INFECTIONOUS DISEASE
Infectious Diseases
Student Workbook

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Welcome to the Infectious Disease Module!

This module has a simple goal — to bring real world science into the classroom. To do this we will be learning about biology in a framework that is relevant to our everyday lives, our health!

Even now, in the 21st century, infectious diseases greatly impact our daily habits, economics, and health. The Infectious Disease (ID) Module has five units, each of which builds upon the others that came before it. The goal of each unit is to answer a new question about infectious diseases, and what this means for our health.

- **Unit 1**: Why should we care about infectious diseases?
- **Unit 2**: What does it mean to have an infectious disease?
- **Unit 3**: When does a microbe become a pathogen?
- **Unit 4**: How do pathogens make us sick?
- **Unit 5**: How do we get better?
Unit 1: Where are we heading?

Unit 1: Why should we care about infectious diseases?
Unit 2: What does it mean to have an infectious disease?
Unit 3: When does a microbe become a pathogen?
Unit 4: How do pathogens make us sick?
Unit 5: How do we get better?

In this unit we will see how infectious diseases can wreak havoc in a society, and come to the question — what do we need to know to predict and prevent the impact of infectious diseases? We will also learn about the types of infectious agents that cause disease, how they infect us, and the barriers the body uses to stop infection and keep us healthy.
LESSON 1.1 WORKBOOK

What is an infectious disease and why do we care?

Why should we care about infectious diseases? How do they impact our health and society? In this lesson, we will consider the differences between infectious diseases and other diseases. We will also learn about the main ways that people get infected. Then we will address the question: Do we as a society overreact to outbreaks of the seasonal flu every year?

What is an infectious disease?

An infectious disease is a clinically evident illness with symptoms resulting from the presence of microbial agents. This differs from other types of diseases that might be caused by trauma, genetics, or lifestyle habits such as diet. Given that most microbes don’t cause disease, microbial agents that can cause disease are given a special name — pathogens. In this course we will mostly learn about microbial pathogens that are microscopic (visible only with a microscope) including viruses, bacteria, fungi, and protozoa. We will also learn about select multicellular parasites, which are macroscopic (visible to the naked eye).

Unlike other types of disease, infectious diseases can be acquired and transmitted. This is why infectious diseases are also called communicable diseases or transmissible diseases. This can be confusing because some diseases can be acquired by exposure to toxic chemicals. However, unlike toxic chemicals, infectious agents replicate and can be transmitted from one host to another. Transmission of an infectious disease from an infected to an uninfected host, can occur through different routes that may or may not require actual physical contact.
How we acquire and transmit infections: Getting through the skin

For us to acquire infections, microbes need to gain access to our body by getting through the skin or mucous membranes.

As we will see in more detail later in Unit 1, the skin which is an excellent barrier against infectious agents, is made up of multiple layers of cells. The outer layer of this robust barrier is very dry, which makes life for water-seeking microbes hard. Also, the dead cells on the outer layer of the skin are constantly being shed, getting rid of any attached microbes. A few microbes such as the fungus that causes ringworm infection manage to cause infections on the skin's surface. Diseases like ringworm are generally transmitted by touching an infected person or their clothes. However, for many microbes to cause a disease, access to the deep tissues or blood is essential, and this can only occur when the intact skin barrier is broken. This can happen in many ways!

Insect or animal bites:

An insect or animal carrying an infectious microbe can transmit it to humans by biting through the skin. These carriers of pathogens are called vectors of disease. When a vector, like a mosquito, bites a person it penetrates the skin releasing the infectious microbe directly into the deep tissue or bloodstream. Numerous diseases caused by viruses (yellow fever, rabies), bacteria (plague, typhus), protozoa (malaria, sleeping sickness), and worms (river blindness, elephantiasis) are vector-borne. A particularly unsavory example of an insect bite allowing microbial transmission through the skin is the Reduviid bug, which defecates while biting, allowing the parasites in the insect’s feces to penetrate the skin as the person scratches the itchy insect bite!

1. Infectious diseases can be transmitted through all of the following EXCEPT
a. through the skin
b. through the mouth
c. through the nose
d. toxic chemicals that cause disease
Cuts, wounds or burns:

Accidental breaks in the skin such as deep cuts or burns, allow microbes that are harmless residents of our skin or that are in the air, entry into the deep tissues or blood. If a large number of microbes enter the blood through a site of skin damage, it can result in local infection at the site or even the spread of an infection to vital organs. The bacterium (*Clostridium tetani*) that causes tetanus commonly causes infection in this way.

Medical procedures:

Yet another way for microbes to penetrate the skin is through blood transfusions and contaminated needles, organ transplants, and implants. Multiple infectious diseases are transmitted unintentionally during medical procedures that puncture the skin or place foreign material into a host. However, transmission through these routes is highly preventable through proper screening and precautions.

- **Transfusions and contaminated needles** — Of all the infectious agents that can be acquired through blood transfusions or contaminated needles, none cause greater concern than HIV and hepatitis C viruses.
- **Organ transplants and surgical implants** can also transmit infections. For example, transplantation of heart valves infected with *Staphylococcus* bacteria can cause serious infection and heart failure. Also implantation of catheters (plastic tubes inserted into the body to drain fluids) can transmit bacteria and fungi, causing severe infections!

Microbial exceptions that can break through the skin:

One of the exceptions to the inability to penetrate the intact skin barrier is the parasitic hookworm. It can burrow directly from contaminated soil through barefooted skin, to invade the host.
LESSON READINGS

Getting to and through mucosal membranes

As we will see in more detail later in Unit 1, mucosal membranes line body cavities that are exposed to the external environment, such as the mouth, nose, intestines, urinary tract, and vagina. Mucosal membranes are made up of a single layer of cells called epithelia that protects the underlying organs and absorbs nutrients like food and oxygen coming from the outside.

Unlike the skin, mucosal membranes are wet, due to mucus secretion that protects the epithelia. Given the moisture and presence of nutrients, pathogenic microbes often flourish on the surface of the mucosa. In addition, the single layer of cells can be broken by many pathogens, allowing them to access the deep tissues or blood inside the body. Pathogenic microbes may gain access to and through mucosal membranes in many ways.

Through the mouth:

Microbes can enter the body through the mouth in contaminated food or water and can end up directly in the digestive system. They can also be transmitted by the ingestion of infected body fluids such as saliva, vomit, and breast milk. Once inside the digestive system, microbes have to overcome host defense mechanisms, such as stomach acid. Some bacteria and yeasts are resistant to stomach acid and can escape the stomach alive, although in reduced numbers. Microbes that survive the stomach’s acid barrier enter the small intestine, where they meet enzymes and bile salts that can digest them. They also encounter the strong sweeping force of peristalsis, which is the strong contraction and relaxation of muscles in the small intestine that propels food through the digestive tract. Few microbes survive the upper reaches of the small intestine, and the pathogens that do, often have unique mechanisms to adhere to the mucosal lining of the small intestine. For example, the bacteria that cause cholera and its milder relative, travelers’ diarrhea, survive the small intestine, where they produce powerful toxins that cause diarrhea. The microbes are then shed from the body, in the large volumes of watery fecal matter; and in areas that have poor sanitation, end up contaminating the water sources. These microbes can then be transmitted to anyone who drinks the contaminated water!
DEFINITIONS OF TERMS

Urethra — the tube that leads from the bladder and discharges urine to the outside of the body.

Placenta — an organ that connects the developing fetus to the uterine wall to allow nutrient uptake, waste elimination, and gas exchange via the mother’s blood supply.

For a complete list of defined terms, see the Glossary.

Through the nose:

Some microbes are acquired when we touch an infected person or surface and then touch our noses. Other microbes reach the nose through the air in water droplets or aerosols expelled by breathing, coughing or sneezing. Once inhaled, most microbes are effectively removed by hair in the nose and mucus. However, pathogens like the flu virus are able to bypass these barriers and take up residence within the nasal cavity or even the lungs, where they attach to, or penetrate the epithelial lining to survive.

Through the genitourinary tract:

The genital organs and the urethra are potential entry points for microbes, especially through sexual contact. Like the stomach, the natural pH of the vagina is acidic, making it inhospitable for most microbes. Few microbes can linger in the urethra because it is periodically flushed by urine. However, there are several sexually transmitted infections (STIs) such as HIV, chlamydia, and gonorrhea caused by microbes that bypass these immune barriers.

Transmission from mother to child:

An infected mother can transmit an infectious disease to her child during pregnancy or during delivery due to the exchange of body fluids across the placenta or during passage through the birth canal. For instance, toxoplasmosis is transmitted through the spread of the parasite Toxoplasma gondii from mother to child through the placenta. Transmission of pathogens through breast milk is another way for infants to acquire infections.

Figure 7: Microbes can be transmitted via aerosols and droplets expelled by sneezing.

Figure 8: An infected mother can transmit the disease to her child during pregnancy or while breastfeeding.
Exposure to infectious microbes doesn't always mean getting sick

Two major factors that contribute to getting an infectious disease are the microbe and the host

**Microbial factors:**

The **infectiousness** of a pathogen describes its ability to enter, survive, and multiply in the host. There are two important factors that contribute to this: the ability of the pathogen to survive and multiply in diverse sites in the body, and the minimum number of microbes needed to cause disease.

- **Versatility** — As you will see throughout the course, most pathogens need a very specific environment or site in the host to cause disease, while others can be transmitted through multiple routes, thus infecting a variety of sites in the host. The latter are more versatile pathogens and thus more infectious.

- **Infectious (infective) dose** — The infectious dose for a particular microbe, is the number of live organisms required to cause infection in a host. The more infectious the microbe, the lower its infectious dose. For instance, *Shigella* is a pathogen which can cause disease even if the host encounters as few as 10 cells! On the other hand, pathogens with a high infectious dose, are less of a threat, because they cannot cause disease unless the host is exposed to a large number of those organisms. Small doses of those microbes are usually harmless because the body’s defense against infection — the **immune system**, effectively kills them. An example is the **commensal microbiota** that reside in our mouths. Routine brushing dislodges them and they can enter the bloodstream in small numbers through cuts in the gums, but are wiped out by the immune system.

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**DEFINITIONS OF TERMS**

- **Dose** — the number of microbes that a host has been exposed to.
- **Immune system** — the defense system that protects the body by constant surveillance for intruders and killing those it encounters.
- **Commensal microbiota** — the microbes that reside within our bodies, that benefit from us, without harming us.

For a complete list of defined terms, see the **Glossary**.
Host factors:

The health of the host and the status of its commensal microbiota play an important role in whether exposure to a pathogen, results in disease.

- **Internal tissue damage** — If the host has damaged tissue or organs due to other diseases, then exposure to microbes leads to infection more easily. For instance, people who have damaged heart valves, are more prone to infections, since the impaired blood flow makes it easier for bacteria to latch onto a tissue site and multiply without being swept away by the blood stream. Another example is that smokers are more prone to lung infections, because their airways have been damaged and the physical barriers that protect against pathogens no longer function very well. Can you think of other examples?

- **Immune status** — As we saw earlier, a normal immune system can fight off most infections, by destroying the invading pathogens. However, when the immune system is suppressed for various reasons such as pregnancy, old age or an immune deficiency disorder such as AIDS, a person is more susceptible to infections.

- **Commensal microbiota** — Non-pathogenic microbes that occupy our skin and our respiratory, digestive and urogenital tracts, protect us by competing with pathogens for attachment space and essential nutrients and sometimes by actively aiding the immune system against these invaders. These ‘friendly’ bacteria are essential to our health for many reasons. Since sites in the host that are easily accessible to microbes, are usually completely occupied by our commensal microbiota, they need to be evicted first in order for pathogens to find space and nutrients for themselves. This is why when antibiotics prescribed for infections are overused, it can lead to more severe infections down the road! Antibiotics wipe out all bacteria, including commensals, thus making it easier for pathogenic bacteria to find space to multiply.

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3. All of the following statements about the Spanish Flu are true EXCEPT:
   - a. Young people in the workforce were dying suddenly
   - b. It killed more US soldiers than the war itself
   - c. It infected almost 30% of all Americans.
   - d. The pandemic was deliberately caused by the Germans.
The Spanish flu pandemic of 1918

The influenza pandemic of 1918–1919 killed 20 to 40 million people — a higher death toll than the Great War of that time, known today as World War I (WWI). It is the most devastating epidemic that the world has ever seen.

WWI was winding down in Europe by the fall of 1918. After a great loss of lives on both sides, the Allies were close to victory against the Germans. Then in pockets across the world, a sickness started to emerge that initially seemed as harmless as the common cold. The influenza of that season however was far more lethal than a cold. In its two year spread, it infected a fifth of the world’s population. Most of the people that died were between the ages of 20 and 40, and this was unusual since influenza usually kills the elderly and the very young. Although it was a global disaster, the name Spanish Flu which came from the early affliction and large mortalities in Spain, was how it came to be known. When it spread to North America, it infected 28% of all Americans. Approximately 675,000 Americans died of influenza during the pandemic, ten times as many as in WWI. Of the U.S. soldiers who died in Europe, half of them succumbed not to the enemy, but to the influenza virus.

The death rate for 15 to 34-year-olds from influenza and the resulting pneumonia, was 20 times higher in 1918 than in previous years, reducing the average life span in the US by 10 years. People got infected by contact on the streets and died rapid deaths. In Boston, stories are told of people getting on the subway and then falling out dead when the doors opened at the next stop. One anecdote told of four women playing bridge together late into the night. Overnight, three of them died from influenza. One physician wrote that patients with seemingly ordinary influenza would rapidly “develop the most vicious type of pneumonia that has ever been seen” and eventually, “it is simply a struggle for air until they suffocate.”

Most of the world felt the effects of the Spanish flu as it spread along the path of its human carriers, following trade routes and shipping lines. WWI, with its mass movements of men in armies and aboard ships, probably aided its rapid diffusion. Not understanding the origins of the deadly disease, the Allies even speculated that the pandemic was biological warfare initiated by the Germans. A national campaign began to exploit the war rhetoric to energize the fight against this new enemy of microscopic proportions.

4. The Spanish Flu was described as a pandemic because
   a. it was an epidemic that spread through human populations across a large region.
   b. it happened within a particular place and time.
   c. of the great amount of people who died in a population (mortality rate).
   d. of cyanosis, a blue or purple coloration of the skin caused by suffocation.
Flu vaccine

Each year the flu season begins as early as October and ends as late as May in the United States, leading to approximately 200,000 hospitalizations and 41,000 deaths. The flu vaccine is designed yearly, to target the three or four viral strains that are anticipated to be the most prevalent that season. Repeated vaccination is needed each flu season because the influenza virus mutates quickly and the ability of our immune system to combat the virus fades with time!

The most common way of making flu vaccines is from hen's eggs and has been used for more than 70 years. Viruses are first injected into fertilized hen's eggs and the eggs are incubated for several days to allow the virus to multiply. The virus is then collected from the fluid in the eggs and used to prepare a vaccine given as a flu shot with a needle or as a nasal spray. These two routes of vaccination are very different: The flu shot does not contain the live virus — it only contains viral proteins, while the nasal spray contains live virus that is weakened so it no longer causes the flu. The flu virus can also be grown in mammalian and insect cells to obtain flu proteins with no egg proteins. This is why it is very important for people with egg allergies to get the non-egg-grown vaccine!

Flu vaccines can be given to people as young as 6 months of age and older. Manufacturing and distribution of flu vaccines typically begins 6–9 months before the flu season because it takes this lead time to make and distribute more than 150 million doses of vaccine used in the USA each year. As a result, you can sometimes get the flu after being vaccinated because the virus in the population has mutated since the time the vaccine was designed. Nevertheless, the Centers for Disease Control and Prevention (CDC) advises people to get vaccinated because an immune memory of an older virus can still provide some “cross protection” against the newer virus. In addition, people of certain age groups and with certain other diseases are particularly susceptible to the flu. For example, older adults, people with chronic health conditions and young children (especially those too young to get vaccinated) are at great risk of getting seriously ill from the flu. For this reason, vaccinating healthy individuals can protect more vulnerable individuals by limiting spread. The goal is to avoid another global pandemic of the proportions of the 1918 Spanish flu. Each year between 3,000 and 49,000 flu-related deaths occur despite the vaccination efforts — mostly of people from vulnerable groups.

5. Why do people with egg allergies have to inquire about the manufacturing process of the flu vaccine before they get it?
   a. Because the vaccine has egg proteins added to it for stability.
   b. Because the vaccine is made in chicken eggs.
   c. Because people with egg allergies are more sensitive to vaccines.
   d. None of the above
Give an example of a precaution we take to prevent the transmission of an infectious disease. Does it make sense to do so?

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If the Spanish flu appeared in your school today, how many students would die if all students got infected? Assume your fellow students are as susceptible now as average individuals in 1918, and that at least 2.5% of everyone infected dies.

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Remember to identify your sources.
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<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
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<tbody>
<tr>
<td>Bile salts</td>
<td>A component of bile that helps in the digestion of food, but also prevents the growth of bacteria.</td>
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<tr>
<td>CDC</td>
<td>Centers for Disease Control and Prevention is a federal US public health agency.</td>
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<tr>
<td>Commensal microbiota</td>
<td>The microbes that reside within our bodies, that benefit from us, without harming us.</td>
</tr>
<tr>
<td>Contamination</td>
<td>The presence of impurities such as microbes.</td>
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<tr>
<td>Cross-protection</td>
<td>Protection conferred on a host by vaccination with one strain of a microorganism which later prevents infection by a slightly different strain.</td>
</tr>
<tr>
<td>Dose</td>
<td>The number of microbes that a host has been exposed to.</td>
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<tr>
<td>Epidemic</td>
<td>The abnormally rapid spread of an infectious disease to a large number of people in a given population within a short period of time.</td>
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<tr>
<td>Epithelia</td>
<td>Form the protective layer of the skin and mucosal membranes.</td>
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<tr>
<td>Host</td>
<td>The organism that the pathogen resides in.</td>
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<td>Immune system</td>
<td>The defense system that protects the body by constant surveillance for intruders and killing those it encounters.</td>
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<tr>
<td>Microbe</td>
<td>An organism that is invisible to the naked eye.</td>
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<tr>
<td>Mortality</td>
<td>A measure of the number of deaths from a disease in a given population.</td>
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<tr>
<td>Mucosal membrane</td>
<td>The thin lining that borders body cavities that are exposed to the external environment.</td>
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<tr>
<td>Mutate</td>
<td>Undergo changes in the genetic makeup.</td>
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<tr>
<td>Pandemic</td>
<td>An outbreak of infectious disease that has spread through human populations across a large geographical region.</td>
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<tr>
<td>Pathogens</td>
<td>Disease-causing microbes.</td>
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<td>TERM</td>
<td>DEFINITION</td>
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<tr>
<td>Peristalsis</td>
<td>Relaxation and contraction of muscles in the small intestine that propels food through the digestive tract.</td>
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<td>Placenta</td>
<td>An organ that connects the developing fetus to the uterine wall to allow nutrient uptake, waste elimination, and gas exchange via the mother's blood supply.</td>
</tr>
<tr>
<td>Route of transmission</td>
<td>The path that a microbe takes to travel from an infected host to an uninfected one.</td>
</tr>
<tr>
<td>Strains</td>
<td>Genetic variants of the same organism or species</td>
</tr>
<tr>
<td>Transmission</td>
<td>The passing of a communicable disease from an infected host to an uninfected host.</td>
</tr>
<tr>
<td>Urethra</td>
<td>The tube that leads from the bladder and discharges urine to the outside of the body.</td>
</tr>
<tr>
<td>Vector</td>
<td>Intermediate carrier of a disease.</td>
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