10

Emerging and Reemerging Infectious Disease Threats

OBJECTIVES

- Describe why diseases "emerge" or "reemerge."
- Discuss the impact of emerging infectious diseases on public health preparedness.
- List the likely sources of emerging infectious diseases in the future.
- Describe how international travel and commerce contribute to emerging infectious disease threats.
- Discuss how microbial adaptation contributes to emerging infectious disease threats.
- List human demographic factors and behaviors contributing to emerging infectious disease threats.
- Identify the epidemiological clues indicating a possible emerging disease.
- Describe various types of surveillance approaches.
- Discuss the breakdown of public health measures and systems.
- Recognize the actions needed for responding to an emerging disease.

Introduction: A Tale of Three Diseases

West Nile Virus

On a Friday afternoon before the Labor Day holiday weekend in 1999, the phone at the New York City Department of Health was answered by the on-call epidemiologist. An infectious disease specialist was calling to report an unusually large number of encephalitis or meningitis cases (inflammation of the brain or covering of the brain and spinal cord) at several hospitals in the borough of Queens. Blood and spinal fluid were tested at the New York State and CDC laboratories and reported positive for Saint Louis encephalitis virus (SLEV), a virus known to occur in the United States but never in New York City. New York City officials immediately began mosquito control programs in an attempt to stop transmission from mosquitoes, the vector for SLEV. Over the next week, test results appeared to be conflicting. Unknown to many of the investigators of the human outbreak, a veterinarian at the Bronx Zoo was investigating an outbreak of central nervous system disease in birds. Wildlife veterinarians were also observing large bird die-offs but could not find a clear cause. By mid-September, both sets of investigators believed the causative agent was not SLEV. By September 27, after expanding testing services to several federal and academic laboratories as well as to the wider family of *Flaviviridae*, it was confirmed that the causative agent for the human outbreak, the avian outbreak, and sentinel mosquito sampling was West Nile virus (see Fig. 10-1). By 2000, the New York City outbreak

Disasters and Public Health. http://dx.doi.org/10.1016/B978-0-12-801980-1.00010-6

FIGURE 10-1 A Culex quinquefasciatus mosquito is known as one of the many arthropodal vectors responsible for spreading arboviral encephalitis or West Nile virus to human beings through their bite. *Photo by James Gathany courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

included 62 confirmed cases and 7 deaths (Johnston and Conly, 2000). By that time, the West Nile virus was documented as having spread halfway across the United States to the Rocky Mountains (Roehrig, 2013).

Influenza A H1N1v

On April 15, 2009, a sample was routinely tested from a young girl with influenza-like illness as part of the US sentinel influenza network. The results indicated this was a uniquely novel strain of influenza A (see Fig. 10-2). On April 17, 2009, a similar result was confirmed 130 miles from the originally identified case. Testing also confirmed that this virus was resistant to both amantadine and rimantadine but sensitive to both oseltamivir and zanamivir, two readily available antiviral medications. There had been sporadic cases of influenza with infection of viruses in the swine lineage, and it was suspected and later confirmed that this novel influenza A, H1N1, was a unique combination of genes most closely related to North American swine-lineage H1N1 and Eurasian swine-lineage H1N1. In the two initial cases, no contact with pigs was discovered through extensive investigation, and it was determined that this novel virus had been spread to these cases by human-to-human transmission, a new behavior for H1N1. By April 23, additional cases were identified in Texas, and samples collected from an outbreak in Mexico were also positive for this new strain. By April 26, a public health emergency, the first in the history of the United States, was declared to allow for the rapid development of a vaccine, mobilization of antiviral medications through the federally resourced Strategic National Stockpile, and enhanced surveillance through reporting and testing. Travel advisories were put into place, and upon discovery of additional cases internationally, the World Health Organization (WHO) raised the pandemic level from phase 4 to the pandemic level phase 5. The largest number of cases occurred in people between the ages of 5 and 24 years old. Major

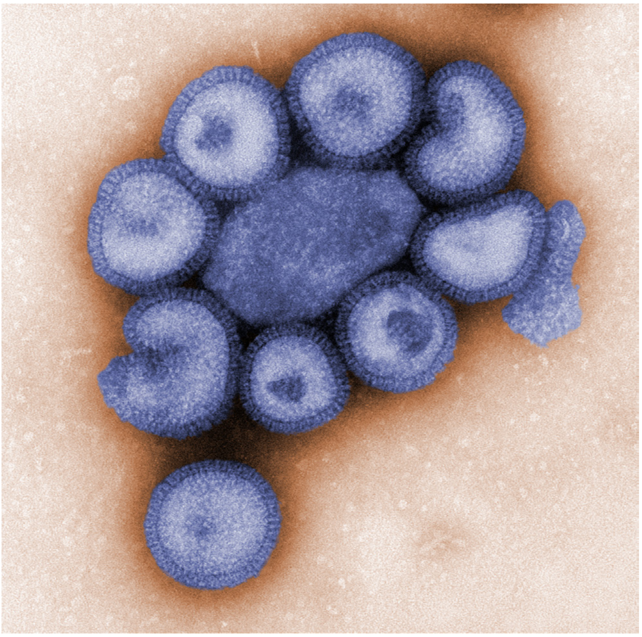

FIGURE 10-2 This negative-stained transmission electron micrograph depicts the ultrastructural details of a number of influenza virus particles or "virions." *Photo by Dr. F.A. Murphy courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

morbidity (illness) and mortality (death) occurred in pregnant women, and middle-aged people with chronic diseases and obesity, but overall the fatality rate was low. Few cases were reported in people over the age of 65, indicating that this group may have had immunity. Levels of influenza illness remained high in the summer of 2009, unusual for the North American continent. Rapid molecular analysis of the viral genome led to rapid production of a vaccine. In the late summer, the Food and Drug Administration announced the monovalent vaccine would be licensed via a "strain change" pathway, which is similar to how seasonal influenza vaccines are licensed. This meant production would be expedited, since the same methods would be used as those used to produce seasonal flu vaccine and additional safety and validation studies would not need to be completed. By September, 2009, 5 months after the first case was identified, prototype vaccine was delivered to US states for use. H1N1 is now included in seasonal vaccines (Gatherer, 2009).

Ebola Virus Disease

Ebola virus disease (EVD) was first described in 1976 in two simultaneous outbreaks in sub-Saharan Africa. In December 2013, a small outbreak of EVD was reported in a forested area in southeastern Guinea (see Fig. 10-3). It has been postulated that the index case, a boy, was in direct contact with bats. This was the 26th reported Ebola outbreak in history but the first to be reported in West Africa. EVD then spread to Liberia and Sierra Leone, all

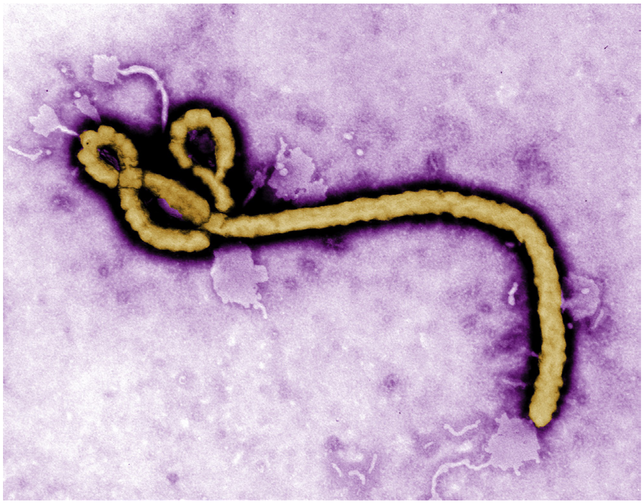

FIGURE 10-3 Transmission electron micrograph revealed some of the ultrastructural morphology displayed by an Ebola virion. *Photo by Dr. F.A. Murphy courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

through direct contact with the outbreak in Guinea (WHO, 2014). In Guinea, Liberia, and Sierra Leone as of August 13, 2015, there have been over 28,000 cases and 11,000 deaths. A small outbreak of 20 cases occurred in Nigeria, and one case occurred in Senegal. Several cases were reported outside of the area, mostly in healthcare or humanitarian workers returning to their home countries. There were also imported cases in the United States and Spain which led to secondary infections of medical workers but did not spread further. In both countries, the management of companion animals and environmental cleanup were challenging issues. Several factors contributed to the devastation of this epidemic: poverty, population density, infrastructure decline after years of armed conflict, serious gaps in health and medical infrastructure with little to no surge capacity, and a delay in coordinated response. In spite of the significant risk to underresourced healthcare workers (comprising 10% of the dead), a major humanitarian medical response was launched internationally. In October 2014, controls on people traveling out of the area went into effect with exit screening for symptoms, entry screening in most countries, and active monitoring of travelers in some countries after arrival. This screening program controlled movement and by actively monitoring attempts to identify people who may become ill early in the course of the disease, getting them to healthcare in a controlled manner and with appropriate infection control practices in place. Healthcare facilities and providers in many countries stockpiled personal protective equipment, implemented infection control training, and implemented screening processes in order to be prepared. On January 28, 2015, the WHO reported for the first time since the week ending June 29, 2014, that there had been fewer than 100 new confirmed cases reported. The focus of the response shifted from slowing transmission to ending the epidemic. In July 2015, results of early testing of a vaccine appeared very promising. By the end of 2015, the Ebola Outbreak in West Africa reached over 28,000 cases and 11,000 deaths making it the largest Ebola outbreak in history (CDC, 2015). Prior to this, the largest was a 2000–2001 Uganda outbreak with 425 cases and 224 deaths (CDC, 2001). At the time this chapter was written, public health professionals around the world continued to watch closely the progression toward stopping, and continued success in recovering from, this devastating Ebola epidemic.

Emerging Infectious Disease Definitions

Bacteria Plural of bacterium. A single-celled microorganism that can exist independently as a free-living organism or as parasite dependent upon a host organism.

Emerging Infectious Diseases Illnesses caused by pathogenic organisms with an increasing incidence in humans. Infectious diseases with increased incidence over the past two decades or those which threaten to increase in the near future are considered "emerging." Emerging infectious diseases include pathogens which are newly evolving, spreading to new geographic areas, are previously unrecognized, or are old infections reemerging due to lapses in public health measures.

Fungi Single-celled or multicellular organisms which cause infections in healthy persons or serve as opportunistic pathogens in persons who are immune compromised. Examples include histoplasmosis and aspergillosis.

Helminths Parasitic worms which live in humans or other animals and derive nourishment from their host. Examples include the tapeworm, fluke, or nematode.

Healthcare-Associated Infection (HAI) An adverse localized or systemic infectious condition occurring in a healthcare setting with no evidence that the infection was present at the time of admission.

Pathogen A biological organism capable of causing disease or illness to its host.

Prion The smallest infectious particle. It is an infectious strand of protein which replicates and leads to disease, and is similar to a virus. Prions are the causative agents of diseases such as mad cow disease and Creutzfeldt–Jakob disease.

Protozoa A single-celled parasitic organism that can only multiply inside a host organism.

R Nought (R_0) A metric widely used in assessing disease transmissibility or the basic reproductive rate. It represents the average number of subsequent cases which one case generates during its infectious period.

Rickettsia A group of microorganisms requiring other living cells for growth like viruses, but having cell walls, using oxygen, and having metabolic enzymes like bacteria. Rickettsia are typically transmitted by ticks, mites, or lice. Typhus is one example of a disease caused by rickettsia.

Virus An infectious organism consisting of a nucleic acid molecule in a protein coat. It is only able to multiply inside the living cells of a host.

Emerging Infectious Disease

Emerging infectious diseases (EIDs) are some of the most challenging public health issues facing the global community. The hypothesis of "disease emergence" may have helped shaped the growth of global health initiatives, particularly at the World Health Organization (Brown et al., 2005; Lakoff, 2010). EIDs are caused by pathogens that: (1) have increased in incidence, geographic, or host range; (2) have changed pathogenesis; (3) have newly evolved; or (4) have been discovered or newly recognized (Lederberg et al., 1992).

In most developed countries, routine and seasonal outbreaks challenge health departments and healthcare systems, but reporting, investigation, and treatment protocols are typically in place, trained on, and easily implemented. Vaccination programs and antiviral and antimicrobial medications mitigate many recurring infectious disease risks.

Those who have been exposed to or infected with recurring illnesses have developed some immunity. However, novel infectious diseases pose challenges that often exceed the immune function of populations and the capabilities of public health systems around the world.

Factors Contributing to Emerging Infectious Diseases

There are several factors that permit infections previously not seen globally or in specific locations to emerge or reemerge after periods of quiescence. Those factors include:

- international travel and commerce
- economic development
- human demographic factors and behavior
- technology and industry
- microbial adaptation
- breakdown of public health measures and systems

International travel and commerce and the movement of goods and people permits the movement of sick people and disease vectors into areas previously not visited, thereby exposing others to pathogens previously not encountered. International tourism has expanded consistently for over 60 years. From 1950 to 1980 it grew more than ten-fold from 25 million in 1950 to 278 million in 1980. It nearly doubled again between 1980 to 1995 reaching 528 million and again by 2013 reaching 1.087 billion. Annual growth in tourism is expected to grow by over 3% each year reaching 1.8 billion international annual tourist arrivals in 2030 (UN, 2014). Modern transportation systems allow for rapid movement of people and with them diffusion of illness at a greater speed than during the preavia tion travel era. When travel was slower, often by caravan or ship, those who were ill could recover, layover, or succumb without transporting disease as easily.

Increased international travel is believed to have played a major role in the spread of HIV/AIDS. Some virologists suspect that HIV was present at very low levels in remote areas of West Africa for perhaps as long as 100 years in animals before the disease reached epidemic proportions and was officially isolated by scientists in 1983 (Krause). Hunting animals as a source of protein created greater exposure of humans to the disease, and development of the transcontinental highway from Point-Noire, Zaire (now the Democratic Republic of Congo) to Mombasa, Kenya, may have allowed truck drivers and traders along this route to carry the virus into the general population.

Airline travel has its own unique risks, with recirculated air in the confined space of an aircraft which could expose travelers to airborne diseases such as tuberculosis (see Fig. 10-4). Passenger compartment conditions have some similarities to the holds of ships in sea-crossings known historically for harboring EIDs. With the ease of global travel, people with increased luxury income can visit developing countries, exposing those populations to novel diseases, or return home with novel infections after several hours of airline travel and before signs or symptoms of illness become apparent.

FIGURE 10-4 CDC quarantine officer Danitza Tomianovic entering a plane in order to assess the status of an ill traveler at the Miami International Airport. This image was captured during an October 2008 preparedness exercise. *Photo by Christine Pearson courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

Economic development may result in changes of land use from agriculture to industry, disrupting established ecosystems. Altering natural habitats by building dams and creating deforestation–reforestation programs alters the balance of ecosystems, allowing some species to overflourish or die out. Additionally, there may be movement of people into land previously occupied by vegetation and animals, exposing those who resettle to novel or previously contained pathogens and/or vectors. Zoonotic diseases, those which infect animals, comprise 60–75% of EIDs (Taylor et al., 2001). In *The Coming Plague: Newly Emerging Diseases in a World out of Balance*, medical journalist Laurie Garret writes "In this fluid complexity, human beings stomp about with swagger, elbowing their way without concern into one ecosphere after another (Garrett, 1994)." In addition, the effect of climate change on emerging diseases is unknown; however, Lindgren et al. (2012) point out that climate change interacts with "a complex web" of all drivers of emerging diseases and therefore cannot be ignored. Alterations of the geographic ranges of birds in Europe and North America have also been demonstrated. Many migrating birds carry pathogens, and changes to migratory bird habitats may result in human exposures to new pathogens (Fuller et al., 2012). Climate change may also have effects on vector development, vector physiology, and vector habitat, ultimately affecting human vector-borne disease risks (Parham et al., 2015).

Human demographic factors and behavior including population density, population growth, and population distribution not only may affect the spread of people into geographic regions not previously inhabited, but it also can expose them to new pathogens. In addition, it may affect how disease transmission occurs from human to human. In many parts of the world, an increase in urban population is not matched by an increase in urban infrastructure and is accompanied by poverty, poor sanitation, and inadequate housing. Conflict can result in population shifts to new geographic areas, disruption of critical infrastructure (including public health and health systems), and economic stress. Poverty from any cause not only affects sanitation and vector control, but may force people into risk behaviors such as entering the sex trade. Once ill, people living in poverty may not have access to healthcare or even have basic hygiene resources. They also may be unable to comply with isolation measures. As populations continue to age and advanced medical interventions such as chemotherapy and immunosuppressive biologicals alter immune function, diseases previously not known to infect humans can emerge. Behaviors such as sexual activity and illicit drug use may also impact novel disease transmission.

FIGURE 10-5 In some countries, cultural practices prohibit euthanasia of unwanted, diseased, and aggressive animals. Ineffective control measures result in overcrowding, unsanitary conditions, death, and disease. *Photo by Ryan M. Wallace, DVM, MPH, courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

Understanding human relationships with animals provides additional insights into EID risks (see Fig. 10-5). Sixty percent of recent emerging diseases are zoonotic. Colocation of open poultry markets and cohabitation with poultry has been identified as an important risk factor for human cases of avian influenza (Dinh et al., 2006; Thorson et al., 2006; Choi et al., 2005). Human cases of high pathogenic avian influenza have occurred in workers depopulating flocks in the Netherlands and Canada (Koopmans et al., 2004; Tweed et al., 2004). Fortunately, few of these outbreaks to date have sustained human-to-human transmission. In 2003, an investigation of a large multistate outbreak of monkeypox was traced back to prairie dogs sold as exotic pets. The prairie dogs had been in close contact with giant Gambian rats from Ghana (CDC, 2003a). This outbreak resulted in increased controls of imported exotic animals and markets. The source of the 2003 severe acute respiratory syndrome (SARS) outbreak has never clearly been identified. The index cases were initially linked to catlike exotic pets related to raccoons called "civet cats" (CDC, 2003b).

This resulted in extensive bans on civet cat transportation and commerce. However, detailed investigation links the causative coronavirus to several wild animals used as food, and there are suggestions that the trade of many types of animals used in food was the source (CDC, 2003a,b; He, 2003a,b; Normille and Enserink, 2003; Guan et al., 2003; Ng, 2003).

Bats play an important role in ecosystems in vector control, seed dispersal, and pollination. However, it is increasingly recognized that bats also play a significant role in the reservoir and transmission of zoonotic infections. Contact with bats has long been recognized as a potential source for rabies, but several findings indicate that bats have a wider spectrum of diseases and may be a reservoir for paramyxoviruses such as measles, mumps, distemper, parainfluenza (Drexler et al., 2012; Messenger et al., 2003), and Ebola (Leroy et al., 2007). Freidl et al. (2015) recently discovered antibodies for influenza A H9 in bats. Influenza A H9 is a zoonotic disease and is a possible candidate for a novel pandemic strain. Human interactions with bats and their habitats can occur in the workplace, home or recreational venues. In an observational study in western Ghana, nearly half of the residents had contact with bats and bat habitats (Anti et al., 2015). Reengineering and reopening closed facilities where bats have populated must be made with prevention methods in place. Entering caves where bats and other animals live must also be approached with infectious disease precautions in mind.

Technology and industry certainly have tremendous human benefits but may also expose populations to conditions which foster EIDs. Some of the most significant issues are changes in food production. Mass agricultural compounds and facilities create environments where changes occur in microbial ecology. Globalization of the food supply allows transportation of organisms on and in food and through accompanying vectors. Food transportation over large distances may also introduce breaches in food security.

Advances in medical technology introduce techniques that allow bacteria to infect people and spaces not formerly at risk. Increases in invasive procedures can result in the introduction of novel organisms.

FDA discovers fungus in steroid shots, meningitis toll increases to 20 in U.S.

Reuters News, October 19, 2012

An epidemiological investigation in 2012 traced the source of a mysterious meningitis outbreak to contamination of methylprednisolone acetate, a steroid injected to relieve back pain. Several lots of the drug were contaminated with a rare fungus called *Exserohilum rostratum.* Over 13,000 patients were potentially exposed and 749 had confirmed infections, resulting in 61 deaths across 20 states (Smith et al., 2013).

The CDC healthcare-associated infection (HAI) 2011 survey of a large sampling of US acute care hospitals found on any given day, about 1 in 25 hospital patients has at least one HAI (see Table 10-1). There were an estimated 722,000 HAIs in US acute care hospitals in 2011, and about 75,000 patients died during their hospitalizations. More than half of all HAIs occurred outside of the intensive care unit.

Table 10-1 Estimated 2011 US Healthcare-Associated Acute Care Hospital Infections

Major Infection Site	Estimated Cases
Pneumonia	157,500
Gastrointestinal illness	123,100
Urinary tract infections	93,300
Primary bloodstream infections	71,900
Surgical site infections from any inpatient surgery	157,500
Other types of infections	118,500
Estimated total number of infections in US hospitals	**721,800**

To read the full report, please visit the CDC HAI Prevalence Survey (Magill et al., 2014).

Contaminated gastrointestinal and bronchoscopy endoscopic devices are among the many advanced technologies associated with increasing outbreaks in healthcare settings, including those of organisms such as *Pseudomonas aeruginosa* and *Salmonella* spp. (Kovalevaa et al., 2013). The US Food and Drug Administration, whose responsibilities include medical devices, issued a warning in March of 2015 raising awareness that several devices with complex designs may be difficult to adequately clean. Many causative agents of healthcare associated infections are especially dangerous but their transmission is preventable. While some causative agents are more common bacteria and viruses such as *Escherichia coli* or norovirus, many are less common, including *Acinetobacter*, *Burkholderia*, *Clostridium*, and *Klebsiella*. In addition, antibiotic-resistant strains such as carbapenem-resistant *Enterobacteriaceae*, methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant *Enterococci* and *S. aureus* are more difficult to control and treat. After the establishment of the European Union in the 1990s and increased economic growth, patient transfer within and between countries expanded. After political changes and the opening of borders, medical care and technology improved. For example, the number of bone-marrow transplant units in central Europe increased from 9 to 85 by 1995, and the number of dialysis units increased from approximately 200 to more than 1500 (Krcmery, 1997). However, Vincent et al. (1995) reported in a one-day prevalence study that 21% of ICU patients in Western Europe had nosocomial or healthcare-associated infections by microorganisms including *P. aeruginosa* and methicillin-resistant *Staphylococcus*.

Microbial adaptation contributes to the development of "super-bugs." This includes both bacteria and viruses (see Figs. 10-6 and 10-7). As discussed in the previous section, antimicrobial resistance is pervasive and is increasing in the face of widespread overuse and misuse of antibiotics. In addition, viruses rapidly adapt to immunologic responses. Influenza viruses provide an example of genetic drift and shift which make them a persistent health threat. Once formed, novel influenza viruses sometimes pose health risks for which humans and/or animals have little to no immunologic protection. These viruses can also develop an increased capacity for animal-to-animal or human-to-human sustained transmission.

Breakdown in public health systems and measures as a result of conflict, economic-based program cuts, or poor infrastructure can produce environments with increased risk and decreased prevention. This situation may result in disease emergence, but may also

FIGURE 10-6 A scanning electron micrograph image of two rod-shaped carbapenem-resistant *Klebsiella pneumoniae* bacteria interacting with a human white blood cell known specifically as a neutrophil. *Photo courtesy of the National Institute of Allergy and Infectious Diseases.*

FIGURE 10-7 CDC microbiologist Valerie Albrecht holding up for observation two Petri dish culture plates that were inoculated with methicillin-resistant *Staphylococcus aureus* (MRSA) bacteria. *Photo by Melissa Dankel courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

result in reemergence of diseases. Diseases which had previously been controlled through sanitation, vector control, or vaccination programs can reemerge if any of the prevention programs fail or stop. In developed countries with successful vaccination campaigns, many diseases have been declared "controlled" or "eradicated." Because of this, political and public interest in continued vaccination programs is waning, or personal risk is considered low relative to the risk (real or perceived) of vaccinations. In the United States there are also many states allowing "opt-out" programs so people may choose not to get vaccinated or have their children vaccinated. In numerous outbreaks this has proved problematic.

Measles Cases Linked to Disneyland Rise, and Debate Over Vaccinations Intensifies

The US antivaccination movement has contributed to increased preventable illnesses and deaths. It is led by misguided conspiracy theorists, minor celebrities, and a small number of "healthcare professionals" who are either unfamiliar with or in denial of the science supporting vaccinations. The above headline appeared in January 2015 in the *New York Times* (Nagourney and Goodnough, 2015). Notable quotes from this report include:

- "We can expect to see many more cases of this preventable disease unless people take measures to prevent it," Dr. Gilberto F. Chavez, the deputy director of the California Center for Infectious Diseases, said. "I am asking unvaccinated Californians to consider getting vaccinated against measles."
- Dr. James Cherry, a specialist in pediatric infectious diseases at UCLA, said the outbreak was "100 percent connected" to the anti-immunization campaign. "It would not have happened otherwise—it would not have gone anywhere," he said. "There are some pretty dumb people out there."
- "The problem is that there are these pockets with low vaccination rates," said Dr. Jane Seward, deputy director of the viral diseases division at the CDC. "If a case comes into a population where a lot of people are unvaccinated, that's where you get the outbreak and where you get the spread."

In Ghent, Belgium, a 2011 measles outbreak was associated with an anthroposophic school which promotes "complementary medicine" (Braeye et al., 2013). Over 65 cases of measles were identified in a school that had low vaccination rates because of the philosophical beliefs of the parents. Leaders of the school were not against vaccination. Striking the balance between individual rights and beliefs, relative risk perception and acceptance, and public health priorities is always challenging.

Likely Sources for Emerging Infectious Diseases

While the next emerging disease can be of any species of infectious organism, trends in recent cases display patterns suggesting which threats may be imminent (See Table 10-2). Coronaviruses such as the causative agents of SARS and Middle East Respiratory Syndrome Co-V (MERS Co-V); filoviruses such as Ebola; and novel influenza viruses, are considered likely candidates. In a study by Taylor et al., 2001 an analysis of emerging species revealed that of those known, there are 175 currently emerging species. Viruses and prions are less than half of the total (44%), and bacteria or rickettsia comprise just under one-third. These

Table 10-2 Emerging Species in Each Major Taxonomic Division

Taxonomic Division	% of Emerging Diseases
Viruses or prions	44
Bacteria or rickettsia	30
Protozoa	11
Fungi	9
Helminths	6

Adapted from Taylor, L.H., Latham, S.M., Woolhouse, M.E., 2001. Risk factors for human disease emergence. Philos. Trans. R. Soc. B Biol. Sci. 356 (1411), 983–989.

potential pathogens may be transmitted by several routes, and the most common route is direct contact (53%), followed by indirect contact (47%), vectors (28%), and for 6% the route of transmission is unknown (Taylor et al., 2001).

Prevention and Preparedness

While it may not be possible to predict which pathogens may emerge or reemerge, it is possible to build infrastructure and take general steps to make populations and public health systems better prepared for the next novel infectious disease outbreak. At the heart of these measures is epidemiological surveillance. Identification of a new illness or disease requires surveillance systems which not only continually monitor "routine" illness, but also have the ability to recognize anomalies when something is not "routine." As described in chapter "Bioterrorism," there have been extensive efforts toward developing early warning epidemiological and environmental surveillance systems for unusual diseases and pathogens. The vital link in identifying a novel disease in a community is the astute clinician. Clinicians must be able to recognize a novel disease, report it appropriately, and feel confident that the information will be quickly analyzed and acted upon. Laboratory support is vital to quickly identifying and characterizing an emerging threat. This includes testing for drug resistance to inform decision-making concerning appropriate medical countermeasures. Continued epidemiological surveillance throughout an outbreak can produce data which may be useful in evaluating and improving the public health and medical response.

Preparedness Actions for Emerging Infectious Disease

- surveillance
- robust outbreak investigation practices
- transmission prevention through containment and control measures
- delivery of medical countermeasures, if any
- public messaging
- recovery to a "new normal"

FIGURE 10-8 Hasan Alkaf, DVM, is shown extracting blood samples from a camel's neck during the investigation into the first reported Middle East Respiratory Syndrome Coronavirus (MERS-CoV) case in Haramout, Yemen. *Photo by Awadh Mohammed Ba Saleh, Yemen, courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

Along with surveillance is the ability of public health responders to perform detailed outbreak investigations to determine the characteristics of the disease. Characterization of the outbreak, identifying the natural course of the illness, and recognizing key risks for infection are necessary in order to learn how the new illness behaves in a population (see Fig. 10-8). This information will also inform control measure decisions. A priority item in the initial characterization of an outbreak is the identification of transmissibility. Unfortunately, as surveillance methods are enhanced and cases are increasingly recognized and reported, transmissibility may be a very difficult thing to quantify. For example, the current analyses of transmissibility for MERS Co-V suggest that it is not a likely pandemic threat because of its low reproduction number or "r nought" (R_0). However, different cluster sizes, demographics, geographies, and public health and healthcare infrastructures may alter the outbreak characteristics and the reproduction number (R_0) (Fisman et al., 2014). Capturing critical data will allow for accurate characterization within the context of the outbreak and will direct response activities such as control measures and medical surge management.

Response and Recovery

The primary control strategy in all infectious disease outbreaks is preventing transmission. Even minimal biosecurity actions can prevent animal-to-human transmission. Separation of potential source animals, such as exotic imported animals and poultry, from routines such as cooking can reduce risk. Effective cleaning of animal waste and habitats should be performed with at least basic respiratory protection. To prevent human-to-human transmission, good hygiene practices such as hand washing, general surface cleaning,

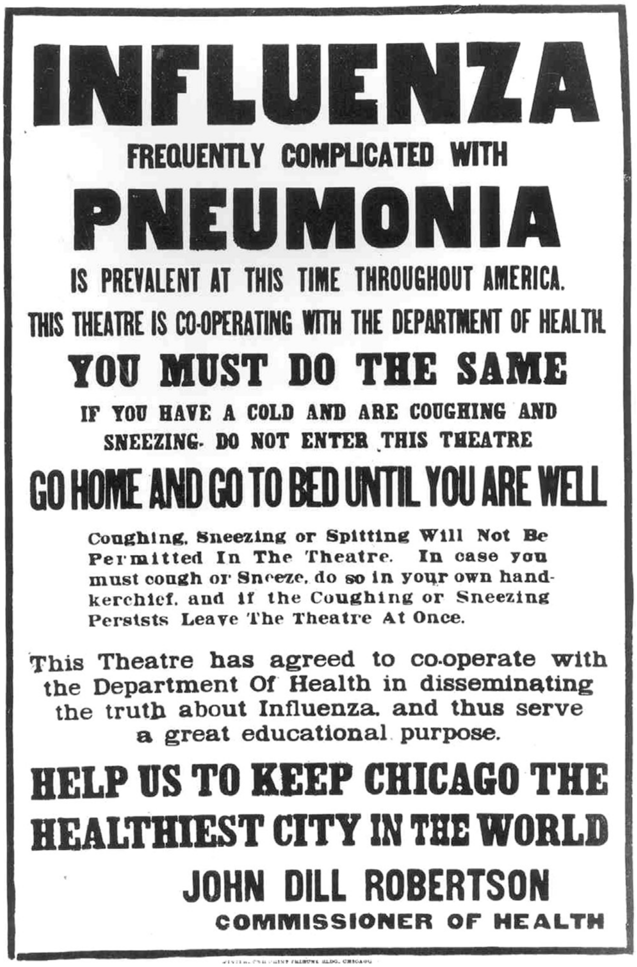

FIGURE 10-9 Influenza warning posters, then and now: Chicago Department of Health poster from the early 20th Century warned those who were ill to stay away from theaters and other public places. *Photo courtesy of the Department of Health and Human Services, Office of the Public Health Service Historian.*

and careful waste disposal should be reinforced. During the 2009–2010 H1N1 pandemic, people were advised to "cough hygienically" into their sleeve to prevent contamination of the hands and then others. Of note, this technique was not without some controversy and was not recommended in the United Kingdom and Spain (Anderson, 2010). Supplying hand wipes and hand sanitizer may be implemented in some locations of businesses, critical industries, and government agencies where other measures may not be reasonable. Social distancing by school closures, limiting mass gatherings, and canceling large events may be necessary (see Figs. 10-9 and 10-10). Quarantine may be considered for individuals who have been exposed but are not yet sick, typically for two incubation periods of the disease. Isolation separates those who are already ill from those who are not ill.

FIGURE 10-10 Influenza warning posters, then and now: New York State poster encouraging patients arriving to hospitals to identify themselves if they have flu-like symptoms. *Image courtesy of the New York State Department of Health.*

In healthcare settings, isolation may begin from early screening of patients at points of entry. This may limit disease transmission to other patients who often have underlying conditions which increase their risks for severe illnesses and complications. Risk management for communicable diseases in emergency departments includes signage to encourage patients to self-identify if they are sick or have an associated travel history. This allows for rapid triage to isolation areas and early institution of personal protective equipment for staff (Puro et al., 2008).

In a 2012 study conducted of 41 facilities in 14 European countries, 83% had isolation rooms, but not all had anterooms, negative pressure, or HEPA filtration. Only 14.6% had all components. Personnel trained in the recognition of highly infectious diseases were available in 24 of the 41, and management protocols were available in 35 of the 41 (Fusco et al., 2012). It would be interesting to see how attention paid to diseases such as Ebola has impacted these numbers.

In addition to human-to-human spread, animal-to-human spread is a common transmission route for EIDs. Zoonotic disease professionals can develop recommendations for vector control when zoonotic diseases threaten human populations. Mosquitoes are the most pervasive disease-carrying vectors. Control measures include reducing standing water breeding sources or using larvicides and adulticides. The recent introduction of engineered *Aedes aegypti* mosquitoes (OX513A), which can reproduce and produce offspring which die rapidly, shows promise in areas with emerging dengue fever (Specter, 2012).

Once control measures are determined, public health agencies must have the legal and social authority to implement recommended measures. The majority of the population typically complies with basic containment measures such as improved hygiene, avoiding ill people, etc. However, some individuals may be reluctant or unable to comply. For example, minimally ill people without paid sick leave may not be able to stay at home without significant economic loss. People may, out of fear, choose to flee quarantine zones. In these cases, agencies need to have flexible, scalable authorities to limit travel outside areas known to have disease. The challenges with quarantine measures were apparent throughout the international response to the 2014–2015 West African Ebola epidemic. In the United States as in many countries, the government has the authority to restrict state-to-state and international travel. State and local health agencies have authority to control intrastate activities. However, political pressure may make it difficult to enact some control measures. School closure is one of the more difficult decisions for government agencies during a public health emergency. For many communicable diseases, children can act as superspreaders because of their behaviors and hygiene lapses. However, many schools function not only as places of education but also deliver significant social programs: safe havens, meals, and day care for working parents with marginal income. To close these schools disrupts very necessary social welfare programs.

Quarantine laws must also respect civil liberties. In the United States for example, quarantine orders must be the least restrictive form of control, have very clear reasons, be time-limited and allow for appeal. Enforcement of quarantine orders requires law enforcement officers to interact, sometimes in close physical proximity, with potentially contagious individuals. Additionally, any enforcement of quarantine of an individual must be heard in the judicial system. The judiciary has its own constitutional constraints of process which are frequently in opposition to the goals of quarantine.

If the EID is susceptible to antibiotics or a vaccine is quickly developed, rapid distribution and dispensing of these medical countermeasures must be conducted. If the illness is highly contagious, programs limiting public interaction during mass dispensing and mass vaccinations will need to be implemented. As discussed throughout this text, it is unlikely that there will be large quantities of medical countermeasures available early on in an emerging or reemerging infectious disease outbreak. Therefore, plans must also be in place for the utilization of scarce resources while complying with ethical and legal frameworks.

Throughout the entire outbreak, appropriate public messaging must be delivered. Messages will contain information about the illness, personal protective actions, and where to go for health care. These messages must communicate risk and how individuals can limit morbidity and mortality. General prescripted public health messages can often be adapted early in an outbreak when detailed information on the threat is not yet specific. Trusted leaders in the community should be used to deliver messages in order to improve compliance and alleviate fear.

A "new normal" may follow as a community recovers from a novel outbreak. Some EIDs become endemic diseases in affected communities and must be included in recurring public health activities. For example, West Nile virus was first introduced to the Western Hemisphere in the late 1990s and is now an annual threat, causing 41,762 cases from 1999 to 2014 and 1765 deaths (CDC, 2014). However, public health responses help to establish new practices in order to limit reemergence. These activities also prepare the community for similar EID threats. Because of ongoing West Nile virus threats in North America, the region is better prepared for emerging threats such as chikungunya and dengue.

Conclusion

Public health has been challenged with EIDs throughout human history. With globalization of populations, commerce, and travel comes globalization of infectious diseases. This exposes people and animals to novel diseases for which they have little to no natural immunity. Rapid transportation and free movement allows sick individuals to spread illness and disease faster than ever before. Preparedness efforts cannot predict the next emerging infection, but public health and healthcare capabilities developed, lessons learned from prior outbreaks, and institutionalization of routine infection control practices may serve to lessen the impact.

Websites

Centers for Disease Control and Prevention (CDC), Healthcare-Associated Infections (HAI). http://www.cdc.gov/hai/.

Centers for Disease Control and Prevention, The 2009 H1N1 Pandemic: Summary Highlights, April 2009–2010: http://www.cdc.gov/h1n1flu/cdcresponse.htm.

Centers for Disease Control and Prevention (CDC), Division of Global Health Protection (DGHP). http://www.cdc.gov/globalhealth/healthprotection/default.htm.

Centers for Disease Control and Prevention (CDC), National Center for Infectious Diseases (NCID), Emerging Infectious Diseases. http://www.cdc.gov/ncidod/diseases/eid/index.htm.

Emerging Infections Network (EINet), University of Washington. http://depts.washington.edu/einet/.

Food and Drug Administration, FDA and CDC Public Health Advisory: Infections from Endoscopes Inadequately Reprocessed by an Automated Endoscope Reprocessing System. http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/PublicHealthNotifications/ucm062282.htm.

State University of New York Levin Institute, Globalization 101. http://www.globalization101.org.

University of Washington, Emerging Infections of International Public Health Importance, On-line Course. http://depts.washington.edu/eminf/.

World Health Organization, West Nile Virus Fact Sheet. http://www.who.int/mediacentre/factsheets/fs354/en/.

World Health Organization, Ebola Situation Reports. http://apps.who.int/ebola/ebola-situation-reports.

World Health Organization, Emergencies Preparedness, Response. http://www.who.int/csr/en/.

References

Andersen, B.M., May 2010. European Centre for disease prevention and control swine flu guidelines: 'cough hygienically' into your sleeve? J. Hosp. Infect. . ISSN: 0195-6701 75 (1), 73–74. http://www.sciencedirect.com/science/article/pii/S0195670110000265.

Anti, P., Owusu, M., Agbenyega, O., Annan, A., Badu, E.K., Nkrumah, E.E., Tschapka, M., Oppong, S., Adu-Sarkodie, Y., Drosten, C., 2015. Human–bat interactions in rural West Africa. Emerg. Infect. Dis. 21 (8), 1418–1421. http://dx.doi.org/10.3201/eid2108.142015.

Braeye, Y., Sabbe, M., Hutse, V., Flipse, W., Godderis, L., Top, G., 2013. Obstacles in measles elimination: an in-depth description of a measles outbreak in Ghent, Belgium, spring 2011. Arch. Public Health 71, 17. http://dx.doi.org/10.1186/0778-7367-71-17.

Brown, T., Fee, E., Cuerto, M., 2005. The world health organization and the transition from international to global public health. AJPH 95 (1), 62–72.

Centers for Disease Control and Prevention (CDC), 2001. Outbreak of Ebola Hemorrhagic Fever--Uganda, August 2000-January 2001. MMWR Morb Mortal Wkly Rep. February 09, 2001, 50 (05), 73–67. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5005a1.htm.

Centers for Disease Control and Prevention (CDC), 2003a. Update: multistate outbreak of monkeypox – Illinois, Indiana, Kansas, Missouri, Ohio, and Wisconsin, 2003. MMWR. 52 (27), 642–646. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5227a5.htm.

Centers for Disease Control and Prevention (CDC), 2003b. Prevalence of IgG antibody to SARS-associated coronavirus in animal traders – Guangdong province, China, 2003. MMWR. 52 (41), 986–987. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5241a2.htm.

Centers for Disease Control and Prevention (CDC), 2014. West Nile Virus, Final Cumulative Maps & Data for 1999–2014. http://www.cdc.gov/westnile/statsmaps/cummapsdata.html.

Centers for Disease Control and Prevention (CDC), 2015. 2014 Ebola Outbreak in West Africa - Case Counts. http://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/case-counts.html.

Choi, Y.K., Seo, S.H., Kim, J.A., Webby, R.J., Webster, R.G., February 20, 2005. Avian influenza viruses in Korean live poultry markets and their pathogenic potential. Virology. ISSN: 0042-6822 332 (2), 529–537. http://www.sciencedirect.com/science/article/pii/S0042682204008165.

Dinh, P.N., Long, H.T., Tien, N.T.K., et al., 2006. Risk factors for human infection with avian influenza a H5N1, Vietnam, 2004. Emerg. Infect. Dis. 12 (12), 1841–1847. http://dx.doi.org/10.3201/eid1212.060829.

Drexler, J.F., Corman, V.M., Müller, M.A., Maganga, G.D., Vallo, P., Binger, T., Drosten, C., 2012. Bats host major mammalian paramyxoviruses. Nat. Commun. 3, 796. http://dx.doi.org/10.1038/ncomms1796.

Fisman, D.N., Leung, G.M., Lipsitch, M., 2014. Nuanced risk assessment for emerging infectious diseases. Lancet. 383 (9913), 189–190. http://dx.doi.org/10.1016/S0140-6736(13)62123-6.

Freidl, G.S., Binger, T., Müller, M.A., de Bruin, E., van Beek, J., Corman, V.M., Koopmans, M., 2015. Serological evidence of influenza a viruses in frugivorous bats from Africa. PLoS One 10 (5), 1–7. http://dx.doi.org/10.1371/journal.pone.0127035.

Fuller, T., Bensch, S., Muller, I., Novembre, J., Perez-Tris, J., Ricklefs, R.E., Smith, T.B., Waldenstrom, J., March 2012. The ecology of emerging infectious diseases in migratory birds: an assessment of the role of climate change and priorities for future research. EcoHealth 9 (1), 80–88.

Fusco, F.F., Schilling, S., DeIaco, G., Brodt, H.-R., Brouqui, P., Maltezou, H.S., Bannister, B., Gottschalk, R., Thomson, G., Puro, V., Ippolito, G., EuroNHID Working Group, 2012. Infection control management of patients with suspected highly infectious diseases in emergency departments: data from a survey in 41 facilities in 14 European countries. BMC Infect. Dis. 12, 27. http://www.biomedcentral.com/1471-2334/12/27.

Garrett, L., 1994. The Coming Plague: Newly Emerging Diseases in a World Out of Balance. pp. 618–619 New York: Farrar, Straus and Giroux.

Gatherer, D., July 2009. The 2009 H1N1 influenza outbreak in its historical context. J. Clin. Virol. ISSN: 1386-6532 45 (3), 174–178. http://www.sciencedirect.com/science/article/pii/S1386653209002534.

Guan, Y., Zheng, B.J., He, Y.Q., et al., 2003. Isolation and characterization of viruses related to the SARS coronavirus from animals in southern China. Science 302 (5643), 276–278.

He, S.F., et al., 2003a. Severe acute respiratory syndrome in Guangdong province of China: epidemiology and control measures. Chin. J. Prev. Med. 37 (4), 227.

He, S.F., et al., 2003b. An epidemiological study on the index cases of severe acute respiratory syndrome occurred in different cities in Guangdong province. Chin. J. Epidemiol. 24 (5), 347.

Johnston, L., Conly, J.M., July–August 2000. West Nile virus – where did it come from and where might it go? Can. J. Infect. Dis. 11 (4), 175–178. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2094770/#B27.

King, N.B., 2004. The scale politics of emerging diseases. The history of science society. OSIRIS 19, 062–076.

Koopmans, M., Wilbrink, B., Conyn, M., Natrop, G., van der Nat, H., Vennema, H., Meijer, A., van Steenbergen, J., Fouchier, R., Osterhaus, A., Bosman, A., February 21, 2004. Transmission of H7N7 avian influenza A virus to human beings during a large outbreak in commercial poultry farms in the Netherlands. Lancet. ISSN: 0140-6736 363 (9409), 587–593. http://dx.doi.org/10.1016/S0140-6736(04)15589-X.

Kovalevaa, J., Peters, F.T.M., van der Mei, H.C., Degener, J.E., April 2013. Transmission of infection by flexible gastrointestinal endoscopy and bronchoscopy. Clin. Microbiol. Rev. 26 (2), 231–254.

Krcmery, V., 1997. Trends in nosocomial infections in europe: comparison between Western and Central Europe. J. Clin. Microbiol. Infect. 3 (7), 18.

Lakoff, A., 2010. Two regimes of global health. Humanity 1 (1), 59–79.

Lederberg, J., et al. (Ed.), 1992. Emerging Infections: Microbial Threats to Health in the United States. Institute of Medicine, National Academy Press.

Leroy, E.M., Epelboin, A., Mondonge, V., Pourrut, X., Gonzalez, J.-P., Muyembe-Tamfum, J.-J., Formenty, P., 2007. Human ebola outbreak resulting from direct exposure to fruit bats in Luebo, Democratic Republic of Congo, 2007. Vector Borne Zoonotic Dis. 9 (6), 723–728.

Lindgren, E., Andersson, Y., Suk, J.E., Sudre, B., Semenza, J.S., April 2012. Monitoring EU emerging infectious disease risk due to climate change. Science 336 (6080), 418–419. http://dx.doi.org/10.1126/science.1215735.

Magill, S.S., Edwards, J.R., Bamberg, W., et al., 2014. Multistate point-prevalence survey of health care–associated infections. N. Engl. J. Med. 370, 1198–1208.

Messenger, S.L., Rupprecht, C., Smith, C., 2003. Bats, emerging virus infections and the rabies paradigm. In: Kunz, T.H., Fenton, M.B. (Eds.), Bat Ecology. University of Chicago Press, Chicago, pp. 622–679.

Nagourney, A., Goodnough, A., January 21, 2015. Measles Cases Linked to Disneyland Rise, and Debate Over Vaccinations Intensifies. New York Times. http://www.nytimes.com/2015/01/22/us/measles-cases-linked-to-disneyland-rise-and-debate-over-vaccinations-intensifies.html.

Normille, D., Enserink, M., 2003. Tracking the roots of a killer. Science 301, 297–299.

Ng, S.K.C., 2003. Possible role of an animal vector in the SARS outbreak at Amoy Gardens. Lancet 362, 570–572.

Parham, P.E., Waldock, J., Christophides, G.K., Hemming, D., Agusto, F., Evens, K.J., Fefferman, N., Gaff, H., Gumel, A., Ladeau, S., Lenhart, S., Mickens, R.E., Naumova, E.N., Ostfeld, R.S., Ready, P.D., Thomas, M.B., Velasco-Herandez, J., Michael, E., February 16, 2015. Climate, environmental and socio-economic change: weighing up the balance in vector-borne disease transmission. Phil. Trans. R. Soc. B 370. http://dx.doi.org/10.1098/rstb.2013.0551. 20130551.

Puro, V., Fusco, F.M., Lanini, S., Nisii, C., Ippolito, G., 2008. Risk management of febrile respiratory illness in emergency departments. New Microbiol. 31, 165–173.

Roehrig, J.T., 2013. West Nile virus in the United States-a historical perspective. Viruses 5 (12), 3088–3108. http://dx.doi.org/10.3390/v5123088.

Smith, R.M., Schaefer, M.K., Kainer, M.A., Wise, M., Finks, J., et al., October 24, 2013. Fungal infections associated with contaminated methylprednisolone injections. N. Engl. J. Med. 369 (17), 1598–1609.

Specter, M., July 9, 2012. The Mosquito Solution. New Yorker Magazine. http://www.newyorker.com/magazine/2012/07/09/the-mosquito-solution.

Taylor, L.H., Latham, S.M., Woolhouse, M.E., July 29, 2001. Risk factors for human disease emergence. Philos. Trans. R. Soc. Lond. B Biol. Sci. 356 (1411), 983–989.

Thorson, A., Petzold, M., Chuc, N., Ekdahl, K., 2006. Is exposure to sick or dead poultry associated with flu-like illness? A population-based study from a rural area in Vietnam with outbreaks of highly pathogenic avian influenza. Arch. Intern. Med. 166 (1), 119–123. http://dx.doi.org/10.1001/archinte.166.1.119.

Tweed, S.A., Skowronski, D.M., David, S.T., Larder, A., Petric, M., Lees, W., Li, Y., Katz, J., Krajden, M., Tellier, R., Halpert, C., Hirst, M., Astell, C., Lawrence, D., Mak, A., 2004. Human illness from avian influenza H7N3, British Columbia. Emerg. Infect. Dis. 10 (12), 2196–2199. http://dx.doi.org/10.3201/eid1012.040961.

United Nations (UN), 2014. World Tourism Organization. UNWTO Tourism Highlights. Edition. http://www.e-unwto.org/doi/pdf/10.18111/9789284416226.

Vincent, J., Bihari, D.J., Suter, P.M., et al., 1995. The prevalence of nosocomial infection in intensive care units in Europe: results of the European prevalence of infection in intensive care (EPIC) study. JAMA 274 (8), 639–644. http://dx.doi.org/10.1001/jama.1995.03530080055041.

World Health Organization (WHO), 2014. Ebola response team 2014. Ebola virus disease in West Africa—the first 9 months of the epidemic and forward projections. N. Engl. J. Med. 371, 1481–1495.

World Health Organization (WHO), 2011. West Nile Virus Fact Sheet. http://www.who.int/mediacentre/factsheets/fs354/en/.