



A GUIDE TO
OUTBREAKS OF
EMERGING
INFECTIOUS
DISEASES

A GUIDE TO

OUTBREAKS OF EMERGING INFECTIOUS DISEASES

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KEY FACTS

HUMAN PATHOGENS

Infectious diseases are caused by infectious agents, which gain entry into a host organism and disrupt its normal bodily functions.¹ Many infectious diseases of humans are also *communicable*, meaning the infection can pass from one person to another.

While many microorganisms are harmless and even helpful, those that cause disease are called *pathogens*.¹ There are over 1,400 recognized human pathogens that fall into several categories, including viruses, bacteria, and fungi.²

Some human pathogens can be neutral under one set of conditions and pathogenic under others. An increase in *virulence*, or the severity of disease caused by a pathogen, is sometimes triggered by certain conditions within the body after the pathogen has been dormant for period of time.

All known life forms are susceptible to infections and the resulting diseases. An organism that a pathogen infects is called a *host*. Some pathogens can reproduce without a host. Some may persist in the environment. A habitat or organism where a pathogen lives and multiplies is called a *reservoir*.^{1,3} Organisms that are reservoirs often do not themselves exhibit debilitating disease. This enables them to be long-term carriers of the pathogen and thus a continuing source of new infections.

All known life forms, including humans, are susceptible to infections and the resulting diseases.



Infectious disease researchers feed macaque monkeys on the streets of Dhaka, Bangladesh, and collect samples of their feces for testing.

Photo courtesy of Tangled Bank Studios

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Table 1. Types of human pathogens ^{1, 2, 4}			
Type of pathogen	Number of species known to infect humans	Examples	Resulting disease in humans
Bacteria Bacteria are prokaryotes, one-celled living organisms that lack a nucleus and organelles. Not all bacteria require a living host to survive, but many pathogenic types thrive in a human host.	538	<i>Salmonella typhi</i>	Typhoid fever
		<i>Vibrio cholerae</i>	Cholera
		<i>Borrelia burgdorferi</i>	Lyme disease
Fungi While some fungi are multicellular organisms (like mushrooms), most pathogenic fungi are unicellular yeasts and molds.	317	<i>Exserohilum rostratum</i>	Fungal meningitis
		<i>Candida</i> species	Thrush and other yeast infections
Helminths Helminths are multicellular wormlike parasites that are generally large enough to be seen with the naked eye. Some can live for years within their host and grow to substantial size.	287	<i>Schistosoma</i> species	Swimmer's itch
		<i>Trichinella spiralis</i>	Trichinosis
Viruses Viruses consist of genetic material encased in a protein shell. By many definitions, they are not living organisms, because they must use a host to replicate and spread.	206	West Nile virus	West Nile fever
		Influenza A virus	Influenza
		<i>Varicella zoster</i> virus	Chickenpox in children, shingles in adults
Protozoa Protozoans are complex unicellular parasites able to survive in harsh conditions. Many types are able to move using structures like cilia or flagella.	56	<i>Cyclospora cayetanensis</i>	Cyclosporiasis
		<i>Plasmodium</i> species	Malaria
		<i>Trypanosoma brucei</i>	Sleeping sickness
Prions Prions are misfolded proteins that can cause the misfolding of other proteins they come into contact with. Prions can be transmitted from one individual to another but can also result from inherited genetic mutations. Prion infections generally lead to degenerative neurological diseases.	<10	Creutzfeldt-Jakob disease agent	Creutzfeldt-Jakob disease (a fatal neurodegenerative disease)

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TRANSMISSION OF PATHOGENS

A defining characteristic of every pathogen is its route of transmission. Major routes of transmission (see table 2) vary from one pathogen to another, and some are able to transmit via multiple routes.

In general, the routes of transmission fall into two major categories. *Direct transmission* occurs via immediate physical contact between an infected individual and another. Depending on the pathogen, direct transmission can occur during sexual contact or through more casual contact such as holding hands.¹ *Indirect transmission* does not require direct physical contact with an infected individual. Pathogens may be transmitted indirectly by airborne particles, contaminated food or water, or contact with contaminated objects.

A defining characteristic of every pathogen is its route of transmission.

Table 2. Transmission Routes of Pathogens ¹		
Transmission route	Examples	More information
Blood and other bodily fluids	Ebola virus Hepatitis C virus HIV Papillomaviruses	Pathogens can be carried in blood and other bodily fluids such as mucus, saliva, urine, or semen. They may be transmitted via direct contact with open cuts, sores, or membranes, or via sexual intercourse. Bodily fluids can also transmit pathogens indirectly, such as through blood transfusions or contaminated needles.
Vertical	Zika virus	As opposed to typical person-to-person transmission between two separate individuals, direct transmission from a mother to her child in utero, referred to as <i>vertical transmission</i> , may also occur.
Airborne	Influenza A virus <i>Legionella</i> <i>Mycobacterium tuberculosis</i> <i>Bacillus anthracis</i>	Airborne pathogens are aerosolized into particles small enough to remain suspended in the air. Some may be dispersed in a cough or sneeze, or become aerosolized in air-conditioning units. Some fungi and bacteria are dispersed in spores that remain infective months or even years after they were produced.
Water/foodborne	<i>Salmonella typhi</i> <i>Vibrio cholerae</i> Hepatitis A virus Norovirus	Some pathogens such as <i>E. coli</i> can pass in the feces of an infected individual and contaminate a food or water source. These typically cause diseases with gastrointestinal symptoms and tend to be endemic in areas with poor infrastructure or deficient sanitation systems.
Vector-borne	West Nile virus Zika virus <i>Borrelia burgdorferi</i>	Organisms that transmit a pathogen from one host to another, typically arthropods such as ticks and mosquitoes, are referred to as vectors. ¹ After biting an infected host, the vector may then transmit the pathogen to another organism.

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ZOONOSIS AND SPILLOVER

While some pathogens infect only one type of host organism, others are able to infect multiple species. When a pathogen is able to infect a nonhuman animal species and also infect humans, the resulting disease in humans is called a *zoonosis*.⁵ *Zoonotic* transmission from an animal host to a human is sometimes referred to as a *spillover event*.

Over the past several decades, the number and geographic range of zoonotic pathogens have steadily increased. Bats and rodents are the most common known mammalian reservoirs of zoonotic pathogens.⁶ Often, the infected animals show little or no evidence of disease themselves, but when passed to humans the same pathogen may cause severe symptoms in the human host. Spillover events have initiated large outbreaks of diseases such as Ebola and Nipah, both of which can be traced back to bats.



Photo by Aileen O'Hearn

A sign at Kenema Government Hospital in Sierra Leone warns residents about the rats that carry Lassa virus. Lassa virus causes a hemorrhagic fever that is endemic in West Africa. The rats that carry it both contaminate food supplies and are hunted for meat in many West African communities.

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EMERGING INFECTIOUS DISEASES

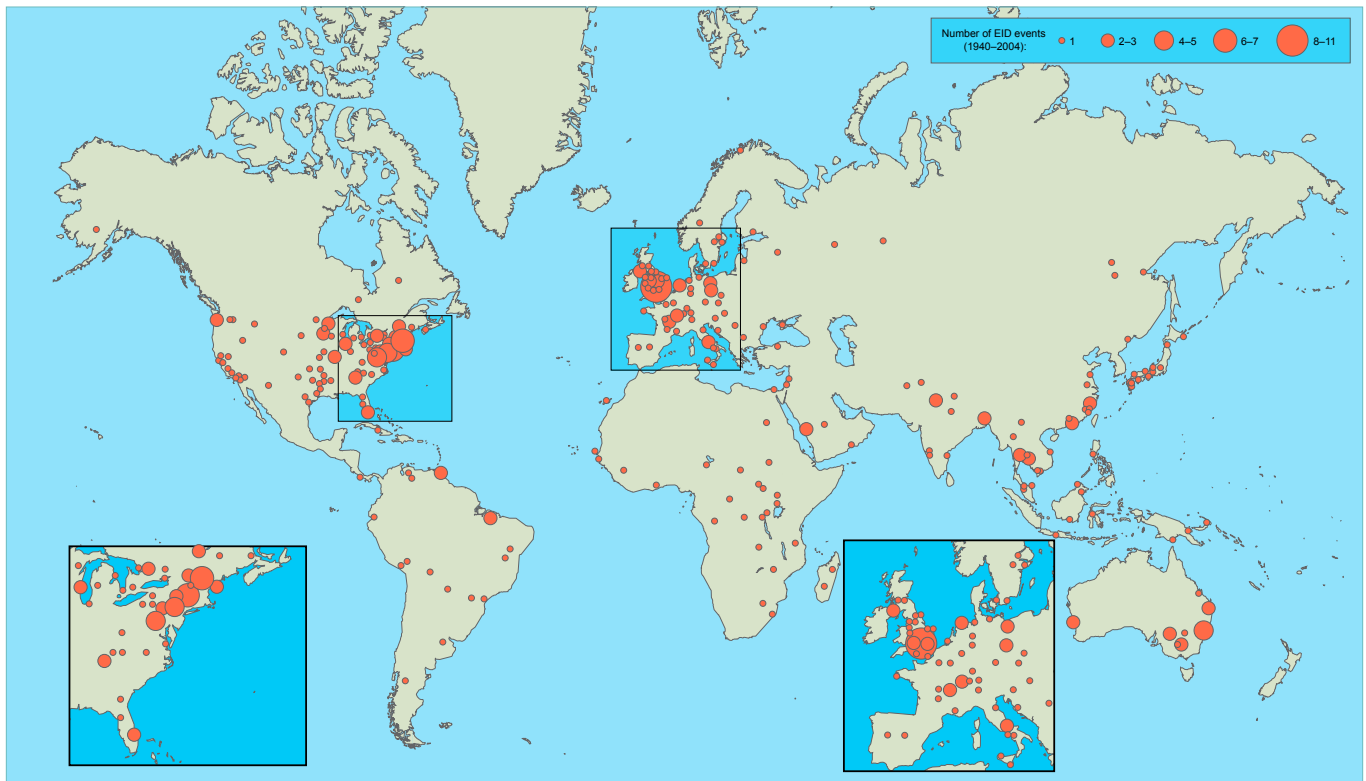
Some infectious diseases have persisted in human populations for thousands of years. Examples of historical infectious diseases include yellow fever (caused by yellow fever virus), leprosy (caused by *Mycobacterium leprae*), rubella (caused by the rubella virus), and smallpox (caused by the variola virus).

By studying patterns of disease over time, researchers have identified previously undetected diseases or diseases whose prevalence has recently increased or expanded into new areas.^{1,7,8} These are referred to as *emerging infectious diseases (EIDs)*. One of the most well-known EIDs in recent history is acquired immunodeficiency syndrome (AIDS), which is caused by the human immunodeficiency virus (HIV). AIDS is thought to have emerged in Africa in the early part of the 20th century, likely the result of a zoonosis via chimpanzees, and has since become a heavy public health burden throughout the world.⁹

Surveys of the medical literature have shown a steady increase in EIDs over the past half-century.^{2,10} Since the 1940s, scientists have identified more than 300 EIDs around the globe (Figure 1).

Since the 1940s, scientists have identified more than 300 emerging infectious diseases around the globe.

Figure 1. Geographic origins of EIDs worldwide between 1940 and 2004.¹⁰



Adapted from Jones et al., 2008.

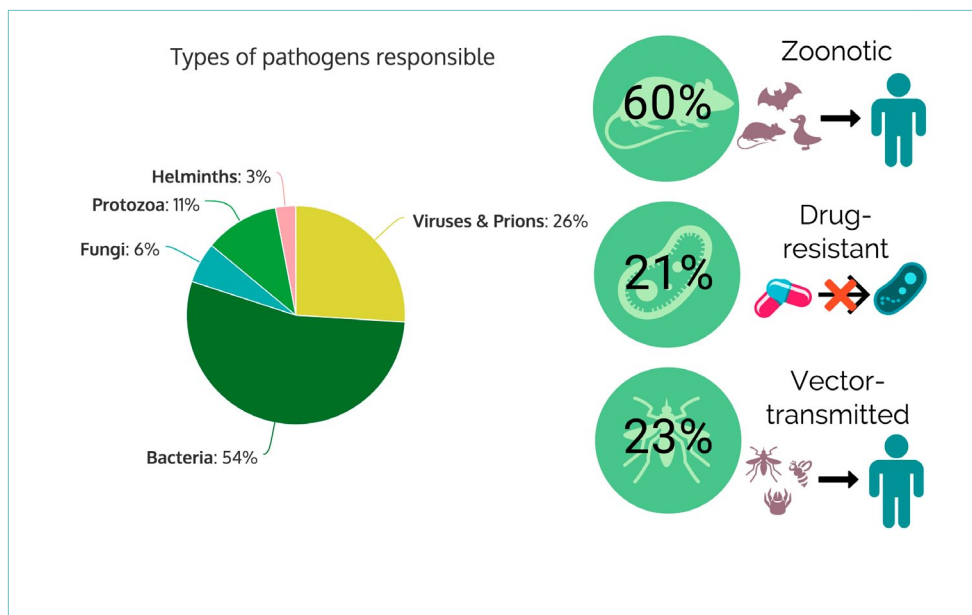
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Re-emerging Diseases

The human population also experiences *re-emerging diseases*. These are diseases that were previously on the decline and then resurge.^{1,34} An example is measles, which was nearly eliminated in the U.S. thanks to widespread vaccination. Since 2005, however, measles has re-emerged, with a number of outbreaks in populations with low vaccination rates.³⁵

Viruses and bacteria are responsible for the majority of recent EIDs. Sixty percent of EIDs are zoonotic, 21 percent are drug-resistant, and 23 percent are transmitted by a vector (Figure 2).¹⁰

Figure 2. Emerging Infectious Diseases (EIDs) 1940–2004.¹⁰



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CAUSES OF EMERGING INFECTIOUS DISEASES

EIDs are driven by the growth of the human population, which has risen from 2.5 billion in 1950 to 7.4 billion in 2016 and continues to increase at an estimated rate of 1 to 2 percent every year. Human activities set the stage for situations that may lead to the emergence of new human-adapted pathogens and outbreaks of disease.

- **Urbanization.**¹⁰⁻¹² Spread and persistence of diseases are strongly associated with population density. The United Nations estimates that as of 2014, 3.9 billion people, or more than half the world's population, live in urban settings, compared to only 20 percent that were urban-dwelling a century ago.
- **Global travel.**^{8, 11, 12} Travel occurs on an extraordinary scale today. We carry pathogens with us, helping them to expand their geographic and host ranges.
- **Increased contact with wildlife.**¹³ Humans increasingly encroach on wild habitats to expand agricultural, housing, and industrial territory. As a result, humans and their domesticated animals are exposed to new pathogens harbored in wildlife.
- **Adaptation to new hosts.**¹⁴ Pathogens evolve over time and can gain the ability to infect a wider range of hosts. Viruses in particular have high mutation rates and fast generation times, which help facilitate these adaptations.
- **Antibiotic misuse and overuse.**^{15, 16} Antibiotics are often incorrectly prescribed, not taken as directed, or overused in home and agricultural settings. This excessive and improper use of antibiotics has led to the evolution of new antibiotic-resistant variants of bacterial pathogens whose treatment options are limited.
- **Natural disasters.**¹⁷ Natural disasters can disrupt housing and infrastructure, creating opportunities for pathogens to infect people in vulnerable situations. For example, multiple outbreaks of bacterial, fungal, and viral infections occurred following Hurricane Katrina.
- **Poor infrastructure/unsanitary conditions.**¹⁷ Food and water sources in areas with minimal healthcare resources, poor infrastructure, crowded living conditions and/or deficient sanitation systems are at high risk of contamination, which can lead to widespread and long-lasting outbreaks.
- **Low vaccination rates.**¹⁸ Outbreaks of vaccine-preventable diseases can occur when too few people in a given location are vaccinated. Low vaccination rates may result from lack of vaccine availability or affordability, or personal choice.
- **Bioterrorism.**^{19, 20} Pathogens can be dispersed with malicious intent as a type of biological weapon. For example, a 2001 outbreak of anthrax was the result of anthrax spores being intentionally sent through the U.S. Postal Service.

The human population continues to increase at an estimated rate of 1 to 2 percent every year.

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KEY STRATEGIES FOR CONTROLLING OUTBREAKS

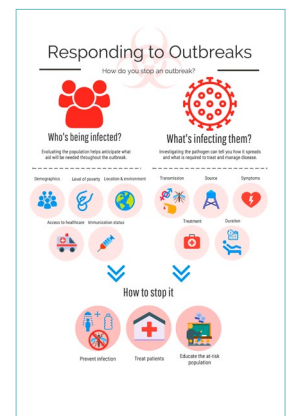
BEHIND EVERY OUTBREAK

The term *outbreak* refers to a greater-than-expected increase in the number of cases of a disease in a given region or population; even a single case may sometimes be considered an outbreak. The term *epidemic* describes the disease's progressive spread into a wider region. The term *pandemic* refers to an epidemic that spreads across a large region, generally spanning multiple countries or continents.

Responding to outbreaks effectively requires carefully planned and implemented public health strategies and cooperation among public health officials. Cases of highly contagious diseases can quickly multiply on an exponential scale to overwhelming numbers, and a speedy response, especially to the earliest cases, is essential for control. Important components include effective surveillance programs for early detection, and thorough information-gathering on the origin of the outbreak and populations at risk. Considering the characteristics of both the pathogen and the at-risk population is critical for determining how to manage an outbreak, and for developing the most effective strategies for treating, controlling, and preventing the infectious disease at hand.¹⁸ (See Addendum, page 18: “[Responding to Outbreaks.](#)”)

The Public Readiness and Emergency Preparedness Act (PREP Act)³⁶

The PREP Act allows the Department of Health and Human Services to issue a declaration giving legal immunity to those involved in administering medical countermeasures against diseases or other threats that pose a public health emergency. This means that entities and individuals involved in developing or distributing drugs or vaccines not yet completely tested and approved are immune from liability if ill effects ensue. One such declaration was issued during the 2014 Ebola outbreak to allow the expedited administration of several vaccine formulations that were still in the research and development stage.



(See Addendum, page 18: “[Responding to Outbreaks.](#)”)

Important information about the pathogen includes:

- *Location and circumstances of initial infection*
- *How the pathogen is transmitted*
- *Characteristics of the resulting disease*
- *What treatment is required*

Important information about the at-risk population includes:

- *Demographics, such as age and sex*
- *Vaccination rates and past exposure status*
- *Level of poverty*
- *Access to healthcare resources*
- *Location and environment*

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Recent outbreaks of Nipah virus disease, Ebola virus disease, and Zika fever have garnered global attention. All three are zoonotic viruses, but there are important differences among them—including the at-risk populations, symptoms, routes of transmission, and therefore containment strategies. (See Addendum, page 19: “[Characteristics of recent outbreaks, of emerging viral pathogens](#)” which outlines some key aspects of outbreaks resulting from these three viruses.)^{21-23, 24-27, 28-30}

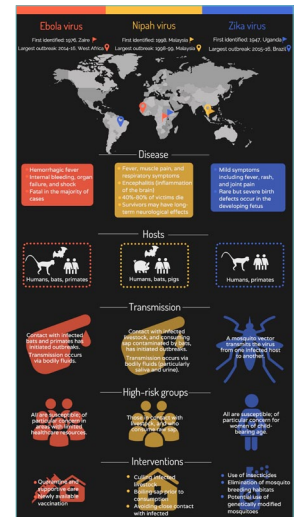
Contact tracing

A method sometimes used in managing an outbreak is [contact tracing](#). All the people an infected individual has been in contact with are monitored for a length of time, usually the length of the [incubation period](#) of the pathogen in question, or the time between exposure to the pathogen and onset of disease. If symptoms arise, they can then be promptly treated and further spread can be avoided.

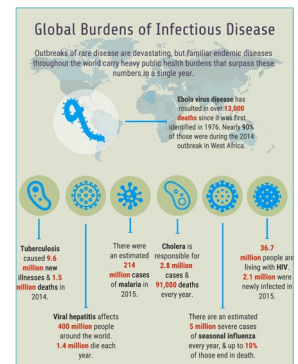
BEYOND AN OUTBREAK

Managing an infectious disease outbreak does not stop with curbing transmission and the occurrence of new cases. Once control measures are in place, continued surveillance and aid is necessary for recovery. Multiple factors can affect the ability of a community or region to recover from an outbreak:

- **Disorder.** Depending on the circumstances of the outbreak, civil infrastructure may be in disarray. Families may be separated, resources such as food and water may be exhausted, and conditions may be unsanitary. Continuous aid during recovery is essential to halting new transmission cycles that may rekindle an epidemic.
- **Potential for endemicity.** Pathogens may persist in the population unnoticed, or be harbored temporarily in a nonhuman reservoir. These conditions can create cycles of ongoing [endemic](#) disease. (See Addendum, page 20: “[Global Burdens of Infectious Disease](#).”) In addition to outbreaks of rare diseases described here, endemic diseases impose continuous health burdens throughout the world.
- **Societal and cultural issues.** Some illnesses are accompanied by strong culturally influenced stigmas. Infected individuals or their friends and families may be ostracized or even assaulted. Examples of disease-associated stigmas include the early years of the AIDS epidemic in the U.S., as well as the 2014 Ebola outbreak in West Africa. Public education and the implementation of recovery programs for survivors can ameliorate these cultural difficulties involved with disease.



(See Addendum, page 19: “[Characteristics of recent outbreaks, of emerging viral pathogens](#).”)



(See Addendum, page 20: “[Global Burdens of Infectious Disease](#).”)

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LONG-TERM STRATEGIES

EIDs are inevitable, but it is possible to control localized outbreaks and stop them from becoming pandemics. Implementing long-term solutions and establishing global partnerships are crucial for effective disease control:

- **Cooperation.**³¹ Pathogens do not acknowledge political borders. Communication and cooperation among authorities are essential for effective disease management. The 191 member states of the World Health Organization share information from medical centers throughout the world regarding disease outbreaks.
- **Surveillance.**³² Prevention and timely control of outbreaks require rigorous surveillance of pathogen reservoirs and suspected disease cases. Surveillance includes directly monitoring animals and the environment for evidence of pathogens, as well as reports of disease from clinics and hospitals.
- **Research funding.**²⁰ Government funding is allocated for biodefense research to characterize pathogens and develop medical countermeasures, and takes place at academic institutions, government agencies, and biotechnology companies.
- **Food security.**^{33,10} Increased food security can reduce human encroachment on wildlife habitats, the source of over 70 percent of zoonotic EIDs. Developing sustainable food sources can help alleviate the need to expand agricultural territory and hunt for bushmeat, both of which have contributed to spillover events.
- **Antibiotic usage reform.**¹⁵ Antibiotic abuse promotes the growth of resistant pathogens, enabling outbreaks of disease that are difficult to treat and control. Drug-resistant infections currently make up 21 percent of EIDs. More stringent laws and guidelines governing antibiotic use in home, hospital, and agricultural settings, as well as patient and physician education, are needed to stop this trend.
- **Public education.** Educating the population on how pathogens spread, how to avoid infection, and when and where to seek treatment can help maintain healthy communities.

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RESOURCES AND CONTACTS

<http://www.cdc.gov/outbreaks/>

Centers for Disease Control and Prevention (CDC) Current Outbreak List

<http://www.healthmap.org/en/>

Aggregated data on disease outbreaks from ProMED Mail, the World Health Organization, GeoSentinel, the World Organisation for Animal Health, the Food and Agriculture Organization of the United Nations, Eurosurveillance, Google News, Moreover, the Wildlife Data Integration Network, Baidu News, and Soso Info

<http://www.who.int/csr/don/en/>

World Health Organization (WHO) Disease Outbreak News

<http://www.who.int/mediacentre/factsheets/fs200/en/>

World Health Organization (WHO) fact sheet on global infectious disease surveillance

<http://ecdc.europa.eu/en/Pages/home.aspx>

European Centre for Disease Prevention and Control

<http://www.epimodels.org/drupal-new/>

Models of Infectious Disease Agent Study (MIDAS)

<http://www.ecohealthalliance.org/>

EcoHealth Alliance

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GLOSSARY

Communicable disease: An infectious disease that can spread from one person to another, directly or indirectly.

Contact tracing: A method of disease control in which individuals who were in contact with a sick person are closely monitored for symptoms. If symptoms arise in one of those contacts, the individual can be promptly treated and his own contacts monitored for symptom development.

Direct transmission: Transfer of an infectious agent from one individual to another via immediate physical contact, usually via infected bodily fluids.

Emerging infectious disease (EID): A disease that is newly introduced to a population, that is expanding into new geographic areas, or whose prevalence is increasing after a decline in cases (the latter is also referred to as a *re-emerging infectious disease*).

Endemic: Ongoing occurrence of a disease in a particular population or region.

Epidemic: Widespread occurrence of a disease, in excess of the expected rate, in a particular community or geographic area. The definition for *outbreak* is similar, but *epidemic* is generally used to describe the spread of an infectious disease into a wider area, and *outbreak* to describe its initial appearance. (See also *outbreak* and *pandemic*.)

Host: An organism that a pathogen infects and within which it completes its life cycle.

Incubation period: The time between an individual's exposure to a pathogen and the onset of disease.

Indirect transmission: Transmission of a pathogen by something other than an infected individual, such as an intermediate vector or a contaminated object.

Infectious disease: A disease caused by invasion of a host's body by a microorganism, called a *pathogen*, that disrupts the host's normal bodily functions.

Morbidity: Diseased state; also, the rate of disease within a given group.

Mortality: Death; also, the rate of death within a given group.

Outbreak: Occurrence of a disease, in excess of the expected rate, in a particular community or geographic area; even a single case may be considered an outbreak. The definition for *epidemic* is similar, but *outbreak* is generally used to describe an infectious disease's initial appearance and *epidemic* to describe its spread into a wider area. (See also *epidemic* and *pandemic*.)

Pandemic: Widespread occurrence of a disease, in excess of the expected rate, across a vast region, spanning multiple countries or even continents and often affecting a significant portion of the region's population. (See also *epidemic* and *outbreak*.)

Pathogen: A microorganism capable of causing disease.

Re-emerging disease: An infectious disease previously in decline that has reappeared or is on the rise.

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Reservoir: A host organism or an environmental habitat within which a pathogen lives and multiplies; reservoirs often do not themselves exhibit debilitating disease, enabling them to be long-term carriers of the pathogen.

Spillover event: The initial passage of a zoonotic pathogen from an animal host to a human host.

Vector: An organism that transmits a pathogen from one host to another.

Vertical transmission: The in utero transmission of a pathogen from a mother to her child.

Virulence: The degree of damage caused by a pathogen to its host.

Zoonosis: An infectious disease transmitted from animals to humans; the plural form is *zoonoses*.

Zoonotic: Of or relating to pathogens able to pass between animals and humans.

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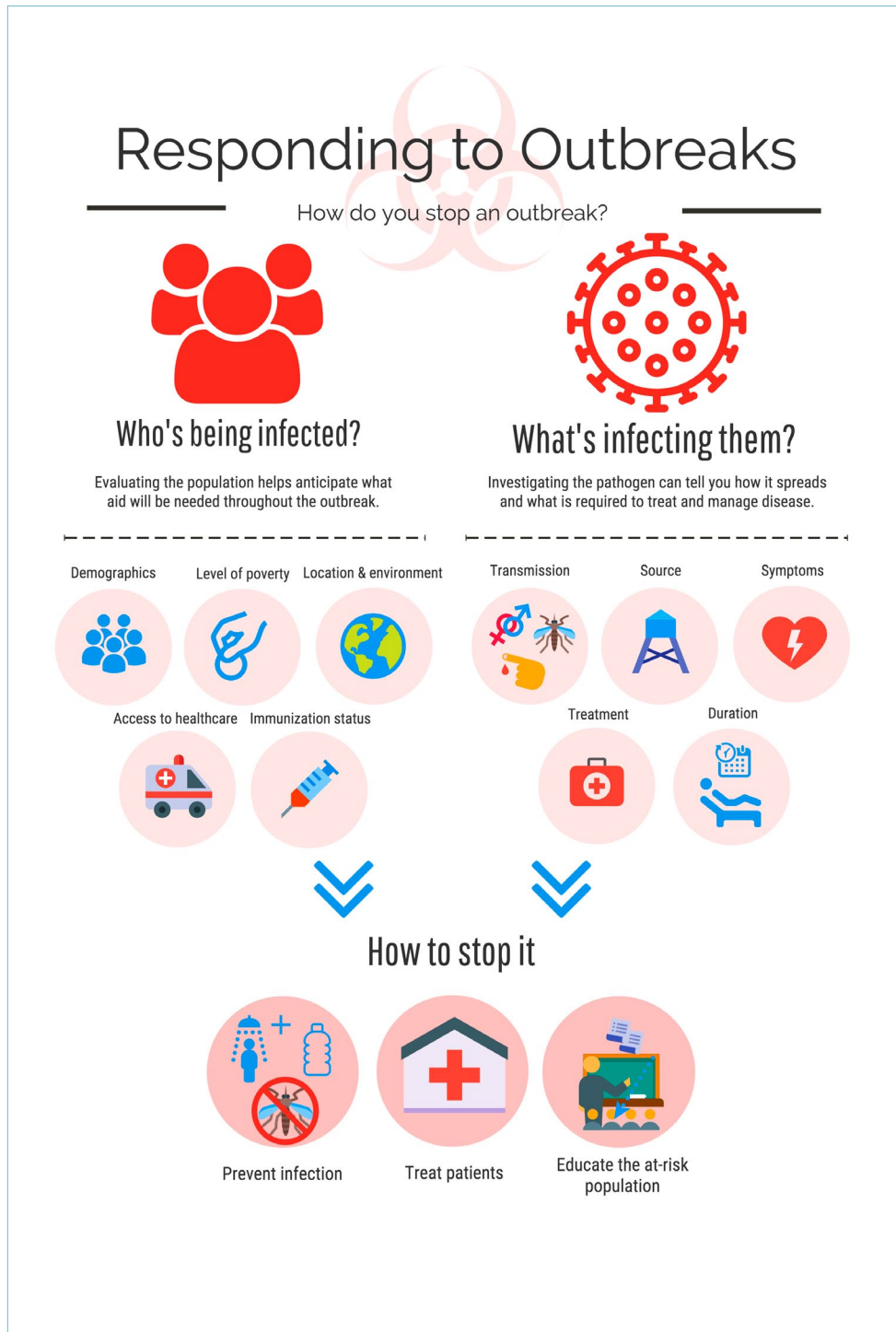
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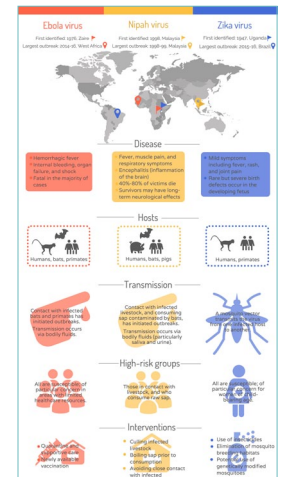
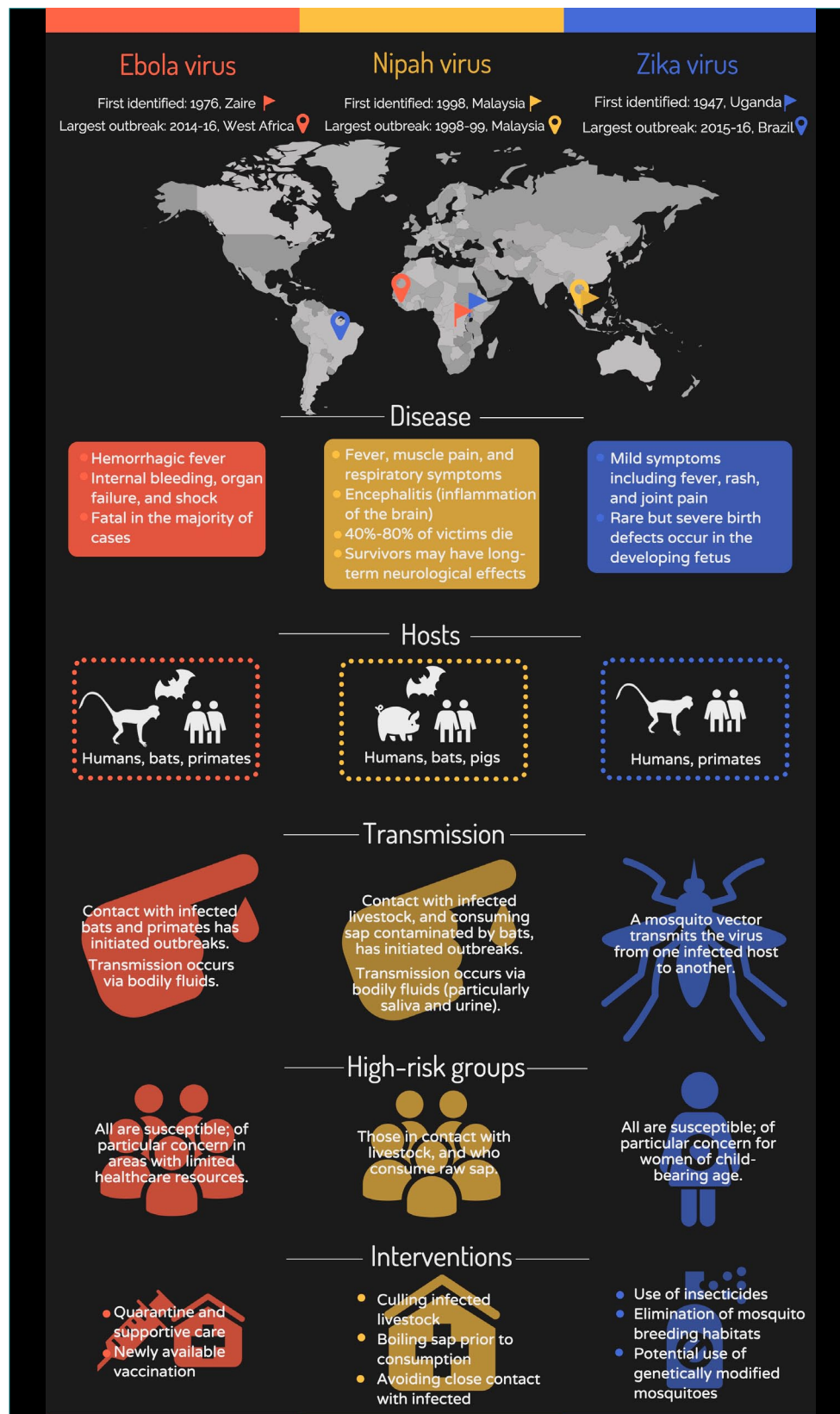
ADDENDUM

Responding to Outbreaks



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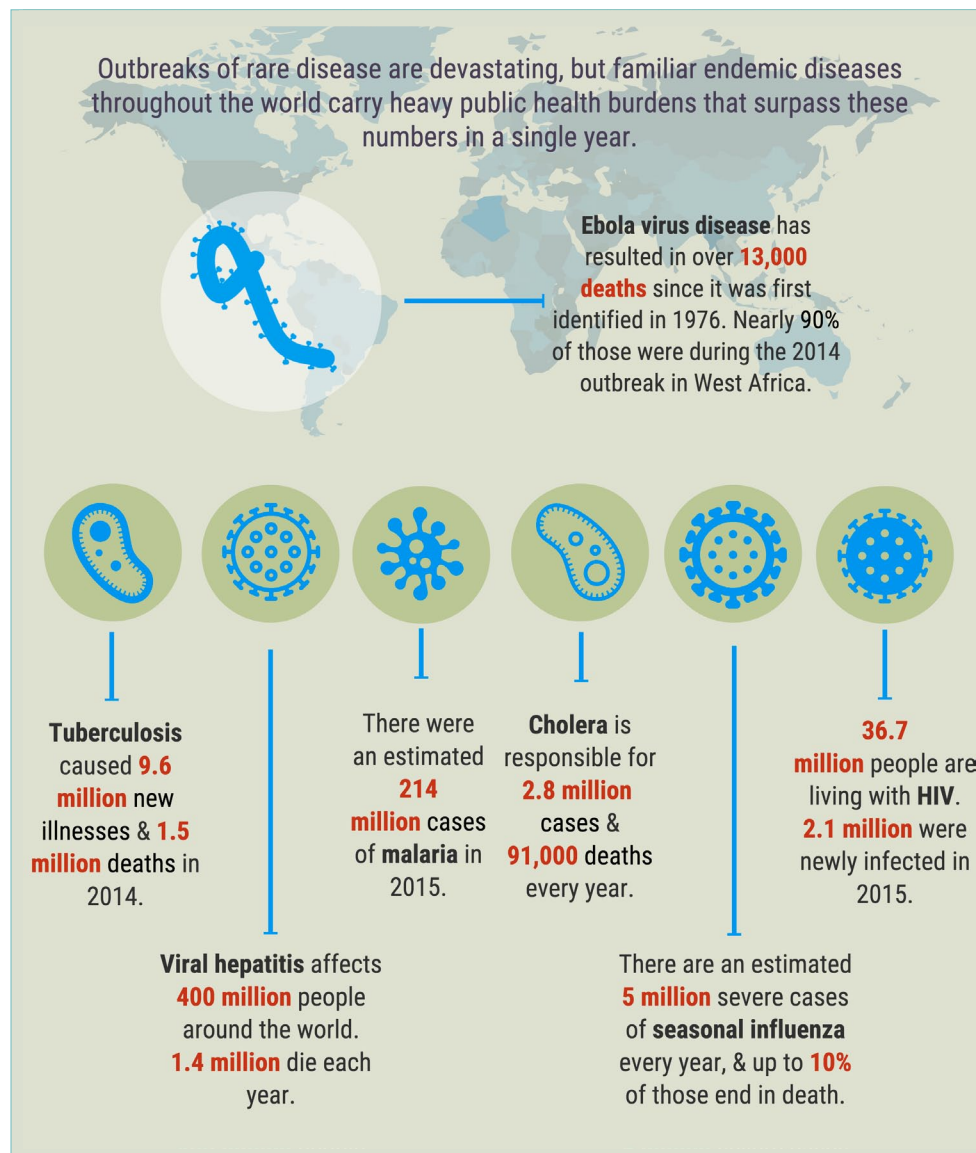
Characteristics of recent outbreaks of emerging viral pathogens.



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A GUIDE TO OUTBREAKS OF EMERGING INFECTIOUS DISEASES

Global Burdens of Infectious Disease.



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Characteristics of recent outbreaks of emerging viral pathogens.

