21.3: Infectious Diseases

Typhoid Mary

Her real name was Mary Mallon (1869-1938), but she was nicknamed “Typhoid Mary.” She gained notoriety (as evidenced by this newspaper article) by being the first person in the United States to be identified as an asymptomatic carrier of the pathogen that causes typhoid fever. Over the course of her career as a cook, Mary Mallon was thought to have infected 51 people, three of whom died. She was twice forcibly quarantined by public health authorities and died after a total of nearly 30 years in isolation. Typhoid fever is caused by bacteria that are spread by eating or drinking food or water contaminated with the feces of an infected person. Risk factors include poor sanitation and poor hygiene. Typhoid fever is one of many infectious diseases that can spread in human populations.

Figure \(\PageIndex{1}\): Typhoid Mary
All infectious diseases are caused by infections with pathogens or disease-causing agents, but not all infections cause infectious diseases. **Infection** is the invasion of an organism’s body tissues by pathogens, which multiply and damage or poison the host tissues. The reaction of the host’s immune system to the pathogens may contribute to the tissue damage. Infectious disease is an illness resulting from an infection. It occurs when an infection causes noticeable symptoms.

### Types of Pathogens

Infectious diseases kill more people in low-income countries than any other cause, and they are important causes of death elsewhere. Many different types of pathogens can cause infectious diseases. Besides bacteria and viruses, human pathogens include fungi, protists, helminths, and prions.

- **Bacteria**: The vast majority of bacteria are at least harmless if not beneficial to human hosts. Relatively few bacteria cause human diseases, but of those that do, the disease burden they exert on human populations may be great. **Disease burden** is the impact of a disease on a population as measured by financial cost, mortality, morbidity, or other indicators. One of the bacterial diseases with the highest disease burden worldwide is tuberculosis. It is caused by the bacterium *Mycobacterium tuberculosis*, which kills about 2 million people a year, most of them in sub-Saharan Africa. Other bacterial diseases that burden human populations include strep throat, pneumonia, shigellosis, tetanus, typhoid fever, cholera, diphtheria, syphilis, and leprosy.

- **Viruses**: Viruses are little more than DNA or RNA in a protein coat. Viruses are not usually classified as living things because they cannot survive or reproduce on their own. They require the cells of a host to provide the machinery for protein synthesis and reproduction. Many types of viruses are pathogenic to humans. Common human diseases caused by viruses include influenza, mumps, measles, chickenpox, hepatitis, AIDS, yellow fever, herpes, polio, and the common cold.

- **Fungi**: Fungi (singular, fungus) are eukaryotic organisms in the Fungus Kingdom. Some fungi are unicellular organisms; others are multicellular. Many fungi consume dead organisms. Many others are parasites of plants or animals, including humans. Human diseases caused by fungi include candidiasis, histoplasmosis, ringworm, and athlete’s foot. People with a compromised immune system are particularly susceptible to certain fungal diseases, such as candidiasis, which is pictured below, and cryptococcosis, which is a defining opportunistic infection for AIDS patients (see the concept [HIV and AIDS](https://bio.libretexts.org/Bookshelves/Human_Biology/Book%3A_Human_Biology_(Wakim_and_Grewal)/21%3A_Disease/21.1%3A_Infectious_Diseases/21.1.2%3A_Infectious_Diseases)) to learn more.


*Figure 1 (PageIndex{2}): Oral infection with yeast (candidiasis) is an opportunistic infection in this immune-compromised HIV patient*
• **Protists**: Protists are an informal grouping of simple eukaryotic organisms that are not plants, animals, or fungi. Some protists — particularly those called **protozoa** — are significant parasites of human organisms. They include five species of the parasitic genus Plasmodium that cause malaria. Malaria places a tremendous disease burden on human populations. In 2015, there were 214 million cases of malaria worldwide resulting in an estimated 438,000 deaths, 90 percent of which occurred in Africa. Other human diseases caused by protists include giardiasis, toxoplasmosis, trichomoniasis, Chagas disease, leishmaniasis, trypanosomiasis (sleeping sickness), and amoebic dysentery.

• **Helminths**: Helminths, also commonly known as parasitic worms, are multicellular organisms, which when mature can generally be seen with the naked eye. Helminths infect animals including humans. Most live in the host’s intestines, but some live in other organs, such as muscles or blood vessels. Helminths take nourishment and protection from the host and cause disease in return. Examples of helminthic infections in humans include infections by tapeworms, roundworms, pinworms, and hookworms (see photo below).

Figure \(\PageIndex{3}\): These two hookworms are attached to the intestinal mucosa of a human host

• **Prions**: Prions are infectious agents composed entirely of proteins. Prions are misfolded proteins that replicate by converting their properly folded counterparts, in their host, to the same misfolded structure they possess. Prions are transmissible and a few of them are known to cause human diseases, including Creutzfeldt–Jakob disease (CJD), an incurable and universally fatal neurodegenerative disease. CJD is similar to the better-known prion disease in cows, called mad-cow disease. In both the human and bovine (cow) diseases, brain tissue degenerates rapidly, and the brain develops holes like a kitchen sponge.

### Identifying Pathogens: Koch’s Postulates

The human body has more microorganisms that it does human cells. The majority of microorganisms that live in or on the human organism are actually beneficial or at least harmless to the human host (except in the case of immune-compromised individuals). Given a huge load of microorganisms in and on the human organism, how can scientists determine which species of microorganism causes a particular disease? The 19th-century physician and microbiologist Robert Koch (pictured below) is best known for developing four basic criteria, or postulates, for deciding whether a disease is caused by a particular microorganism. **Koch’s postulates** are tabulated below:

Koch’s postulates

1. The microorganism must be found in abundance in all individuals suffering from the disease and should not be found in healthy individuals.
2. The microorganism must be isolated from a diseased individual and grown in pure culture.
3. The cultured microorganism should cause disease when introduced into a healthy individual.
4. The microorganism must be re-isolated from the inoculated individual and then identified as being identical to the original microorganism.

In the first and third postulates, Koch originally used the word “must” instead of “should.” He changed the wording when he learned that some carriers of cholera and typhoid were asymptomatic and remained healthy.

Since Koch presented his postulates, scientists have come to realize that all four postulates may not apply to every pathogenic microorganism. For example, while bacteria can be grown and identified in pure culture (Figure (PageIndex(5))), this is not the case with all pathogens, including viruses and prions. Therefore, these pathogens fail to meet the second postulate. Taking these and other exceptions into account, Koch’s postulates can be viewed as sufficient but not necessary criteria for establishing a specific agent as the cause of a disease. The postulates still inform the basic approach scientists take to this research. Koch’s postulates are also important for their historical significance. They led to the scientific identification of many human pathogens, which allowed the development of ways to prevent and cure diseases.
Figure \(\PageIndex{5}\): All of the bacteria growing on these culture plates have been determined to cause human disease. Each independent colony arises from a different species of bacterium. The size, color, shape, and form of each colony is characteristic of its bacterial species.

How Pathogens Cause Disease

Pathogens usually gain entrance to a human host through the mucosa in orifices like the oral cavity, nose, eyes, genitalia, or anus. Some pathogens may be swallowed and gain access through the mucosa lining the digestive tract. Other pathogens may enter a human host through breaks in the skin. Once pathogens gain entrance to a host, they multiply inside the host, either at the site of entry or at other sites after migrating from the entry site. Some pathogens live and multiply inside host cells; others live and multiply in host body fluids.

Within the host’s tissues, pathogens may cause damage by releasing toxins. For example, *Clostridium tetani* releases a toxin that paralyzes muscles, causing the disease known as tetanus. Typically, the more pathogens that are present, the greater the severity of illness, but there is considerable variation in the virulence of pathogens. The poliovirus is not very virulent. Fewer than 5 percent of people infected with poliovirus actually develop any noticeable symptoms of the disease. On the other hand, CJD prions are so virulent that they cause severe disease and death in every infected individual.

How Pathogens Are Transmitted

For pathogens to survive and repeat the cycle of infection in other hosts, they or their progeny must have a means of leaving one host and entering another. Transmission of pathogens from infected to noninfected human hosts occurs through many different routes.

- **Airborne Transmission**: One of the most common routes is an airborne transmission. As illustrated in the figure below, this occurs when pathogens in droplets are expelled from an infected host’s respiratory system during coughing or sneezing. The pathogens are then inhaled by nearby people, who become new hosts for the pathogens. Flu and the common cold can spread this way.
Figure \(\PageIndex{6}\): Common airborne pathogens include flu and cold viruses.

- **Direct Contact**: Many pathogens spread from person to person through direct contact between an infected person and a new host. This can happen when people have skin-to-skin contact or touch the same surfaces. Athlete’s foot and warts are transmitted this way. Another form of direct contact is oral transmission. This occurs when pathogens spread through direct oral contact, for example, by kissing, or by sharing items that go in the mouth, such as drinking glasses or eating utensils. Mononucleosis and oral herpes spread through oral contact.

- **Fecal-Oral Transmission**: Fecal-oral transmission is also very common. It occurs when pathogens in feces from an infected host enter the mouth of a new human host in fecally contaminated food or water or on contaminated fingers. Cholera and many types of gastroenteritis are transmitted this way. Helminth infections are also usually spread via a fecal-oral route. Adult worms may live and produce eggs in the human host for several years. Generally, thousands or even hundreds of thousands of eggs are released each day. The eggs are then shed from the human host in feces. The eggs that hatch develop into larvae that may be consumed by a new human host in contaminated food or water. After being ingested, the larvae develop into adult worms that parasitize the new human host.

- **Vector Transmission**: Vector transmission occurs when pathogens are carried by a vector organism from infected hosts to new hosts, usually through biting them. Mosquitoes, fleas, and other insects are common vectors. The figure below describes four diseases that are spread by mosquito vectors.

- **Vertical Transmission**: Vertical transmission occurs when pathogens travel from an infected woman to her embryo or fetus during pregnancy or to her infant during or soon after birth. Examples of diseases that can be transmitted this way include HIV infection and rubella. You can learn more about this type of transmission in the concept Embryonic Stage.

- **Sexual Transmission**: Sexual transmission occurs when pathogens spread through sexual activity between an infected host and a new host. Sexual transmission generally requires direct contact between mucous membranes or their secretions. This can occur during any type of sexual contact, including vaginal, anal, or oral contact. Sexually transmitted infections include chlamydia and gonorrhea. To learn more about sexual transmission, read the concept Sexually Transmitted Infections.
Transmission of Prions: Prions have unusual means of transmission. Some people have become infected with prions by eating meat from cows infected with mad cow disease. Prions that cause the human disease called kuru have been transmitted through cannibalism. Kuru is a deadly disease that was once commonly found in women and children of the Fore tribe in Papua New Guinea. Women and children were most often infected because they were more likely than males to eat highly infective brain material from the cannibalized bodies. Solving the mystery of this disease and its mode of transmission resulted in two Nobel Prizes.

Managing Infectious Disease

Infectious diseases must be correctly diagnosed so the appropriate treatment can be prescribed. Most infectious diseases can be treated if not cured. Many infectious diseases can be prevented through commonsense behaviors or immunizations.

Diagnosing Infectious Disease

Most minor infectious diseases — such as upper respiratory infections and diarrheal diseases — are usually diagnosed on the basis of their signs and symptoms. However, determining the specific pathogen that is causing the disease may be necessary to choose the best treatment. Many pathogens can be identified by growing samples from a patient on a...
culture medium or by examining samples from the patient under a microscope. Most bacteria can be identified from a culture based on the size, color, and shape of the colony. Viruses can be identified by using cells grown in culture as the medium. If viruses are pathogenic, they infect and kill the cultured cells. Biochemical tests can also be used to identify specific pathogens in patient samples. Some pathogens can be detected by testing for the chemical products they produce, such as acids, alcohols, or gases. Another potential diagnostic tool is a serological test, which identifies pathogens by their antigens and whether they bind to specific antibodies.

**Treating Infectious Disease**

Not all infectious diseases require treatment. Many minor infectious diseases are usually self-limiting and people get better on their own. For more serious infectious diseases, pharmaceutical drugs may be needed. Drugs have been developed to treat most types of infectious diseases. Different types of drugs are generally required to treat different types of pathogens.

- Bacteria can often be killed with antibiotic drugs. Antibiotics typically work by destroying the cell wall of bacterial cells, causing the DNA inside to spill out. This makes the bacterial cells incapable of producing proteins, so they die. This generally cures the disease. Several different classes of antibiotics have been developed. Different types of bacteria are susceptible only to certain classes of antibiotics. Some bacteria have evolved the ability to resist some or all classes of antibiotics (see Explore More below).

Figure \(\PageIndex{8}\): Clotrimazole is an anti-fungal cream that is commonly used to treat and cure athlete’s foot and other fungal infections of the skin.

- Unlike bacteria, viruses are not killed by antibiotic drugs. However, antiviral drugs have been developed to help the immune system fight off viral infections. Antiviral drugs are generally not as effective at curing viral infections as antibiotics are at curing bacterial infections.

- Most fungal infections can be treated or cured with antifungal medications. These may be taken orally or applied topically, depending on the disease. Most antifungal drugs are available only with a doctor’s prescription, but a few can be purchased over the counter (OTC). An example of an OTC antifungal product is pictured below.

- Infections by protozoa are treated with antiprotozoal drugs. Because protozoans may vary greatly in their biology, drugs effective against one pathogen may not be effective against another. Several anti-malarial drugs have been developed, but the Plasmodium pathogens are evolving resistance to most of them.

- Several drugs are available to kill worms in human hosts. Different drugs must be used for different helminthic parasites. The drugs kill off the adult worms, which are then shed in the host’s feces.

Unfortunately, infectious diseases caused by prions are not treatable at present. They are considered incurable and inevitably fatal diseases. The good news is that scientists are actively working to find ways to treat or cure prion diseases.
Preventing Infectious Disease

You have probably heard the expression “an ounce of prevention is worth a pound of cure.” It certainly applies to infectious diseases. Some side effects of treating minor infectious diseases can be worse than the disease symptoms. For example, taking an antibiotic for a minor sinus infection might lead to diarrhea or a vaginal yeast infection as beneficial bacteria are killed off along with harmful bacteria and causing homeostatic imbalance. It’s almost always better to avoid getting sick in the first place than to treat a disease after it occurs. Hygienic habits and immunizations are the most effective ways to prevent the spread of infectious disease.

Hand washing and Other Behaviors

Frequent hand washing is the single most important defense against the spread of many pathogens, especially those transmitted through direct skin contact or the fecal-oral route. Hand washing can also reduce the spread of respiratory illnesses such as flu and the common cold because flu and cold viruses can be spread on people’s hands when they touch their nose, mouth, or eyes. For the most effective way to wash your hands in order to prevent infection, see the Feature: My Human Body below.

What else can you do to protect yourself? You can use condoms to avoid sexually transmitted infections where there is a risk of transmission, for example, with a new partner. Condoms are the only method of contraception that also helps prevent the spread of such infections. Preventing the spread of infectious diseases transmitted by vectors often involves controlling the vectors or at least exposure to the vectors. For example, the numbers of mosquitoes can be reduced by removing sources of standing water around homes. Insect repellents and mosquito nets (like the one pictured below) can be used to reduce human contact with vectors.

Figure 19: This bed canopy mosquito net can help protect people from mosquito-transmitted diseases such as malaria. It reduces the chances that people will be bitten by mosquitoes during the night when the insects are most active.

Immunization

Diseases that can be prevented with vaccinations include many otherwise common and potentially serious early childhood infections such as measles, mumps, chickenpox, whooping cough (pertussis), and diphtheria. Vaccinations also are recommended for older children against the human papillomavirus (HPV) that causes genital warts and may lead to cervical cancer in females. Annual vaccines for influenza (see the photo below) are highly recommended as well, especially for young children and older adults. Pneumonia vaccines are also advised in certain people, particularly the elderly.
Some people cannot safely receive vaccines. For example, children with a compromised immune system or cancer may not be able to safely receive routine childhood vaccinations. To help protect such vulnerable people from being exposed to infectious diseases, it is important for populations to maintain high levels of vaccination. When a critical portion of a population is immunized against an infectious disease, most members of the population are protected against that disease even if they have not been immunized. This is known as herd immunity. You can see how it works in the figure below. The principle of herd immunity applies to many infectious diseases, including influenza, measles, and mumps, to name just a few.

Figure \(\PageIndex{10}\): A White House nurse prepares to administer the H1N1 flu vaccine to President Barack Obama at the White House in December of 2009.

Figure \(\PageIndex{11}\): This figure shows how herd immunity contains the spread of an infectious disease. The top
box depicts a population in which no one is immunized and an outbreak occurs. In the middle box, some of the population is immunized but not enough to confer herd immunity, so many people become sick. In the bottom box, a critical portion of the population is immunized, protecting most population members from infection, even those who have not been immunized.

Emerging Infectious Diseases

New infectious diseases are showing up in human populations. Called emerging infectious diseases, they can come about in a number of ways, most of which are influenced by human actions. New infectious diseases can emerge when previously harmless microorganisms evolve to become pathogenic to humans or when microorganisms that infect nonhuman animals jump to human hosts. Infectious diseases can also spread to faraway populations where people have no prior exposure and natural immunity to them. Human actions that influence the emergence of new infectious diseases include:

- human encroachment on wild habitats. This may happen with residential development, mining, farming, or logging activities. It may bring humans into contact with insects and other animals that harbor previously unknown microorganisms that are pathogenic to people.
- changes in agriculture. The introduction of new crops attracts new crop pests and the microbes they carry to farming communities. This exposes people to new pathogens.
- uncontrolled urbanization. The rapid growth of cities in many developing countries concentrates large numbers of people in crowded areas with poor sanitation. Such conditions foster the transmission of pathogens that may not have been able to spread in small, dispersed rural populations.
- modern transportation. Ships and other cargo carriers often inadvertently carry microscopic pathogens or their infected vectors to distant places where they can infect people who have never been exposed to them before. International jet travel allows infected people to carry pathogens to distant populations, even before their first symptoms appear.

Feature: My Human Body

Proper hand washing is the single most important behavior you can adapt to avoid infection by pathogens. The most effective hand washing method is to use soap and warm running water and the following procedure:

1. Wet hands with warm water, keeping hands below the forearms to prevent contaminated water from moving from the hands to the arms.
2. Apply about 5 mL (1 teaspoon) of liquid soap and rub it all over the hands for at least 20 seconds. Be sure to wash the most commonly missed areas, which are the thumb, wrist, areas between the fingers, and skin under the fingernails. Ideally, you should use a nail brush to remove any debris or microorganisms under the fingernails.
3. Rinse thoroughly. Make sure the water flows from the wrist to the fingertips to ensure that any microorganisms are washed off the skin rather than up onto the arms.
4. Dry hands thoroughly with a clean towel or hot air blower. Properly dispose of any used towels. If possible, use towels to turn faucets on and off and to open the bathroom door.

Summary

- All infectious diseases are caused by infections with pathogens, or disease-causing agents, many of which are...
microorganisms. Types of pathogens and examples of the diseases each type causes include: bacteria (e.g., tuberculosis and strep throat), viruses (e.g., influenza and the common cold), fungi (e.g., ringworm and athlete's foot), protists (e.g., malaria and giardiasis), helminths (e.g., tapeworm and hookworm), and prions (e.g., CJD and mad-cow disease).

- In the 19th century, Robert Koch developed four criteria, or postulates, for deciding whether a disease is caused by a particular microorganism. The postulates are now viewed as sufficient but not necessary criteria. They still inform the basic approach to identifying pathogens and historically led to the discovery of many human pathogens.

- Pathogens cause disease by invading and multiplying in host tissues, causing damage and releasing toxins. Typically, the more pathogens there are in the host, the greater is the severity of the disease. However, pathogens also vary greatly in their virulence.

- Transmission of pathogens from infected to noninfected human hosts can occur through a variety of different routes: airborne transmission, direct contact, fecal-oral transmission, vector transmission, vertical transmission, and sexual transmission. Prions can be transmitted by eating contaminated nervous tissue from an infected individual.

- Infectious diseases must be correctly diagnosed so the appropriate treatment can be prescribed. Most infectious diseases can be treated with drugs if not cured. Hygienic habits, especially frequent handwashing, and immunizations are the most effective ways to prevent the spread of infectious diseases. A high level of vaccination in a population provides herd immunity to population members who cannot be vaccinated for medical reasons.

- Emerging infectious diseases are new infectious diseases that are appearing for the first time in human populations, mainly because of human actions such as encroachment on wild lands. Emerging infectious diseases come about in a number of ways. For example, some pathogens of nonhuman hosts jump to human hosts and start causing disease in them.

**Review**

1. What are infectious diseases?
2. Name types of pathogens and give an example of a human disease caused by each type of pathogen.
3. What are Koch’s postulates? What is their current significance?
5. List six common routes of transmission of pathogens.
6. Why is the correct diagnosis of a pathogen important for selecting the appropriate treatment of an infectious disease?
7. What are the most effective ways to prevent the spread of infectious diseases?
8. How does herd immunity come about, and why is it important?
9. Explain how and why emerging infectious diseases are appearing in human populations.
10. Explain why Koch’s first postulate alone would not provide sufficient evidence to prove that a specific microorganism causes a disease. In particular, discuss why postulates three and four are required.
11. What is a disease burden?

   A. How many infectious pathogens are in an infected person.
   
   B. How many people are killed by an infectious disease each year?
   
   C. How rapidly an infectious disease spreads.

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D. The impact of a disease on a population, including the number of deaths and the associated financial impact.

12. Give an example of a human disease that is caused by a protist and transmitted by a vector.

13. What kind of treatment do you think might be given for leprosy? Explain your reasoning.

14. True or False. The direct contact route of pathogen transmission requires skin-to-skin contact.

15. True or False. Some people who are infected with a pathogen never show symptoms.

Explore More

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Scientists at Harvard Medical School have developed an innovative and fascinating way to study the emergence of antibiotic resistance in bacterial pathogens. To learn more, watch this video:

Check out this video to learn about Ebola Virus: