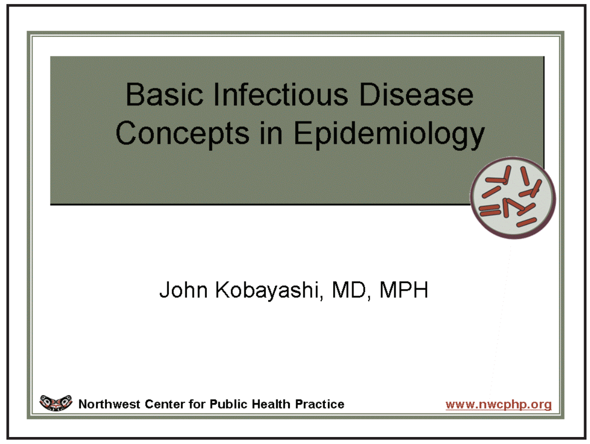
Basic Infectious Disease Concepts in Epidemiology

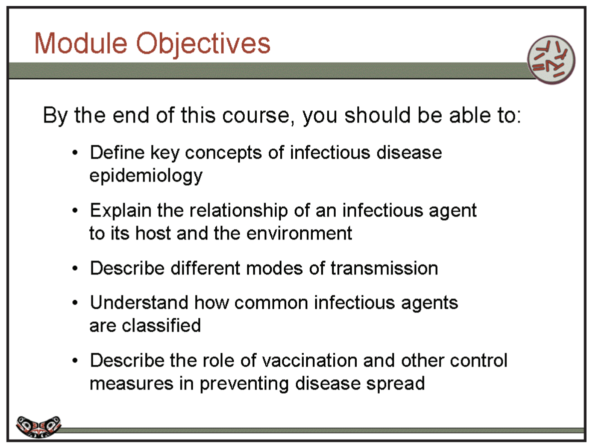
Transcript

Introduction



Hello, my name is John Kobayashi. I'm on the Clinical Faculty at the Northwest Center for Public Health Practice at the School of Public Health and Community Medicine at the University of Washington in Seattle. From 1982 to 2001, I was the State Epidemiologist for Communicable Diseases at the Washington State Department of Health.

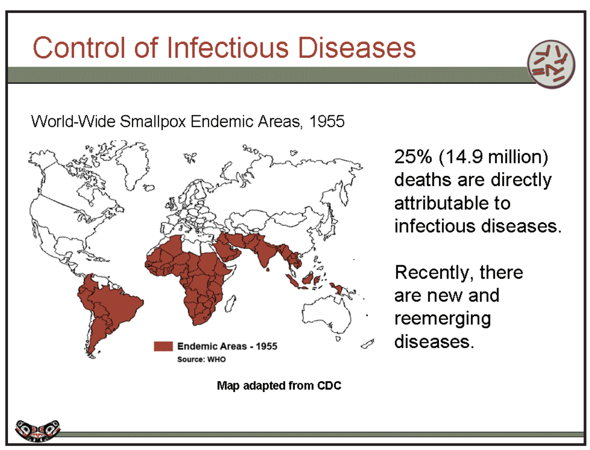
Module Objectives



By the end of this course, you should be able to:

- Define key concepts of infectious disease epidemiology,
- Explain the relationship of an infectious agent to its host and the environment,
- Describe different modes of transmission,
- Understand how common infectious agents are classified, and
- Describe the role of vaccination and other control measures in preventing disease spread.

Control of Infectious Diseases



Over the years, great progress has been made in controlling infectious diseases, outbreaks, and epidemics. However, it's easy to forget that only 50 years ago smallpox, for example, was continuously (or endemically) present in many parts of the world.

Infectious diseases still accounts for the leading cause of deaths worldwide, with an estimated 25% (14.9 million) deaths directly attributable each year to infectious diseases. Furthermore, in recent years, the world has experienced many newly emerging and reemerging diseases. Infectious diseases have a devastating impact on human suffering, as well as severe social and economic consequences.

Basic Infectious Disease Concepts in Epidemiology
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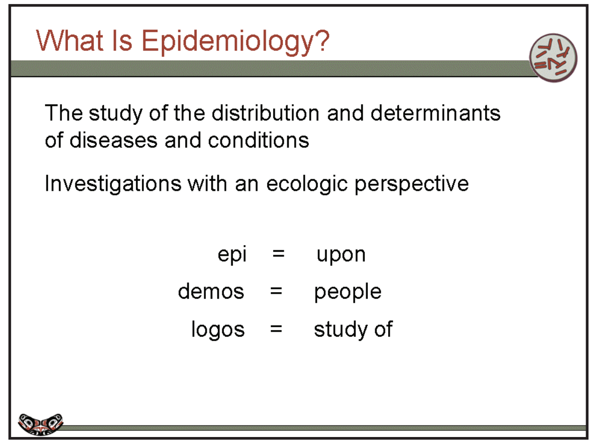
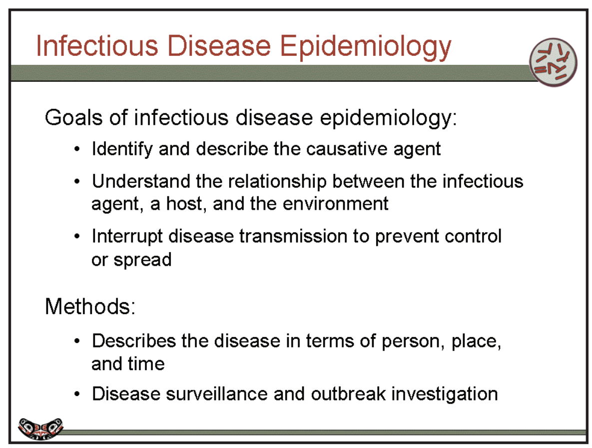
What Is Epidemiology?



One public health tool to investigate these problems is epidemiology. Epidemiology is the study of the distribution and determinants of diseases and conditions. The problems that can be studied by epidemiology range from infectious to non-infectious diseases (such as cancers, strokes, and heart disease) to injuries and risky behaviors (such as drug abuse or smoking).

Generally, epidemiologic studies are investigations with an ecologic perspective. Rather than focusing on individuals, people are viewed in groups, and investigated in the context of the environment or communities where they live. This ecologic approach is reflected in the origin of the word "epidemiology," from the ancient Greek words: Epi meaning upon, demos meaning people, and logos meaning study of.

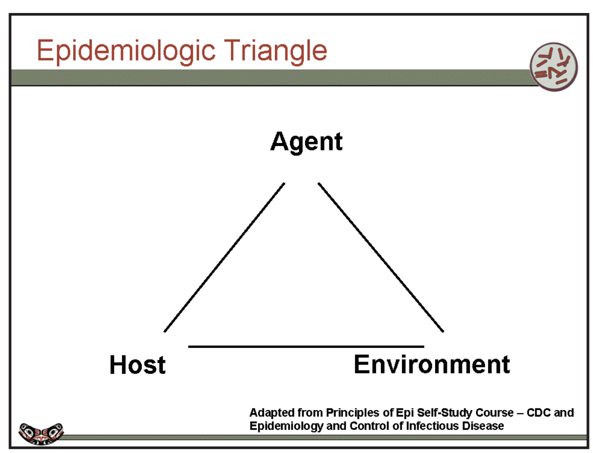
Infectious Disease Epidemiology



In epidemiology, we study the occurrence of disease in a population. With infectious diseases, we try to identify the causative agent and to understand the relationship between an agent, the host, and the environment. This is to understand where agents originate, how they are spread in a population, and how to prevent or control that spread.

Investigations are initially performed through descriptive epidemiology, which studies the disease in terms of person, place, and time. I will discuss these terms, along with surveillance and outbreak investigation, in further detail later.

Epidemiologic Triangle



We can think about infectious diseases as a relationship between the agent, or microscopic organism causing the disease, a susceptible person, or host, and the environment that brings the host and the agent together. As we study a disease, we are concerned with how the agent invades, leaves, and is transmitted between hosts. If we know how the disease is spread or the mode of transmission, then we can identify ways to halt or reduce spread.

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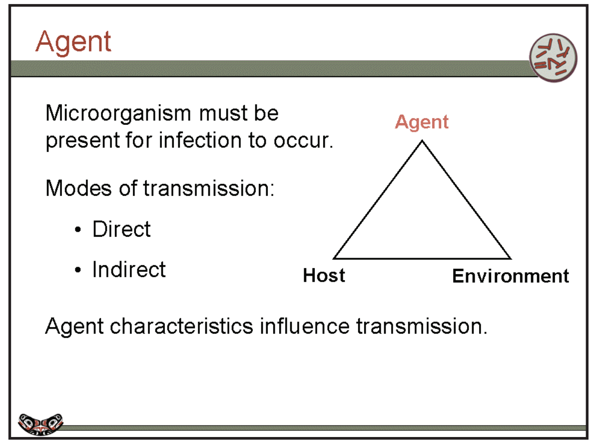
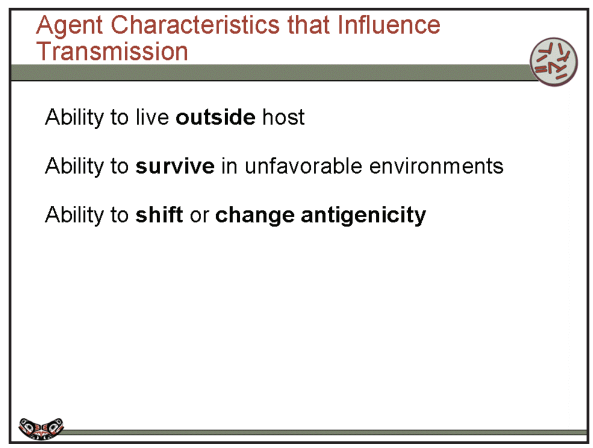
Agent

The agent is an infectious microorganism, such as a virus or a parasite, that must be present for the disease to occur. These organisms may be passed from person to person, or they can be acquired from the environment through various modes of transmission. The modes can be direct or indirect. Certain agent characteristics influence how these organisms are passed from person to person or from the environment.



Agent Characteristics that Influence Transmission

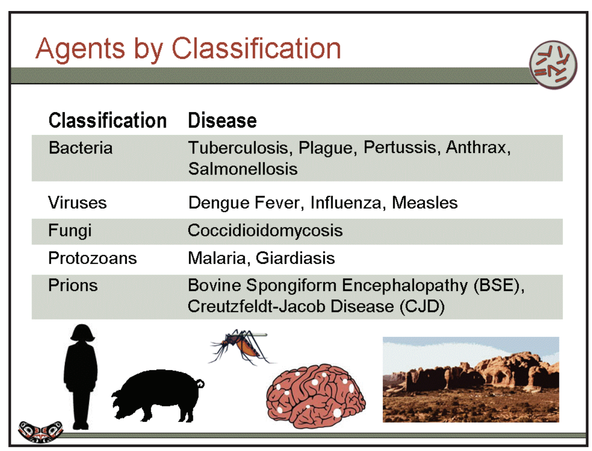
Once we have established the mode of transmission of an agent, we can study factors that enhance or reduce the organism's likelihood of transfer to a host. These include: its ability to live outside the host, to survive in unfavorable environments, or by shifting antigenicity, or the ability to induce an immune response.



Agents by Classification

This chart shows a classification of agents and some diseases they cause. Some, like pertusssis and measles, only affect humans. Others are zoonoses, or diseases affecting both animals and humans. These include plague, anthrax, and salmonellosis. While many are transmitted from one person to another, some, like dengue and malaria are transmitted through mosquitoes.

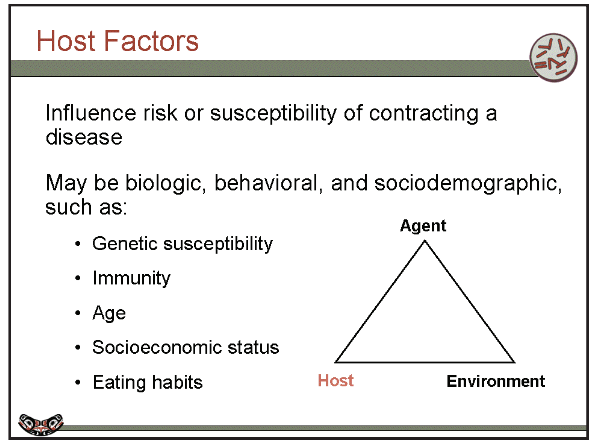
One fungus causes coccidiodomycosis, frequently involving fever and a respiratory illness and sometimes a chronic illness resembling tuberculosis. This fungus normally lives in the soil in certain parts of the world, such as the southwestern United States, and is transmitted through inhaling contaminated dust.



Prions are transmissible agents that are able to cause abnormal folding of normal cellular proteins in the brain. These cause progressive diseases of the brain in a variety of animals and humans. These include Bovine Spongiform Encephalopathy or BSE, commonly known as “Mad Cow Disease.” It also includes Creutzfeldt-Jacob Disease (CJD), a rare neurological disease, which occurs worldwide in about one of one million people per year. An even more rare disease in humans, called variant CJD, is related to BSE.

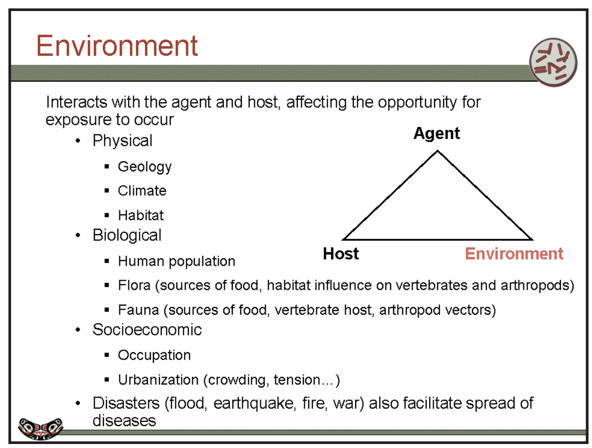
Host Factors

Host factors refer to the risk of exposure because of some behavior or other individual characteristic, or how susceptible that person will be once exposure occurs. These characteristics may be either biologic, behavioral, or sociodemographic and include characteristics such as genetic susceptibility, immunologic status, age, socioeconomic status, and other behavioral characteristics (such as eating habits).



Environment

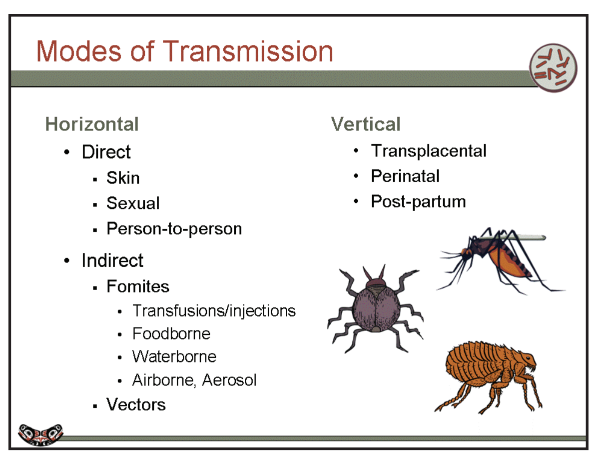
Environmental factors are also important in determining the risk of infection. These factors influence contact between humans and the physical, biological, and socioeconomic worlds. These external variables include: the geology, climate, and physical surroundings, such as hospitals or nursing homes. Besides other humans, this involves contact with, plants, animals, and arthropod vectors, such as mosquitoes, which transmit malaria. Socioeconomic factors include occupation, population displacement (such as with refugees), or urbanization. Disasters can be considered as an environmental factor that makes disease spread more likely.



Interactive Exercise 1

Modes of Transmission

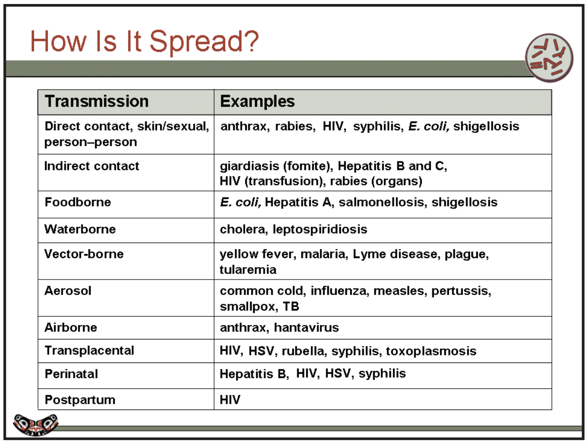
When an agent is transmitted between hosts or from a host to the environment, the type of spread can be divided into two categories: horizontal or vertical transmission. Horizontal transmission can be either direct, through close personal contact, or indirect, through fomites or vectors. Fomites are inanimate objects contaminated with some microorganism. These may be contaminated transfusion products or injections, contaminated food, water,



or air. Vectors are organisms that do not cause disease by themselves but by transmitting pathogens from one host to another. Examples are mosquitoes that transmit malaria or West Nile Virus, fleas that transmit plague, and ticks that transmit Lyme Disease.

Vertical transmission involves infectious disease spread from the mother to child. Common terms include transplacental, meaning transmission from mother to child through the placenta, perinatal, meaning the period before, during, or slightly after birth, and post-partum, meaning after birth. Transmission during any of these situations is vertical transmission.

How Is It Spread?


How Is It Spread?

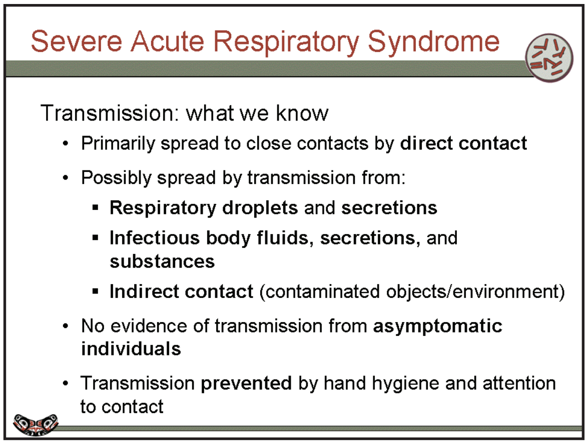
Transmission	Examples
Direct contact, skin/sexual, person–person	anthrax, rabies, HIV, syphilis, *E. coli,* shigellosis
Indirect contact	giardiasis (fomite), Hepatitis B and C, HIV (transfusion), rabies (organs)
Foodborne	*E. coli,* Hepatitis A, salmonellosis, shigellosis
Waterborne	cholera, leptospiridiosis
Vector-borne	yellow fever, malaria, Lyme disease, plague, tularemia
Aerosol	common cold, influenza, measles, pertussis, smallpox, TB
Airborne	anthrax, hantavirus
Transplacental	HIV, HSV, rubella, syphilis, toxoplasmosis
Perinatal	Hepatitis B, HIV, HSV, syphilis
Postpartum	HIV

This chart shows examples of diseases by their typical modes of transmission. Notice that many diseases are spread through several different pathways. For example, HIV is spread by direct sexual contact, indirect contact through needle-sharing, or from mother to child.

Also, the mode of transmission can depend on the physical composition of the infectious agent. For example, anthrax is spread in its natural form through direct contact with infected animals, contact with infected animal products, such as wool or hides, or by eating contaminated meat. However, in its weaponized form, anthrax is transformed into very small particles that can float through air, becoming an airborne disease.

Interactive Exercise 2

Severe Acute Respiratory Syndrome



Understanding the modes of transmission is an important part of investigating a new pathogen. For example, with SARS, or the Severe Acute Respiratory Syndrome, we know that it is primarily spread through close contact with ill individuals. However, airborne transmission, spread through body fluids, and indirect transmission are possible. Fortunately, SARS is not transmissible from infected individuals who are still well. Transmission can be prevented by careful hand washing, respiratory precautions, and other measures to prevent contact transmission.

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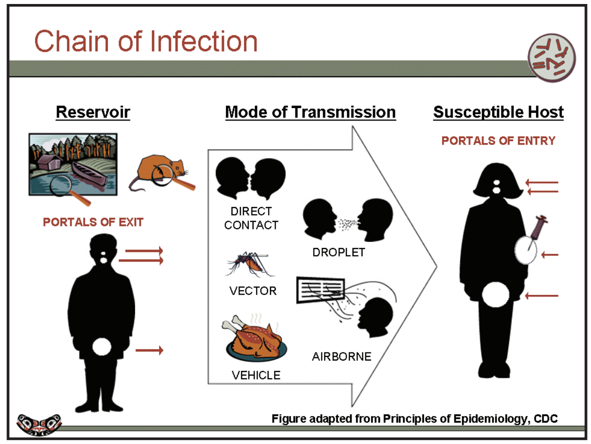
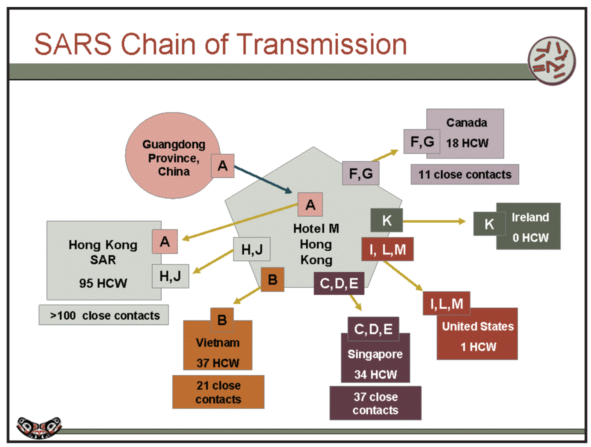
Chain of Infection

We sometimes call the spread between individuals, or between individuals and the environment, "the chain of infection." This diagram shows the different types of reservoirs in the environment where an agent may live until it contacts a host or vector. Reservoirs may include other humans, animals, or some non-living place in the environment. Contact occurs through one of the modes of transmission discussed earlier. This includes direct contact, droplet or airborne spread, vectors, or foods. The agent enters the host through a portal of entry, such as the nose, skin, or mouth.



SARS Chain of Transmission

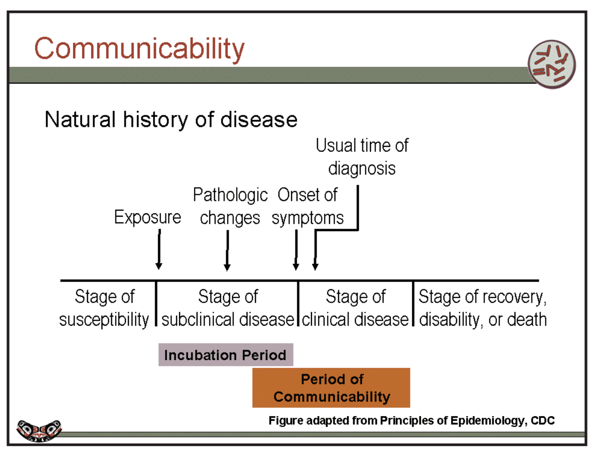
In this example, we can trace the transmission chain from 'Hotel M' in Hong Kong where SARS was spread to six different countries. The chain began with case A. SARS was spread to guests who stayed at the hotel on different floors. They were present at different but overlapping times.



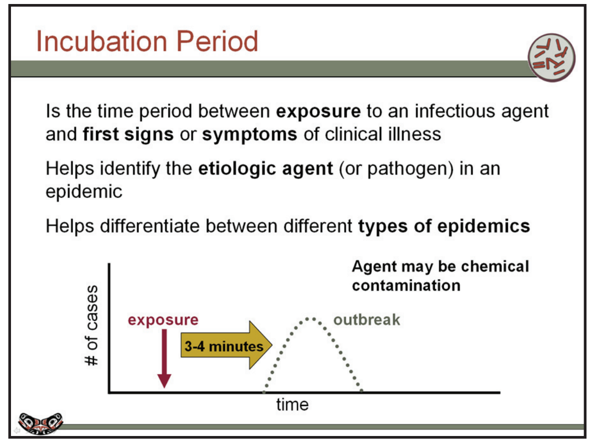
Interactive Exercise 3

Communicability

For infectious diseases, after an agent enters the host, the person will go through a period of subclinical disease. This is when the disease is not noticeable but pathological changes are occurring. This is known as the incubation period. The individual is infected, but the disease is not yet present. The person also frequently becomes capable of passing along the agent during this time. This is known as the period of communicability. In this diagram, the period of communicability and the incubation period overlap. While this is frequently the case, it does not always happen as I mentioned with the example of SARS.



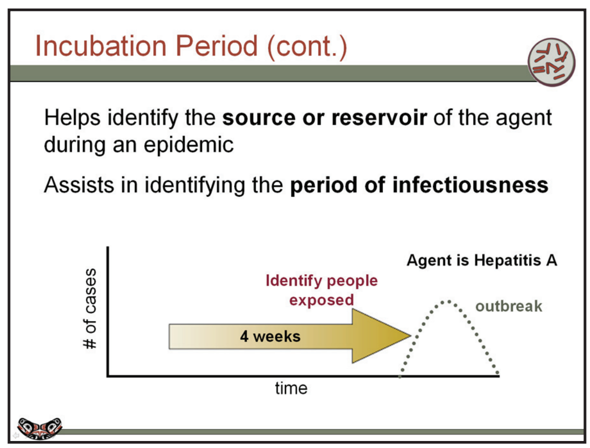
Incubation Period



In summary, the incubation period is the time between exposure to an infectious agent and the first signs or symptoms of a clinical illness. The incubation period can help identify the etiologic agent in an epidemic and can help differentiate between different types of epidemics.

For example, an outbreak of vomiting within a few minutes after exposure to a food or beverage may be related to contamination from a chemical, especially heavy metals such as cadmium, zinc, or copper. Vomiting four to seven hours after a food exposure may be related to a toxin-producing bacteria, such as in staphylococcal food poisoning.

Incubation Period (cont.)

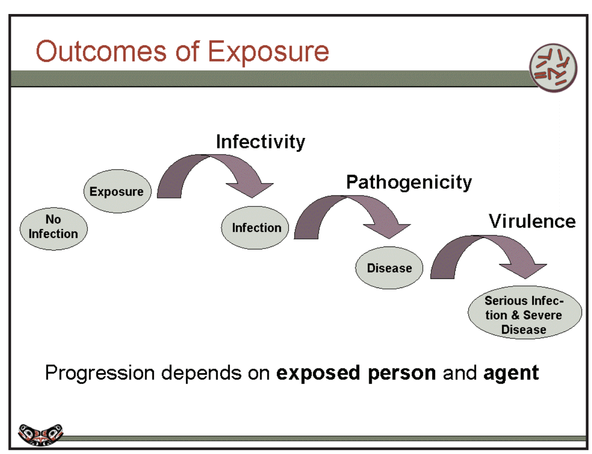


If the pathogen is known, the incubation period can help identify the source or reservoir of the agent during an epidemic. For example, if an outbreak is caused by E. coli O157:H7, the most common incubation period of three to four days can be used to identify the time for the most likely sources of exposure.

Finally, incubation periods can help identify the period of infectiousness. For example, in hepatitis A the incubation period is usually four weeks, and the last two weeks are period of greatest infectiousness. This can help identify people who have been exposed to known cases.

Interactive Exercise 4

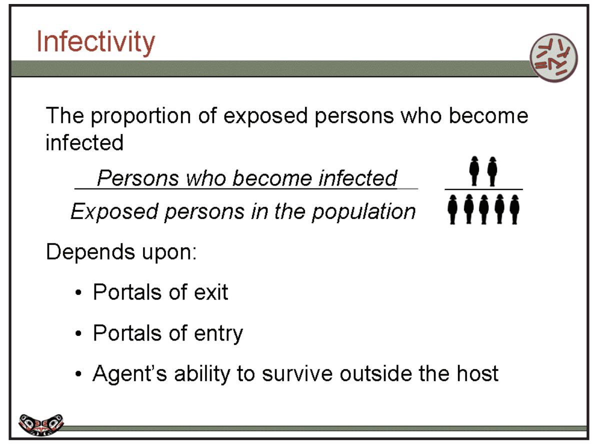
Outcomes of Exposure



For any exposed individual, several outcomes are possible. They include no infection, infection, disease, or serious infection. In some people, the exposure will result in infection. This feature is described by infectivity. In others, the infection will develop clinical disease. This feature is described by pathogenicity. Finally, the disease may be mild, severe, or fatal. The severity of the disease is described by virulence. This progression depends on both the exposed person and the agent itself. In the next few slides, I'll be going over the terms infectivity, pathogenicity, and virulence in more detail.

Infectivity

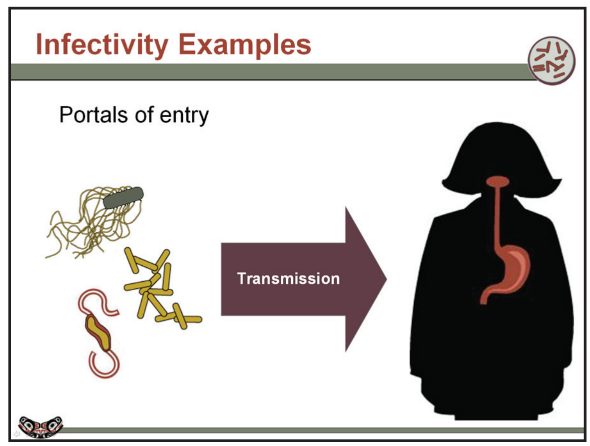
Infectivity describes the proportion of exposed persons who become infected. They can be measured by a rate, which is the number infected divided by the number exposed in the population. Infectivity is affected by the portals of exit, the portals of entry, and an agent's ability to survive outside the host.



Infectivity Examples

Here are some examples of these relationships. The portal of exit is important in plague infections. While all forms of plague are very infectious, plague is much more infectious in pneumonic plague, where the lungs are involved. It is less infectious in bubonic plague, where primarily the lymph nodes are involved.

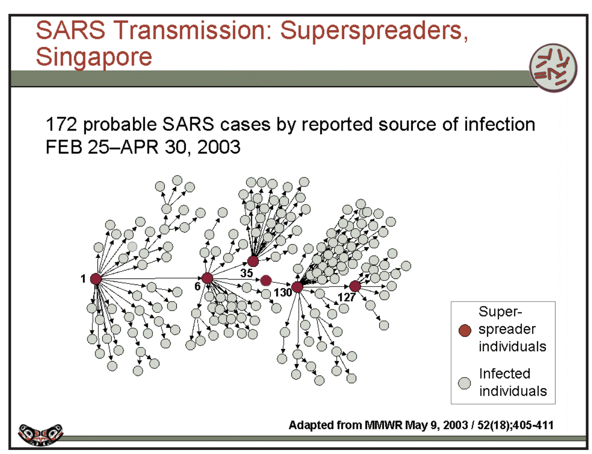
The portal of entry is important in many intestinal bacterial infections, such as salmonella, shigella, and campylobacter, which involve swallowing the bacteria. In all of these, the acid in the stomach acts as a partial barrier to infection. However, if people are using antacids or proton pump inhibititors, the decreased gastric acidy increases infectivity.



The agent's ability to survive outside the host also affects infectivity. A good example is anthrax. Anthrax is a very hardy bacteria that can survive for years in the soil as spores. Cattle who graze in pastures where anthrax deaths occurred can get anthrax years later.

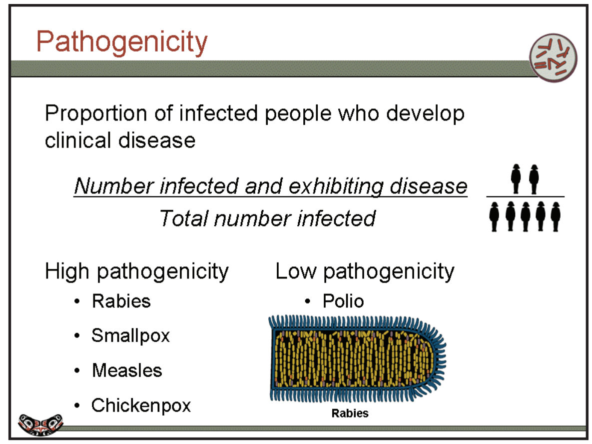
SARS Transmission: Superspreaders, Singapore

This drawing illustrates transmission of SARS by superspreaders, individuals who were much more infective than most SARS cases. It is not known why some SARS cases become superspreaders while most SARS cases transmit disease to a much smaller number of contacts.



Transcript

Pathogenicity

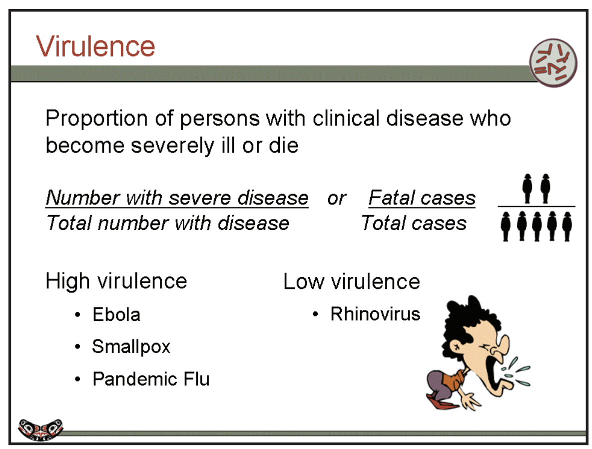


Pathogenicity refers to the proportion of infected people who develop clinical symptoms of the disease. We can measure it by the number of infected people who are exhibiting the disease divided by the total number infected persons.

Here are some examples of highly pathogenic diseases. Note that pathogenicity means the likelihood that infections will result in disease. It does not indicate how severe the disease will be. Therefore, both rabies and chickenpox viruses are highly pathogenic. However, rabies is almost always fatal, while chickenpox is a relatively mild illness.

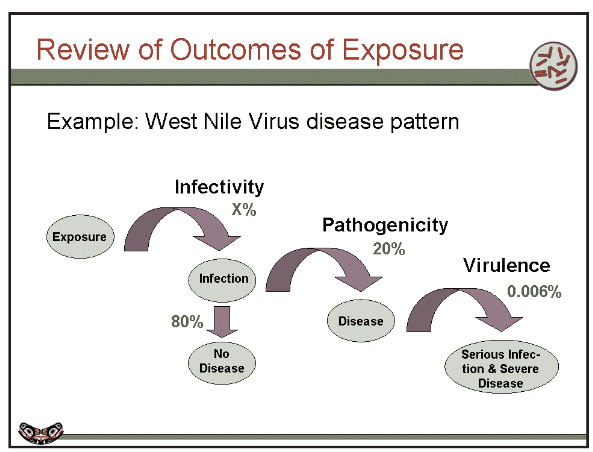
On the other hand, polio virus is of low pathogenicity, since most people infected with polio virus do not become ill at all. However, a small percentage of infected people become extremely ill, leading to paralysis or death. Without vaccination, this illness occurs frequently enough to cause severe epidemics.

Virulence



Finally, we describe virulence, which is the proportion of persons with clinical disease who become severely ill or die. This is measured by the number with severe disease or fatal cases, divided by the total number with disease. Highly virulent pathogens include the ebola virus, smallpox, and pandemic flu. A microbe with a low virulence is the rhinovirus, which causes the common cold.

Review of Outcomes of Exposure

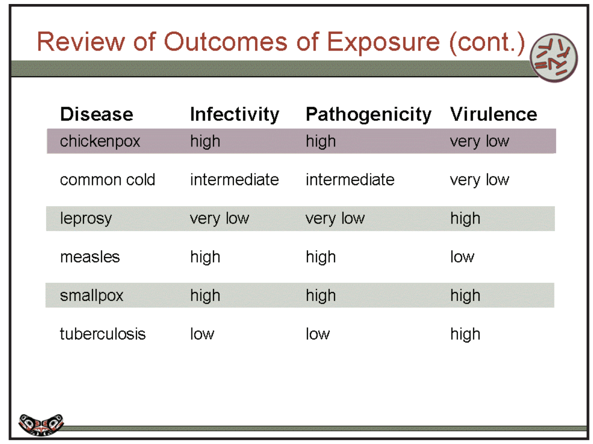


An example of this disease pattern is West Nile Virus infections. Some of the people exposed to the virus become infected. About 80% of the people infected with West Nile Virus do not develop disease. Up to 20% of those infected will develop disease symptoms, such as fever, headaches, and malaise, for a few days to a few weeks. Of those who develop disease, about one in 150 will have severe neurologic symptoms.

Transcript

Review of Outcomes of Exposure (cont.)

This table shows that different pathogens have a wide variety of characteristics regarding infectivity, pathogenicity, and virulence. For example, the bacteria causing leprosy is of low infectivity (meaning that it is not easy for it to be transmitted) and low pathogenicity (meaning that it infrequently causes disease). But it is highly virulent (meaning that when it does cause disease, it is severe). On the other hand, the chickenpox virus is highly infective (that is, exposure is very likely to result in infection) and highly pathogenic (that is, a person is very likely to develop chicken pox disease when they are infected with the virus). However, it is of low virulence (that is, a person is unlikely to die from chicken pox).



Disease	Infectivity	Pathogenicity	Virulence
chickenpox	high	high	very low
common cold	intermediate	intermediate	very low
leprosy	very low	very low	high
measles	high	high	low
smallpox	high	high	high
tuberculosis	low	low	high

Interactive Exercise 5

Descriptive Epidemiology

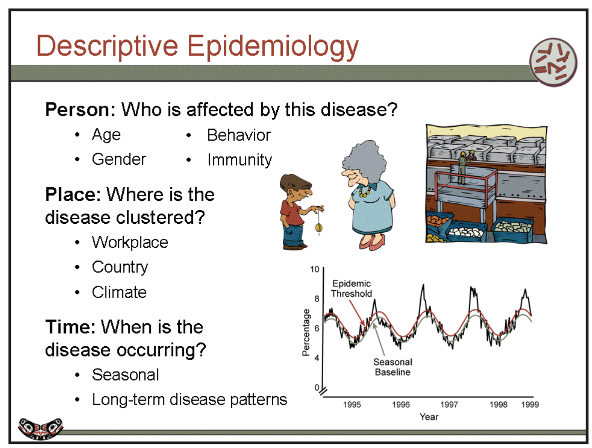
In epidemiology, a great deal can be learned about diseases and pathogens by describing them in terms of person, place, and time. This means asking questions such as the following:

Who is affected by the disease? Are the ill people young or old, male or female? Are the illnesses associated with particular behaviors, such as foods consumed, or social behaviors? Once people are infected, do they develop immunity, or is it possible to become infected more than once?

Where are the affected people? Where do they live, work, and travel, and in what type of climate?

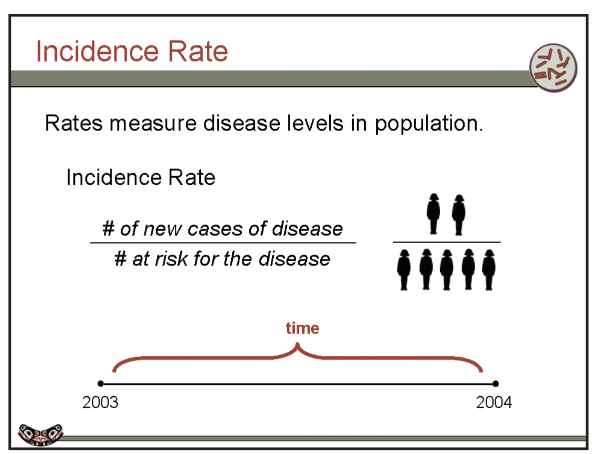
When is the disease occurring? Does it occur constantly, or is it seasonal? What are the long-term trends of disease occurrence?

This type of investigation is known as descriptive epidemiology. To learn more about how we study these important descriptors of infectious disease, see the module on outbreak investigations.



Incidence Rate

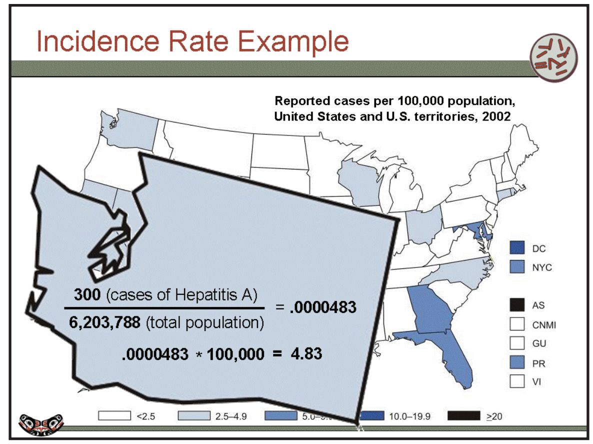
Another class of epidemiologic tools are rates that measure the disease level in the population and aid us in conducting descriptive epidemiology.



Basic Infectious Disease Concepts in Epidemiology

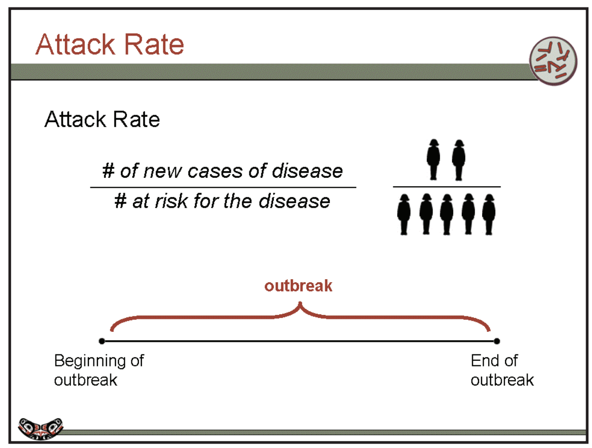
Transcript

An incidence rate measures the proportion of new cases of disease within a population during a given period of time.



Incidence Rate Example

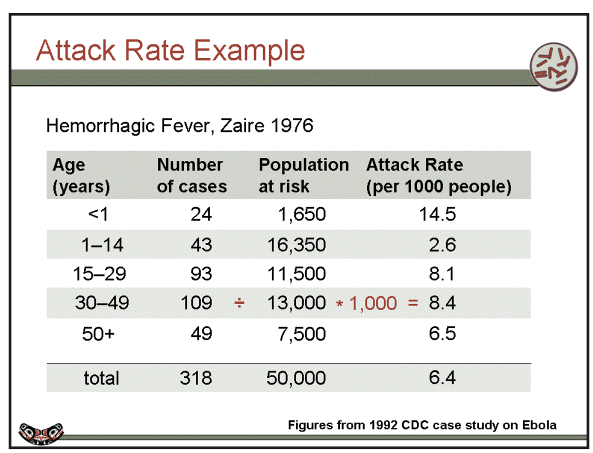
This slide shows hepatitis A incidence rates in the US by state. The rates are hepatitis A cases reported in 2002, per 100,000 population. The hepatitis A cases for a year in a state are divided by the state's population. In this example, the rates are multiplied by 100,000 to make them greater than one, rather than expressing rates as tiny fractions. In other situations the rates may be multiplied by 100, 1,000, or even one million.



Attack Rate

We also use attack rates, which measure the proportion of people at risk who develop the disease in an outbreak.

Attack rates are similar to incidence rates, except the time interval is the period of an outbreak, as opposed to a set period of time.



Age (years)	Number of cases		Population at risk		Attack Rate (per 1000 people)
<1	24		1,650		14.5
1–14	43		16,350		2.6
15–29	93		11,500		8.1
30–49	109	÷	13,000	* 1,000 =	8.4
50+	49		7,500		6.5
total	318		50,000		6.4

Attack Rate Example

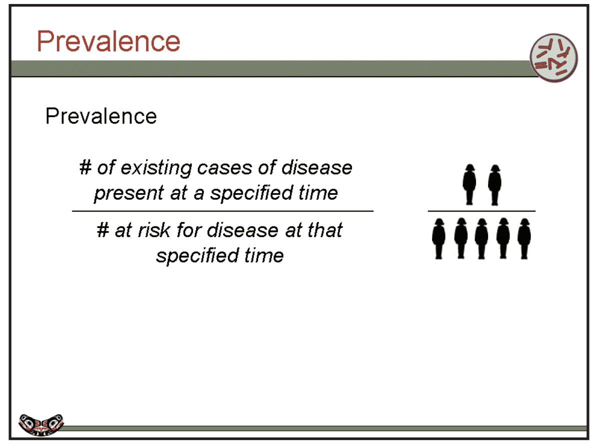
This table shows cases and attack rates of hemorrhagic fever in Zaire.

In this table, hemorrhagic fever cases and the people of one community in Zaire are classified by age. For example in the 30-49 year age group, there were 109 cases and 13,000 people. For this age category, the attack rate was 109 divided by 13,000 times 1,000, or 8.4 cases per thousand people.

In this outbreak, although the largest number of cases were reported in people 30-49 years old, the highest attack rate was in children less than 1 year old.

Prevalence

Prevalence gives us the proportion of currently existing (that is new and old) cases of disease or a condition in a population.

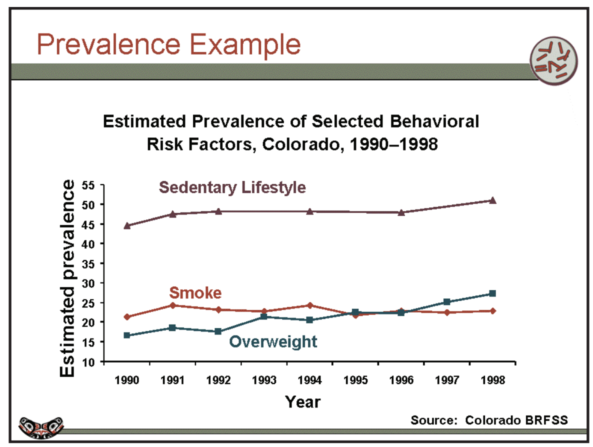


Prevalence Example

This graph shows the prevalence of sedentary lifestyles, smoking, and obesity in Colorado.

Remember that the prevalence does not only include the new cases of a disease or a condition. It includes the existing cases, both new and old.

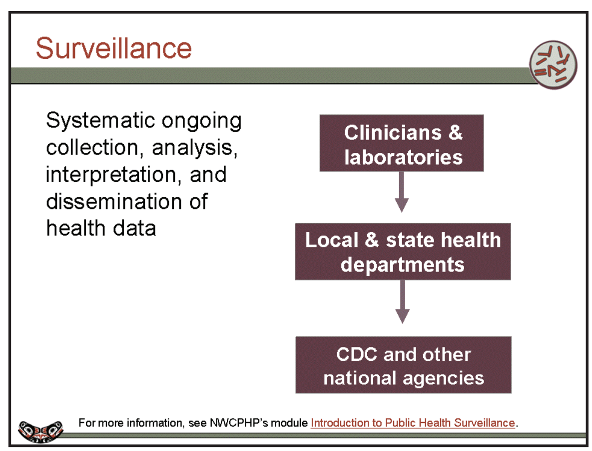
Therefore, the people represented in this graph may have smoked for example, for one year, or many years.



Interactive Exercise 6

Surveillance

Surveillance is the systematic, ongoing, collection, analysis, interpretation, and dissemination of health data. Data typically flows from clinicians and laboratories to local and state health departments and finally to the Centers for Disease Control (CDC) and other federal agencies. We use this system with infectious diseases to measure the disease burden, to monitor trends, and to alert us when we have an outbreak. Surveillance data can guide decision making for interventions and control, program planning, and resource allocation. For further information, see the online epi module on surveillance.

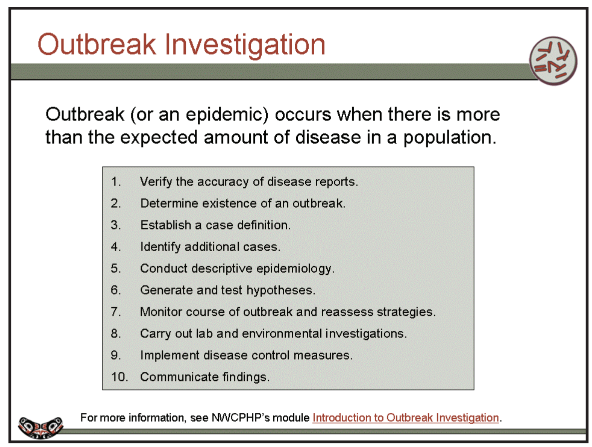


Reportable Conditions

The CDC's Nationally Notifiable Conditions is a list of diseases and conditions for which surveillance is recommended in the United States. See your state health department Web site for the legally required reportable diseases in your jurisdiction.

Outbreak Investigation

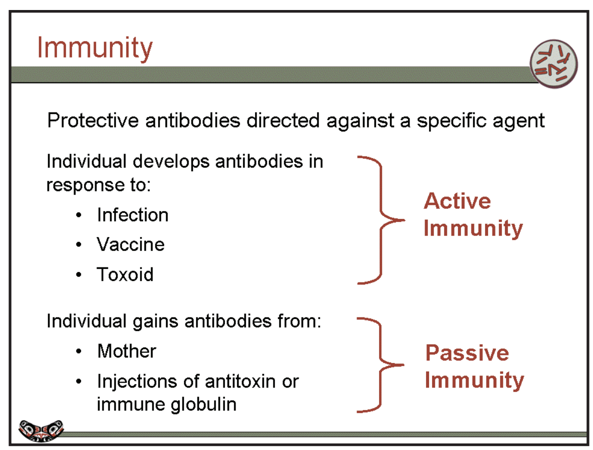
In epidemiology, an outbreak or an epidemic occurs when there is more than the expected amount of disease in a population. When we detect a cluster or rise in disease rates, we investigate the outbreak using a series of steps listed here. These steps may vary or may be performed in a slightly different order, depending on the situation. For further information, see the module on outbreak investigations.



Immunity

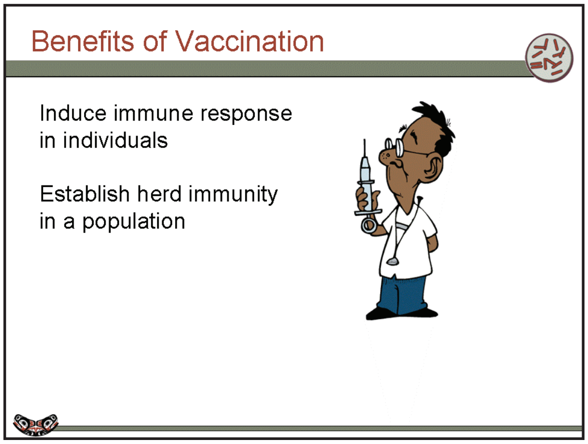
As we discussed earlier, a variety of biological and behavioral factors affect an individual's ability to resist infection. One of these factors involves the body's specific acquired immunity, which refers to protective antibodies that are directed against a specific agent.

An individual can gain protective antibodies in two ways. First, antibodies can develop in response to an infection, vaccine, or toxoid. This is called active immunity. Second, the unborn child can acquire antibodies from the mother through the placenta before birth. Also, later in life, the antibodies can also be injected as antitoxin or immune globulin. This is called passive immunity.



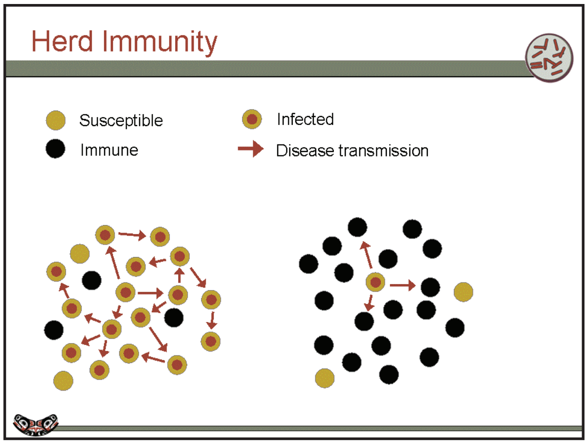
Active immunity and passive immunity differ on how quickly protection occurs and on how long the protection lasts. Active immunity through immunization requires a few days or weeks for the protection to occur. However, the protection is long lasting, for many months or years, depending on the vaccine. In contrast, passive immunity occurs very quickly, but the protection lasts only a few weeks or months.

Benefits of Vaccination



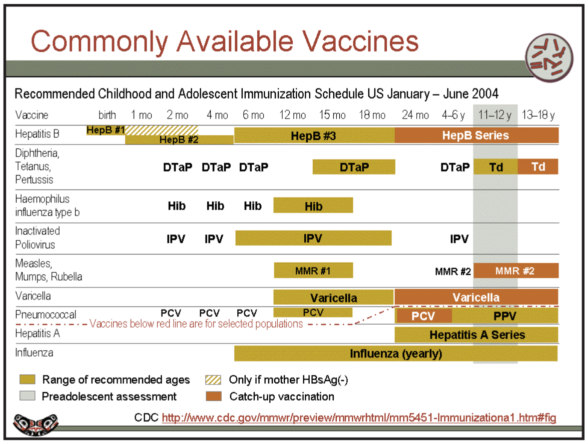
By exposing an individual to an agent or antigen whose virus or bacteria has been killed or weakened, we can induce an immune response without clinical symptoms. If we induce immunity in this way to enough people, we can establish herd immunity in a population.

Herd Immunity



This diagram illustrates the principle of herd immunity. The circles represent people. They are in two colors, representing those who are susceptible to a disease and those who are immune, either through natural disease or through vaccination. The arrows represent transmission of a disease from one person to another. For highly infectious diseases, if most people are susceptible, the infection will rapidly spread to almost all. However, if for example, 95% of people are immune through vaccination or a disease history the remaining susceptibles may be protected even if the disease is introduced.

Commonly Available Vaccines

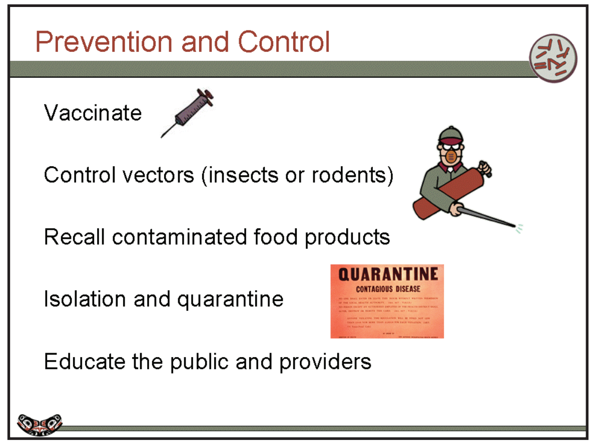


Most common vaccines are administered during infancy or childhood. This table illustrates the recommended vaccination schedule for children and adolescents in the United States.

Transcript

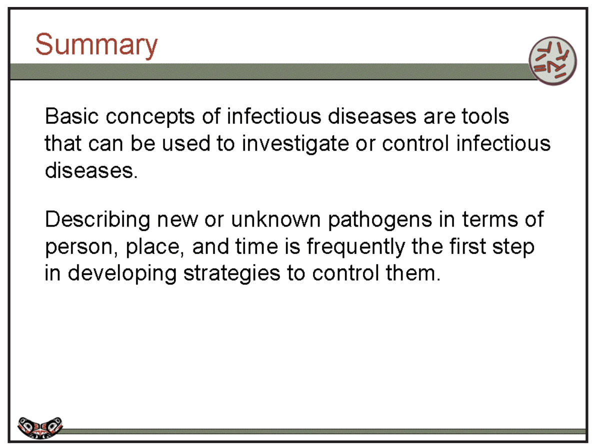
Prevention and Control

Not all diseases can be prevented with vaccines. We must rely on other forms of prevention and control, which will vary, depending on the disease at hand. These measures include controlling vectors such as insects or rodents, or recalling contaminated food products. It may be necessary to perform isolation or precautions to prevent disease transmission from ill individuals, or enact quarantine measures or precautions to prevent disease transmission from exposed individuals who are still well. Finally, education of the public and health care providers is an important part of any prevention and control strategy.



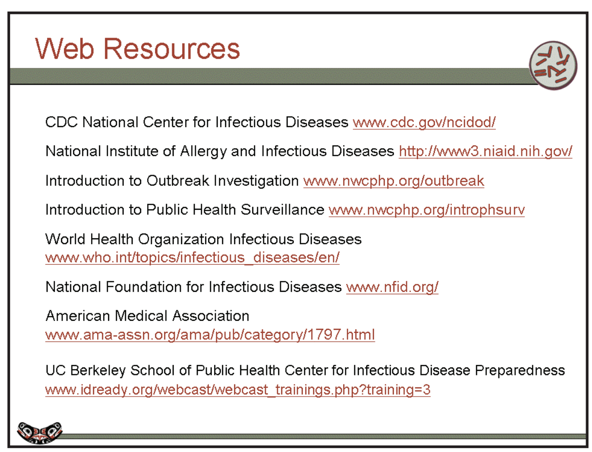
Summary

In summary, basic concepts of infectious diseases are tools which can be used to investigate or control infectious diseases. Describing new or unknown pathogens in terms of person, place, and time is frequently the first step in developing strategies to control them.



Web Resources

Here are some links that provide further information about this topic. You can also access these links in the attachments drop down menu at the top of the screen.



Final Assessment