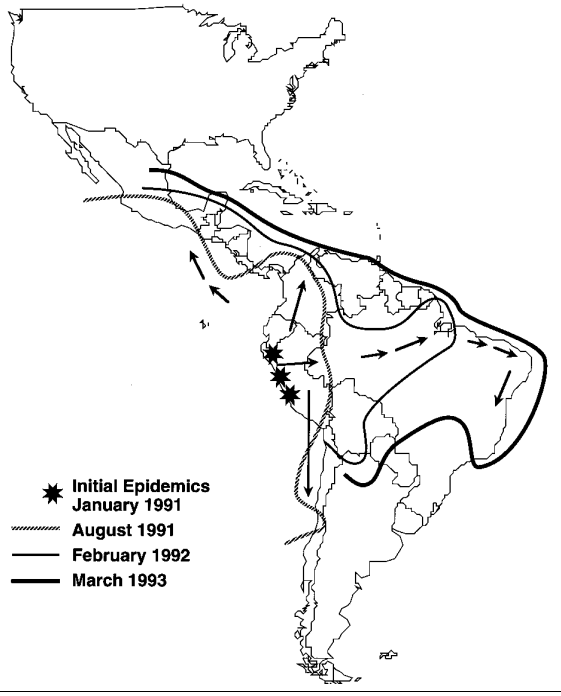
Antimicrobial resistance as a factor in emergence warrants considerable emphasis. Since antimicrobial agents were introduced for general use in the 1940s, substantial reductions in deaths from many bacterial and parasitic diseases have been documented. However, as a consequence of widespread antimicrobial use, drug resistance has emerged in the United States and abroad as a major public health crisis both in community and institutional settings. Drugs that once seemed invincible are losing their effectiveness for a wide range of community-acquired infections, including TB, gonorrhea, pneumococcal infections (a leading cause of otitis media, pneumonia, and meningitis), and for hospital-acquired enterococcal and staphylococcal infections (Figure 5). Resistance to antiviral (e.g., amantadine-resistant influenza virus and acyclovir-resistant herpes simplex), antifungal (e.g., azole-resistant *Candida* sp.), and antiprotozoal (e.g., metronidazole-resistant *Trichomonas vaginalis*) drugs is also emerging, and drug-resistant malaria has spread to nearly all areas of the world where malaria occurs. Concern has also arisen over strains of HIV resistant to antiviral drugs. Increased microbial resistance has resulted in prolonged hospitalizations and higher death rates from infections, has required much more expensive, and often more toxic, drugs or drug combinations (even for common infections), and has resulted in higher health care costs.[59]

## Surveillance of Emerging Infections

Surveillance is the single most important tool for identifying infectious diseases that are emerging, are causing serious public health problems, or are diminishing in importance. The morbidity, mortality, and cost of infectious diseases can be measured through surveillance. The quality of the nation's health care system and effectiveness of health regulations (e.g., microbial safety of food and water) can only be adequately assessed if effective surveillance systems are in place.

The varied strata of modern society present numerous challenges to surveillance. For example, assessing the health of traditionally underserved or transient populations, such as migrant workers, the homeless,

Figure 4. Spread of Epidemic Cholera—Latin America, 1991–1993

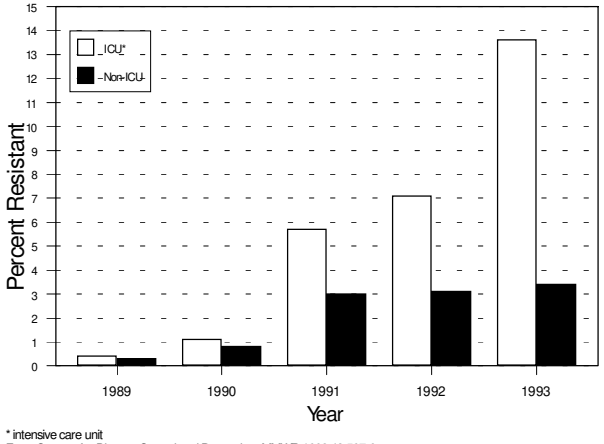


or inner-city minorities, is difficult, but such populations are often the first and most seriously affected by emerging infectious diseases. Health care delivery and earlier recognition of emerging infectious diseases are enhanced when susceptible populations are targeted for surveillance. Emerging infectious threats from abroad challenge existing surveillance capabilities because global surveillance of emerging infections is fragmentary at best.

In addition to monitoring specific diseases and syndromes, gathering information about the numerous factors that affect disease emergence is also important. Understanding and controlling arthropod- or rodent-borne diseases, for example, require knowledge of the geographic distribution of potential reservoirs and vectors. Changing ecologic developments, such as changes in land use, may enhance the emergence of infectious diseases, such as Lyme disease, by altering the distribution of vectors or placing greater numbers of persons in closer contact with vectors and animal or environmental reservoirs of novel pathogens that previously had little contact with potential human hosts.

Monitoring the development of antimicrobial drug resistance or enhanced virulence in known pathogens can also facilitate early intervention, prevent morbidity and mortality, and reduce costs. For example, reliable information about drug-resistant *S. pneumoniae* is needed to guide clinicians who treat such common infections as pneumococcal pneumonia in adults and otitis media in children.[60,61] Changes in virulence, such as those in certain subtypes of group A streptococcus, underscore the public health importance of monitoring trends in virulence characteristics of known pathogens.[62] Similarly, changing antigenic structures of known pathogens, such as antigenic drift in measles virus, should be closely monitored, so that necessary changes in vaccine composition can be implemented promptly if indicated.[63] Ongoing assessments of drug and vaccine availability can also identify potential shortages, and careful monitoring of antimicrobial drug use will be essential to managing the current crisis of antimicrobial drug resistance.[64]

Figure 5. Increasing Incidence of Vancomycin-Resistant Enterococci in U.S. Hospitals by Year—National Nosocomial Infections Surveillance System (NNIS), 1989–1993




* intensive care unit
From Centers for Disease Control and Prevention. MMWR 1993;42:597-9.

## Understanding Emerging Infections Through Applied Research

Developing appropriate responses and control strategies for emerging infectious disease threats depends on linking laboratory science and epidemiology with public health practice. Innovative approaches to combining surveillance and applied research are essential for controlling infectious diseases.[65] Epidemiologic studies, including investigations of both outbreaks and sporadic disease, are critical to the rapid identification of risk factors for new diseases and provide important prevention information early in the evolution of a potential epidemic. Such studies are often the first integral step toward identifying the cause of an infectious disease outbreak. Other areas of applied research in infectious disease epidemiology needed to address emerging diseases include economic analyses of the impact of emerging infectious diseases and cost-effectiveness analyses of proposed interventions, the study of behaviors that affect risk, and measurement of the effectiveness of public health interventions.

When a new or previously unrecognized infectious disease is suspected, clinicians, epidemiologists, and laboratorians work together to obtain case histories and collect and evaluate tissue and serum specimens. Such multidisciplinary efforts include the expertise of infectious disease pathologists, molecular biologists, and others with critical laboratory skills who coordinate their activities to confirm the etiologic agent and develop diagnostic tools for the identification of subsequent cases. A timely example of this process is the ongoing investigation of hantavirus pulmonary syndrome.[47-50]

Establishing the causes of emerging infectious diseases is fundamental to controlling these diseases. Rapid and accurate diagnostic testing capabilities for agents such as *Mycoplasma* are lacking in the United States. In addition, tests designed for use in developing countries, for example, must be practical for field use in areas where expensive reagents and reliable power supplies may not be readily available.

Proper readiness for emerging infectious threats also requires that diagnostic tests for the many new pathogens likely to be encountered be made available to clinical and reference laboratories as soon as it is technologically feasible. Promoting and teaching laboratory techniques appropriate for public health purposes are also critical. The lack of such training for testing of stool specimens for *E. coli* O157:H7 and *Cryptosporidium*, for example, has resulted in delayed recognition of outbreaks. Providing these tools and services will require ongoing federally supported intramural

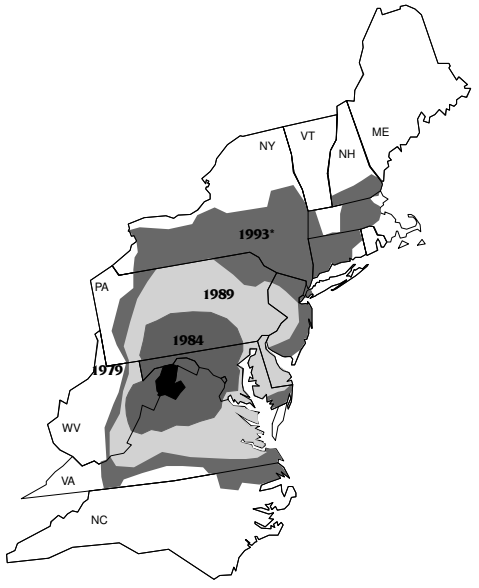
and extramural efforts that target the development and application of rapid diagnostics for emerging pathogens.

The interaction of epidemiology (including surveillance) and laboratory science extends into several other areas of applied research that are relevant to emerging infections. Vaccine development, for example, includes the ongoing assessment of potential vaccine components, evaluation of vaccine efficacy, and studies of the cost-benefit of vaccination programs. Further, integrated approaches to the study of insect vectors and animal reservoirs are critical to understanding emerging vector-borne or zoonotic diseases such as rabies (Figure 6). In investigating HPS, for example, the integrated application of epidemiologic and molecular biologic techniques led to the rapid identification of rodents as carriers of the virus (see Box, page 32). With this critical information, public health officials were then able to rapidly develop and disseminate prevention guidelines.[47-50] Evaluating epidemiologic characteristics and how these diseases are maintained in nature will aid prevention efforts for Lyme disease, viral encephalitides, and other conditions in the United States and for many vector-borne or zoonotic infections worldwide, including malaria, trypanosomiasis, leishmaniasis, rickettsial diseases, and viral hemorrhagic fevers.

Other organisms, such as those that cause coccidioidomycosis, legionellosis, or amoebic meningoencephalitis, do not have specific animal reservoirs but are maintained primarily in the soil or water; the emergence of these diseases may be particularly influenced by ecologic factors. It is also likely that the development of tropical habitats for human settlement and agriculture will increase opportunities for the emergence of new viral diseases and the prominence of several parasitic diseases in humans, but further research is needed to assess the magnitude of these risks and the specific factors that affect them.

Climatic changes, such as global warming, may broaden the distribution of vectors of tropical diseases and thus potentially increase their spread to new places.[66] Furthermore, environmental control measures, such as the treatment of soil to prevent histoplasmosis or the use of insecticides to control insect-borne diseases, may sometimes be warranted, but expanded research is required to ensure that these measures are safe and cost-effective.

Figure 6. The Expanding Epizootic of Racoon Rabies—Eastern United States, 1979–1993




*1993 data provisional
From Fishbein D, Robinson L. N Engl J Med 1993;329:1632-8

Targeted research projects, such as the critical assessment of ecologic factors responsible for the recent large outbreak of coccidioidomycosis in central California or the emergence of epidemic Rift Valley fever and schistosomiasis associated with the damming of the Senegal River in Africa, should provide the information needed to prevent future outbreaks.

Finally, the recent outbreaks of foodborne and waterborne diseases highlight the need for continuing evaluation of food and water processing practices affecting the emergence of infectious diseases.