Unit 1: Why should we care about infectious diseases?

Lesson 1:
Pandemic Flu, did we overreact?
This lesson is intended as an ‘engage’ as well as to address the larger question: Why should we care about infectious disease? You will capture student interest by stimulating a discussion focused on what makes a disease infectious. H1N1 is used to illustrate the potential impact infectious diseases can have. Students are asked to question how we reacted to the 2009 H1N1 epidemic. Did we overreact? The students revisit the question again after watching a video about the Spanish flu pandemic of 1918.

Lesson 2:
How infectious disease has molded history— including ours
This lesson is intended to emphasize that infectious diseases also shape history and our day-to-day lives. You will guide the students to use the Poodwaddle clock to assess current rates of infection and mortality of some of the globally significant diseases they researched. Then, you will explore how they have impacted history. The lesson concludes by asking the students to discuss the lifestyle habits used to avoid infectious disease.

Lesson 3:
What is an infectious agent? (1) What bacteria need to make us sick.
This lesson has two purposes. First it is intended to demonstrate how infectious disease influences our day to day habits as we try minimize our exposure to pathogens. Students will also consider the medical advances, particularly antibiotics, that have been developed to treat infections.
Lesson 4: 
What is an infectious agent?
(2) What viruses do to make us sick
This lesson has two purposes: It introduces viruses by demonstrating how important differences between the relative sizes of bacteria and viruses contribute to their modes of action.

The lesson then extends the previous focus on bacterial structures by showing how viral structures also play important roles in infectivity and disease. However, because students are less likely to have basic familiarity with viruses, the structure is organized as a lecture, rather than as an interactive activity.

Lesson 5: 
So why aren’t we always sick? Our body’s defenses
This lesson is intended to demonstrate that although we are covered in bacteria and exposed to viruses all the time, we rarely get sick. You will engage students in discussions that will develop the idea of sterility and the notion that the interior of the body is sterile while the exterior is non-sterile. This will involve the new concept that exterior is defined as the area in contact with the environment, not merely on the outside.

Based on these ideas, you will introduce the concept that our body has natural defenses designed to protect against infection, and that these defenses are either found on the non-sterile exterior or in the sterile interior.

Lesson 6: 
Quiz: This assesses students understanding of bacterial and viral structure. It also asks students to explain the importance of studying infectious diseases.
**OVERVIEW**

**Rationale:** This lesson is intended as an ‘engage’ as well as to address the larger question: Why should we care about infectious disease? You will capture student interest by stimulating a discussion focused on what makes a disease infectious. H1N1 is used to illustrate the potential impact infectious diseases can have. Students are asked to question how we reacted to the 2009 H1N1 epidemic. Did we overreact? The students revisit the question again after watching a video about the Spanish flu pandemic of 1918.

**Discussion:** When we refer to ‘sickness’ we are usually describing symptoms, whereas when we refer to ‘disease’ we imply a cause. After defining ‘disease’, you will lead a socratic discussion in which you will use student-generated examples of diseases to introduce the concepts of contagion and infectious agents such as bacteria, viruses and parasites. Finally you will produce a consensus definition of infectious disease.

**1918 Flu Video:** You will segue into a discussion about the 2009 H1N1 outbreak by posing the question: ‘Did we overreact to the threat?’ The students will watch a video about the 1918 flu pandemic, which illustrates the magnitude of this pandemic. After watching the video the students will reflect on their previous answers and will consider the question: What information would we have needed to predict whether the 2009 H1N1 outbreak would evolve into a pandemic?

**Wrap Up:** The students should consider if their view of the reaction to H1N1 changed after learning about the 1918 flu pandemic.

**Homework:** The students will research specific examples of infectious diseases and their impacts. This prepares for Lesson 2, in which specific infectious diseases will be discussed in more detail.

---

**The Lesson Plan**

**Pandemic Flu: Did we overreact?**

Before beginning the lesson, the teacher presents an outline of the goals of the Infectious Disease module.

1. **Discussion (10 min):**
   What does it mean if you are ‘sick’ vs. if you have a ‘disease’? What is an infectious disease? Can you give examples of infectious diseases? What are they caused by? What happens if you have an infectious disease? Did we overreact to H1N1?

2. **Activity (20-25 min):**
   Clip from: ‘The 1918 pandemic flu’.

3. **Wrap Up (5 min):**
   Have you changed your mind about whether we overreacted? Why or why not? Could we have made a better prediction of the impact of H1N1? How?

4. **Homework:**
   Write a paragraph about three globally significant infectious diseases, one that is bacterial, one that is viral and one that is parasitic. Identify your sources.
Discussion

Important points for the discussion:

Ask the students:

**What do we mean when we say we’re sick?**
- Sickness is formally defined as the ‘impairment of normal physiological function affecting part or all of an organism’ whereas disease is formally defined as ‘the impairment of health’.
- But the terms are often used to imply other differences. For example, sickness is commonly though of as being less severe than a disease.

**What are examples of a ‘sickness’ compared with a ‘disease’?**
- It should become clear that another important difference is that sickness usually describes *symptoms* like a headache, a stomachache or a cold, while a disease usually describes something with a *cause* like heart disease, diabetes or flu.

Have the students come up with a list of sicknesses vs. diseases that reflects this difference.

Have the students continue their list of diseases focusing on diseases that are infectious.

In a small group come up with a list of diseases
- What makes an infectious disease ... infectious?
- What happens if you get an infectious disease?

Use the following list to guide students to the notion that infectious diseases are caused by infectious agents that are usually bacteria, viruses or parasites.


## Discussion

Below is a list of pathogens and diseases that will be used as examples throughout the course.

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Viruses</th>
<th>Parasites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strep. Pneumonia</td>
<td>H1N1</td>
<td>Lyme Disease</td>
</tr>
<tr>
<td>MRSA</td>
<td>HIV</td>
<td>Malaria</td>
</tr>
<tr>
<td>Cholera</td>
<td>Smallpox</td>
<td></td>
</tr>
<tr>
<td>T.B</td>
<td>Herpes</td>
<td></td>
</tr>
<tr>
<td>Typhoid</td>
<td>Rhinovirus</td>
<td></td>
</tr>
<tr>
<td>E. Coli</td>
<td>(respiratory)</td>
<td></td>
</tr>
<tr>
<td>Anthrax</td>
<td>Papillomavirus</td>
<td></td>
</tr>
<tr>
<td>Chlamydia</td>
<td>Rabies</td>
<td></td>
</tr>
<tr>
<td>Measles</td>
<td>Ebola</td>
<td></td>
</tr>
<tr>
<td>Chickenpox</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For example, infectious diseases are contagious via:

- Sexual contact
- Needles
- Breastfeeding
- Airborne
- Ingestion (eating and drinking)

### Definition of an infectious disease:

An **infectious disease** is a clinically evident illness resulting from the presence of pathogenic microbial agents. These include pathogenic viruses, bacteria, fungi, protozoa, and multicellular parasites. Infectious diseases are also called **communicable diseases** or **transmissible diseases** because they have the potential to be transmitted from one organism to another. In contrast with the toxins that can also cause disease, infectious agents can also replicate.

Transmission of an infectious disease may occur through one or more routes that may or may not require actual physical contact with infected individuals. Examples of such routes are liquids, food, body fluids, contaminated objects, airborne inhalation, or through intermediate carriers of diseases called vectors.

The term **infectivity** describes the ability of an organism to enter, survive, and multiply in the host.

The term **infectiousness** of a disease describes the ease with which the disease is transmitted to other hosts.

A handout covering the definition of infectious disease can be found in the materials folder of this lesson.

---

Have the students name ways in which they know infections can be transmitted.

- This question focuses on the concept that infections are both given and received.
- Separate the diseases into two groups—those transmitted via contact and those not transmitted via contact. Then re-emphasize that not all methods of transmission require the infector and target of infection to be in actual contact.
Discussion

The current variant of the H1N1 influenza virus was identified in April 2009, and is commonly called “Swine flu”. This is misleading. Some influenza viruses can be transmitted from swine to humans, but in this case swine were not the culprit – transmission was between humans. As of July 2010 there had been 94,512 confirmed cases in 122 countries deaths.

Although it is not extremely deadly at this time, H1N1 has instilled fear and panic in millions of people worldwide.

The rest of this lesson aims to illustrate the rationale behind this fear.

Important points:

Ask the students:

What are three things you remember about H1N1? Why did it cause so much fear?

■ Encourage students to recall that H1N1 was a different strain of virus than the common seasonal strain, so its potential impact was uncertain. This uncertainty resulted a large-scale campaign to ensure that everyone was vaccinated.

- Definition of the term pandemic: An outbreak of a disease that is spreading across continents. This differs from an epidemic, which impacts people in a focused region.

Estimate how many people died from H1N1 last year.

■ (18,000)

And how many people died from seasonal flu?

■ (250,000).

What percentage is this?

■ (4%)

Given this information, did we overreact?

■ If so, ask why. Many students will use the low number of deaths caused by H1N1 as evidence to dismiss our behavior. However, the video may persuade students otherwise.
Before showing students the video, explain that H1N1 is not a new strain of influenza. In fact, the 1918 outbreak of H1N1 resulted in a pandemic that changes people's vision of the common flu.

The video clip lasts about 15-20 minutes and focuses on how the population reacted to the epidemic.

The goal of showing this clip in conjunction with the discussion is to emphasize that it is often impossible to predict the magnitude of an epidemic, and whether it will become a pandemic.

**Video:**
The 1918 Spanish Flu

Wrap Up

Ask the students:

Did watching the video prompt anyone to change their minds about whether last year’s response to H1N1 was an overreaction? If so, why?

What information would we need to predict that H1N1 would evolve into a pandemic?

- Although the more information we have about the infectiousness and severity of H1N1 would allow us to predict the immediate consequences of an epidemic with more certainty, it is important to realize that viruses in general and influenza in particular can adapt very quickly by mutation. This makes it almost impossible to predict a virus's future infectiousness and severity.
Wrap Up

A major goal of this module is to give the students the tools to gather and interpret information about infectious diseases, so they will be able to make informed decisions.

These questions initiate that process by introducing the students to the type of questions they will need to ask in order to gather relevant information.

The questions set the tone of the module by emphasizing that the lessons are based on active inquiry, in which relevant questions will be identified and their answers sought from reliable sources.

Below is a list of infectious diseases that greatly impact society as provided by the World Health Organization (WHO):

- African trypanosomiasis (sleeping sickness)
- Influenza (Seasonal)
- Anthrax
- Lassa fever
- Buruli ulcer disease
- Legionellosis
- Cholera
- Leprosy
- Crimean-Congo haemorrhagic fever
- Malaria
- Dengue and dengue haemorrhagic fever
- Marburg haemorrhagic fever
- Ebola haemorrhagic fever
- Measles
- Enteroviruses - non polio
- Meningococcal meningitis
- Haemophilus influenzae type B (HiB)
- Nipah virus
- Hendra virus
- Plague
- Hepatitis A
- Poliomyelitis
- Hepatitis B
- Rift Valley fever
- Hepatitis C
- Smallpox
- Hepatitis E
- Tuberculosis

The goal of the homework is for students to begin to appreciate the extent to which infectious disease impact on society.

Homework

- Write a paragraph about three globally important infectious diseases:
  - One bacterial
  - One viral
  - One parasitic

- Identify your sources**
OVERVIEW

Rationale: This lesson is intended to emphasize that infectious diseases also shape history and our day-to-day lives. You will guide the students to use the Poodwaddle clock to assess current rates of infection and mortality of some of the globally significant diseases they researched. Then, you will explore how they have impacted history. The lesson concludes by asking the students to discuss the lifestyle habits used to avoid infectious disease.

Activity: Generate a list of globally significant infectious diseases: Students will appreciate the extent to which infectious disease remains a worldwide public health problem. Through the poodwaddle clock, students will gain insight into the extent that infectious disease impacts global health today by researching real-time estimates of infection and mortality provided by the Poodwaddle clock.

Lecture and Discussion: Infectious disease in history: Students will discuss how time provides perspective on infectious disease epidemics allowing us to realize their major impact far beyond the mere ability to make a population sick. Infectious disease today: The discussion closes with information about HIV in Africa. Students are encouraged to predict the long-term economic and social impact HIV will have on African society.

Homework: The students will list 4-5 behaviors we have developed to avoid infectious disease transmission. This homework is intended to illustrate how infectious diseases impact our way of life, and will be used to start the next lesson.

Lesson Plan

How infectious disease has molded history – including ours

1. Do Now (5 min):
The teacher uses the homework to generate a list of globally significant diseases and the infectious agents involved.

2. Activity (15-25 min):
Internet activity: Use the Poodwaddle clock to explore current rates of infection and mortality.

3. Lecture/Discussion (10-15 min):
PowerPoint lecture: How the perspective of history shows the full impact of infectious disease. How we can extrapolate how a current infectious epidemic (HIV) impacts African society.

4. Homework:
List 4-5 behaviors developed to avoid infectious disease transmission and describe how the behavior prevents disease?
I. DO

Use your homework to discuss the following with a partner:

What diseases did you choose?
Are they caused by a virus, a bacteria or a parasite?
What source did you use to determine that they are globally significant?

Sources of reliable information include:
- The World Health Organization
- The Centers for Disease Control
- The National Institutes of Health
- The Welcome Foundation
- Wikipedia

Important points for discussion:
- Use the board to generate a list of the diseases that the students chose, indicating whether they are caused by bacteria, viruses, or parasites. Make sure that the list includes AIDS, Tuberculosis and Malaria, which will be the focus of the Poodwaddle activity.

Ask the students:

How did you find evidence that the diseases you chose are globally significant?

Extension: Critique the sources, emphasizing that not every Internet source is reliable. This will be important when they begin to research for their final product.

NOW

Activity

Do Now

Use your homework to discuss the following with a partner:

- What diseases did you choose? Are they caused by a virus, a bacteria or a parasite?
- What source did you use to determine that they are globally significant?

Activity:

- The world population is about 6.5 billion people (that is 6,500 million people).
- How many individuals do you think die from ______ each year?

1. Tuberculosis
2. AIDS
3. Malaria

You should first briefly explain the diseases.

Tuberculosis or TB – is caused by a bacterium. The bacteria are transmitted in micro-droplets of saliva during coughing. The disease leads to shortness of breath, coughing, fever and sweats but can usually be cured with antibiotics.

AIDS is caused by the HIV (human immunodeficiency) virus, which attacks the T cells of the immune system leading to impaired immunity.

Malaria is caused by a parasite which is carried by mosquitoes. The parasite, plasmodium, infects Red Blood Cells (RBC) causing fever, shivering, joint pain, vomiting, and anemia (as a result of the damage to RBCs).
Activity

The goal of using the Poodwaddle clock is to give students a real-time appreciation for the impacts of infectious disease. However the clock is not completely comprehensive.

Poodwaddle Activity:
http://www.poodwaddle.com/worldclock.swf

After watching the video, have the students verify their previous estimates with the actual number of infections obtained from data via the Poodwaddle clock.

Use these numbers to calculate:

1. Error: the difference between their original estimate and the real value from the clock data (estimate – actual).

2. Percent error: The percentage that the error represents (Error/actual) x 100).

After finishing their calculations, or for homework, have the students write a 1-3 paragraph reflection.

Ask the students:

Did you overestimate? Underestimate? Why?

The Poodwaddle World Clock of global health statistics tabulates cause of death, illness, and injury incidence in real time. This allows you to observe the numbers of deaths from both non-infectious diseases (such as cardiovascular disease, asthma, diabetes and cancers) as well as incidence of infectious diseases.

The statistics are estimates calculated from annual figures provided by various sources including the World Health Organization. It is possible to view the clock by year, month, day, week or ‘now’.

Before opening the Poodwaddle clock have the students use the worksheet to make estimates about the number of people that are infected with and die from T.B, H.I.V., and malaria.
Lecture & Socratic Discussion

The following slides illustrate how the perspective of time allows us to realize the full impact of infectious disease epidemics on the course of history.

The Antonine Plague

Infectious disease epidemics and pandemics didn’t just affect those who got sick; they changed the course of history. Infectious disease have always posed a problem to human society, and though we may have overcome some we have inherited others.

Important points:

■ The Antonine Plague in 165-180 A.C. was either smallpox or measles. Pictured below is a plague pit containing the remains of people who died in the Antonine Plague.

■ The epidemic led to a dramatic decrease in the population of Rome, thereby weakening the army and slowing the expansion of the empire. We might all be speaking Latin today if Rome had not been weakened by this epidemic.

■ It was brought back to the Roman Empire by troops returning from campaigns in the Near East.

■ It claimed the lives of two Roman emperors — Lucius Verus, and Marcus Aurelius Antoninus.

■ It caused up to 2,000 deaths a day at Rome, one quarter of those infected.

■ Total deaths have been estimated at five million, as much as one-third of the population in some areas, and it decimated the Roman army.

■ It had drastic effects throughout the Roman Empire, particularly on literature and art.

■ The ancient world never recovered from the plague and historians believe that it contributed to the collapse of the Roman Empire. The Romans’ defense of the eastern and northern territories was hampered when large numbers of troops succumbed to the disease.
Lecture & Socratic Discussion

The following slides illustrate how the perspective of time allows us to realize the full impact of infectious disease epidemics on the course of history.

The Bubonic Plague or The Black Death

Important points

Ask the students whether the world population is increasing.
- They should say yes.

Ask the students to imagine the population shrinking by 30-60%.

- Approximately half the population of Europe died from the Black Death in the 1300s.
- This outbreak of the bubonic plague was one of the deadliest pandemics the world has ever experienced.
- It started in Central Asia and reached Crimea in 1346.
- It is estimated to have killed 30% to 60% of Europe's population by 1400.
- The plague is thought to have returned every generation until the 1700s. During this period, more than 100 plague epidemics swept across Europe.

Ask the students to imagine the effects on society when half the population is lost.

For example, fewer people are available to produce goods and food, to reproduce and to defend the country.
Lecture & Socratic Discussion

The following slides illustrate how the perspective of time allows us to realize the full impact of infectious disease epidemics on the course of history.

The Black Death

Important points

Even before infectious agents could be identified people appreciated that diseases could be transmitted. However, because they didn’t understand the nature of the infectious agent, they were unable to combat it effectively.

- People eventually came to understand that rats carried the Black Death, but they couldn’t do anything about treating the disease, because they didn’t understand that rats aren’t the infectious agent. The disease is actually transmitted by fleas on the rats that carried a bacterium called Yersinia pestis.

Plague Mask Facts:

- The bird’s beak-shaped face-mask was worn by Plague Doctors during the Black Death.
- It acted like a primitive gas mask: the beak usually contained strongly aromatic herbs and spices to combat the terrible stench of unburied corpses and fluids from ill plague patients.
- At the time, people believed that birds spread the plague. Historians think that the mask was used to draw the disease away from the sufferer. Consistent with this, the red glass eye pieces which are thought to protect the plague doctor from evil influences that cause the plague

Ask the students:

What do you think this outfit is for?

- The students may think it looks like a costume for a cult or Halloween.
Lecture & Socratic Discussion

The following slides illustrate how the perspective of time allows us to realize the full impact of infectious disease epidemics on the course of history.

Christopher Columbus brings the plague to America

Important points

This slide illustrates the concept that infectious diseases can be both given and received, and that a population resistant to one may be susceptible to another.

- Before the Europeans arrived, the Americas had been largely isolated from the infectious disease epidemics that spread throughout Europe.

Students may have learned previously that the native Americans were susceptible to the diseases because they were foreign. If they ask this question, agree and ask them to keep this idea in mind because it will be discussed later.

- The diseases from Europe spread rapidly among native peoples and led to a drastic drop in population and the collapse of indigenous American cultures.

It is also important to note that diseases were passed in both directions.

- Syphilis was carried back from the Americas and swept through the European population, decimating large numbers of people.

The bidirectional travel of these diseases reinforces the concept that populations will be particularly susceptible to a ‘foreign’ infectious disease. The concept will be covered in detail in Unit 5 where immunological memory will be discussed.

- The first large-scale contacts between Europeans and native people of the American continents brought overwhelming pandemics of measles and smallpox, as well as other Eurasian diseases.

http://www.bukisa.com/articles/136729_the-15-worst-killer-epidemics-in-history#ixzz0sRyCyShe
Lecture & Socratic Discussion

The following slides illustrate how the perspective of time allows us to realize the full impact of infectious disease epidemics on the course of history.

Plagues as Bioterrorism

Important points

This slide illustrate the concept that people have used infectious disease as bioterrorist agents throughout history.

- The British are thought to have had the first idea to use smallpox as a bioterrorism agent by giving smallpox infected blankets to the indigenous population.
- For example, Lord Jeffrey Amherst, commander of British forces in North America during the French and Indian War (1756–’63) discussed sending infected blankets to hostile tribes.
- According to historian Francis Parkman, Amherst first raised the possibility of giving the Indians infected blankets in a letter to Colonel Henry Bouquet, who would lead reinforcements to Fort Pitt.
- We don’t know if Bouquet actually put the plan into effect. We do know that a supply of smallpox-infected blankets was available, since the disease had broken out at Fort Pitt some weeks previously. We also know that the following spring smallpox was reported to be raging among the Indians in the vicinity.
- The smallpox epidemic between 1775 and 1782 raged across much of North America and killing more than 130,000 people. Overall, smallpox led to the death of military and social leaders, contributing to the downfall of both empires and the subjugation of the American peoples to Europeans.
Lecture & Socratic Discussion

The following slides illustrate how the perspective of time allows us to realize the full impact of infectious disease epidemics on the course of history.

Modern day plagues – HIV

Important points

This slide shows the distribution of a current global pandemic - HIV. The extent of modern travel allows infected individuals to transmit disease over great distances with great rapidity. Hence focal epidemics are converted to global pandemics much more rapidly than in the past.

- The largest recent pandemic is due to HIV.
- Over 30,000,000 people worldwide are living with HIV.
- The number of AIDS cases in the United States and Europe rose steadily through the mid-1990s and then plateaued as a result of increasingly effective efforts to prevent disease.
- In contrast, the disease has continued to spread in the developing world.
- Africa is inhabited by just over 12% of the world’s population and is estimated to have more than 60% of the AIDS-infected cases worldwide, most of which are in sub-Saharan Africa.

The scientific reasons for the spread will be covered later in the Unit – focus on the social consequences here.

Ask the students:

*How could the HIV pandemic change the course of African history?*

- For example, sickness leads to less productivity and increased poverty, which creates a cycle that is difficult to break.
Homework

The homework will give students a chance to reflect on the role of hygiene in combating infectious disease and the common hygiene practices that have been developed to try to reduce its impact.

- Encourage students to think of daily habits like hand washing and drinking clean water.
- They may also list medical advances like vaccination and antibiotics, although these are not the primary focus here.

Homework

- List 4-5 behaviors we have developed to avoid infectious disease transmission, and explain what they are for.
OVERVIEW

Rationale: This lesson has two purposes. The first is to demonstrate how infectious disease influences our day to day habits as we try minimize our exposure to pathogens. Students will also consider the medical advances, particularly antibiotics, that have been developed to treat infections. The second purpose of the lesson is to demonstrate how one class of infectious agent – bacteria – uses its own structures in an attempt to optimize its chances to infect their hosts. You will guide students through a jigsaw activity that will introduce the important concept that the role of a structure in disease can often be inferred from its function. This concept is covered in the following lectures too, as we examine other infectious agents.

Do Now: Students will use their lists of day to day hygiene practices as a starting point for a discussion focused on understanding that exposure to bacteria is synonymous with entry into the body.

Jigsaw: Students will divide into groups that will each examine how one of the key bacterial structures plays a specific role in infectivity.

Teach Back: Each group will present their findings to the class as a whole. You will ensure that the class as a whole has a comprehensive working knowledge of how bacterial structure relates to its role in disease.

Wrap Up: Recap the important structures on the board to ensure that all students understand all the structures.

Homework: Students will reinforce their understanding of the structures that were covered in the jigsaw to ensure that each student understands each structure.

The Lesson Plan

What is an infectious agent?
1. What bacteria need to make us sick.

1. Do Now (10 min):
Discuss the homework about how the daily rituals to prevent infectious exposure may have originated and what they do. If medical advances come up, focus for this lesson on antibiotics.

2. Activity (25-30 min):
Lead a five-minute discussion in preparation for the bacterial structure worksheet. Jigsaw activity and teach-back: how bacterial structures influence their ability to infect their hosts.

3. Wrap Up (5 min):
Recap the important structures on the board to ensure that all students understand all the structures.

4. Homework:
Complete the worksheet for Unit 1.3 bacterial structure worksheet. Read the jigsaw readings in preparation for a quiz during lesson 6.
Important points for discussion:

The main focus of this discussion is on the daily habits that aim to reduce pathogen spread by minimizing exposure to a pathogen. The actual examples you cover are not important, as long as students realize that avoiding infectious diseases is a part of their day-to-day life.

Examples of Student Answers:

- Washing hands after using the bathroom to avoid fecal/oral transmission.
- Bathing to avoid dirty cuts.
- Using clean water to avoid ingesting microbes.
- Cooking food to kill microbes and avoid ingesting live microbes.
- Cleaning silverware to avoid ingesting microbes.
- Using toilets to avoid spreading microbes.
- Changing clothes (like socks) to avoid transmitting infections like fungi.
- Protected sex.
- Avoiding mixing bodily fluids.

Make a note that these hygiene practices are aimed at preventing microbes gaining access to our body.

If a student brings up a medical advance, try to focus in this lesson on advances that have helped control bacterial infections. Antibiotics have reduced the prevalence of diseases like bubonic plague and TB that we discussed previously.

Activity:

- How is a bacterium’s structure unique?
- How does a bacterium’s structure contribute to its ability to cause disease?

The objective here is to have the students understand that bacteria use specific structures to help them infect their hosts.

Understanding how these structures operate will enable them to explore both how infections like MRSA, chlamydia and hamburger disease are transmitted, how they can be treated, and how we get better.
2. Activity

Activity:

- How is a bacterium’s structure unique?
- How does a bacterium’s structure contribute to its ability to cause disease?

What does a bacterium look like?

Activity Instructions:

1. Have the students form six small groups.
2. Have each group of students read a section from the Unit 1.3 Jigsaw in the materials folder of this lesson.
3. Have each group of students prepare a 2-5 minute mini-presentation.
4. The students can use the subsequent slides for their mini-presentations.
5. The students in the audience should complete the Unit 1.3 Wrap-up bacterial structure worksheet while watching the mini-presentations.

Make sure students understand that they need to emphasize the functional roles of each structure in causing disease rather than just explaining what each structure is.

- You should offer support to the students as they work through the reading and determine what they will tell the class.
- You may have all the students participate in the actual presentation, or ask just a few representative students to speak.
### Activity

The following slides are images that the student groups may use to illustrate their teachback.

#### Group 1: Capsule

Make sure that the students in this group discuss:

- Where the capsule is located relative to the cell wall and the plasma membrane.
- What the capsule consists of.
- What the bacteria uses the capsule for.
- Why what the capsule consists of is important in disease.
- Some examples of bacteria that are encapsulated and what kind of diseases they can cause.
- One role of the plasma membrane in disease with an example.

The information can be found in the Unit 1.3 Jigsaw reading.

#### Group 2: Gram Positive

Make sure that the students in this group discuss:

- How murein works.
- Why murein is useful.
- The role of LPA in the gram positive cell wall.
- How the Gram positive cell wall can cause symptoms of bacterial infection, like fever.
- Examples of Gram positive bacteria and the diseases they cause.

The information can be found in the Unit 1.3 Jigsaw reading.

Ask the students:

**Why do bacteria need this extra-protective membrane?**

- This introduces the idea that bacteria, unlike animals and plants, exist as unicellular organisms and that each bacterium is responsible for its own existence. Therefore there is considerable evolutionary pressure to adapt rapidly to the environment.
3. Activity

Group 3: Gram Negative

Make sure that the students in this group discuss:

■ How murein in the cell wall is organized that is different from gram-positive bacteria.
■ What the outer layer of the Gram-negative cell wall contains and why this is important in disease.
■ How the LPS of the Gram-negative cell wall plays a role in disease.
■ Some examples of Gram negative bacteria and the diseases they cause.

The information can be found in the Unit 1.3 Jigsaw reading.

Emphasize that the immune system can recognize cell wall components of both Gram positive and Gram negative bacteria. The bacteria can evade recognition by adapting these structures to make them invisible. We will discuss how later on.

Group 4: Flagellum

Make sure that the students in this group discuss:

■ Why bacteria need to move.
■ How flagella create movement.
■ How flagella can play a role in infection.
■ Some examples of flagellated bacteria and the diseases they cause.

The information can be found in the Unit 1.3 Jigsaw reading.

Make sure the students understand why bacteria may need flagella.

The concept that the ability to actively migrate toward food sources and away from cellular predators of the immune system confers advantages to the bacteria is important.
3. Activity

Group 5: Pili

Make sure that the students in this group discuss:

- Why bacteria need to stick to surfaces.
- How pili are used to adhere.
- How pili can be used to transfer genetic information between bacteria.
- Some examples of bacteria that use pili and the diseases they cause.

The information can be found in the Unit 1.3 Jigsaw reading.

Make sure that students understand why bacteria would want to adhere to each other or to a host.

This should lead the students to the idea that bacteria that shelter together in the host environment may be less exposed to environmental stresses.

Enrichment activity: Introduce the idea of biofilms as a novel means by which bacteria form a resistant colony (see Teacher manual Chapter 2 p.46).

Group 6: Spore

Make sure that the students in this group discuss:

- How bacteria use spores to stay alive in hostile environments.
- What kind of environmental stresses spores protect against.
- Examples of bacteria that sporulate and the diseases they cause.
- The impact of spores on the persistence of infectious disease.

The information can be found in the Unit 1.3 Jigsaw reading.

Make sure the students understand the consequences of sporulation on the persistence of infectious agents.

Anthrax is an excellent example. The inert spores are stable for long periods of time, but when the environment is right, the spores germinate like a seed.
3. Activity

Group 7: Nucleoid and Plasmid

Make sure that the students in this group discuss:

- That the bacterial nucleoid contains its own genes.
- That the bacterial plasmid contains genes that the bacteria have acquired from other bacteria.
- How plasmids impact the ability of bacteria to cause disease.
- Examples of bacteria that have acquired plasmids and the diseases they cause.

The information can be found in the Unit 1.3 Jigsaw reading.

Make sure the students understand the difference between the bacteria’s own genes and the genes they can acquire through a plasmid, as well as the ease by which plasmids are used to transfer genetic information.

4. Wrap Up

Wrap up: Structure is function

Make sure that all the students are familiar with all the important structures and their functions in disease.

Reinforce the idea that the functional roles of each structure contribute to disease and bacterial survival.

Have the students complete the worksheet in the Unit 1.3 Materials folder.
Lesson 1.3

Wrap Up

4.

USE THIS TABLE:

<table>
<thead>
<tr>
<th>Structures:</th>
<th>Functions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capsule</td>
<td>Camouflages the bacterium from the host’s defenses.</td>
</tr>
<tr>
<td>Cell walls with one membrane: Gram Positive</td>
<td>Provides a durable coating that separates the bacteria from its environment. Contains important lipids that activate the immune system.</td>
</tr>
<tr>
<td>Cell walls with two membranes: Gram Negative</td>
<td>Provides a durable coating that separates the bacteria from its environment using two membranes. Contains different lipids that also activate the immune system.</td>
</tr>
<tr>
<td>Flagellum</td>
<td>Allows bacteria to move quickly toward a food source or away from an immune cell predator.</td>
</tr>
<tr>
<td>Pili</td>
<td>Allows the bacteria to adhere to other bacteria and to the host, and avoid being swept away. Also used to exchange genetic information between bacteria.</td>
</tr>
<tr>
<td>Spore</td>
<td>Acts like a bomb bunker to protect the bacteria in an inert state in times of environmental stress.</td>
</tr>
<tr>
<td>DNA</td>
<td>Contains intrinsic or acquired DNA that encodes information for bacterial proteins.</td>
</tr>
</tbody>
</table>

5.

Homework

The objective of the homework is to reinforce the students’ understanding of the structures that were covered in the jigsaw.

Have the students complete the worksheets. Also, remind them that this information will be included in an upcoming quiz.

Homework

- Complete the worksheet on bacteria from Unit 1.3
- Take good notes of all the bacterial structures important in disease for a quiz at the end of this unit.

This homework can be found in the Unit 1.3 materials folder (Unit 1.3 bacteria worksheet).
OVERVIEW

Rationale: This lesson introduces viruses by demonstrating how important differences between the relative sizes of bacteria and viruses contribute to their modes of action. The lesson then extends the previous focus on bacterial structures by showing how viral structures also play important roles in infectivity and disease. However, because students are less likely to have basic familiarity with viruses, the lesson is organized as a lecture, rather than as an interactive activity.

Do Now: Students are not likely to be familiar with the units that measure microbe sizes, but they are important because the identification of an infectious agent partly depends on its size, as we will see later. Therefore you will use analogies to illustrate the sizes difference between bacteria and to familiarize students with the units of measurement used to measure microorganisms.

Lecture and Virus Structure Worksheet: Students are encouraged to extrapolate from their knowledge of bacterial structures to hypothesize how viral structures function. Video clips are used to provide real-time illustrations. Investigating the relationship between viral structure and function provides students with the tools with which to hypothesize how viral structures function in disease.

Wrap Up: Recap the important structures to ensure that all students understand all the structures.

Homework: Through the Venn diagram worksheet, students will consolidate their understanding of how bacterial and viral structures contribute to disease by compiling a “compare and contrast” worksheet.

Lesson Plan

What is an infectious agent?

II. What viruses do to make us sick.

1. Do Now (5 min):
Discuss analogies for bacterial vs. viral size, being critical of students’ accuracy.

2. Lecture and Worksheet (35 min):
In the lecture (20 minutes), explain that viruses, like bacterial infections, use specific structures to help them infect their host cells. The virus structure worksheet (15 minutes) then allows the students to consolidate the information you have given them in the lecture.

3. Wrap Up (5 min):
Reinforce the importance of knowing how viral structures contribute to function and recap the functions of the structures critical to disease.

4. Homework:
Complete the Venn diagram worksheet and use it to study for the quiz on day 6. Also complete the virus structure worksheet if it is not finished during class time.
1. DO NOW

Important points:

Before beginning the discussion/activity ask the students whether they understand the difference between a eukaryote and a prokaryote (as discussed in the background).

- Let the students know that you will be using the word prokaryote and bacteria interchangeably from now on.

- Roughly, a bacteria is a thousand times smaller than a red blood cell, and a virus is a thousand times smaller than a bacteria. Hence a virus is a million times smaller than a red blood cell.

The link on the slide allows you to zoom in on cells and viruses. You must be connected to the internet to use the link.

2. Lecture

Slide One: The size of microbes

How big are microbes?

<table>
<thead>
<tr>
<th>Prokaryotes</th>
<th>Viruses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 micron</td>
<td>1 nanometer</td>
</tr>
</tbody>
</table>

There are a 1000 microns in a millimeter and 1000 nanometers in 1 micron.

http://www.schoolsci.com/howbig.htm

Important points:

The goal here is to familiarize students with the actual units of measurement of bacteria and viruses, since they are unlikely to have encountered such small sizes before.

- Emphasize the importance of the micron as the central unit in these measurements and make sure that students can convert readily between microns and millimeters and between microns and nanometers.

- Most bacteria are of the order of 1 micron in diameter. This means that you would need 10,000,000 bacteria in each ml of water to turn it cloudy. What are the implications of this? - that water might be contaminated with pathogenic bacteria and still appear clear. Explain how this hampered efforts to understand the role of contaminated drinking water in the spread of cholera.

- Viruses are the smallest microbes. They can vary in volume by several hundred fold. Only the largest ones such as smallpox virus are visible with the light microscope, and then only barely. These largest viruses fall within the lower size range of prokaryotes.
Ask the students whether they can think of an analogy linking the size of a bacteria and virus with a red blood cell.

- A legitimate analogy would be that if a virus was the size of your nose, then a red blood cell would be the size of the Empire State Building.
- In this analogy one of your fingers would span the entire continental United States, and an average person would be size of six or seven planet Earths.

**Slide Two: The structure of viruses**

The rest of this lesson focuses on viral structures.

**Important points:**

- The functions of the structures should be discussed in the context of viral attachment, entry, and exit.
- Replication and host damage will be the focus of Unit 4.4.

**Slide Three: The structure of viruses, cont.**

To simplify the discussion of viral structure, it has been broken into three main parts:

1. Viral genome
2. Protein coat (capsid)
3. The envelope

**Important Points**

- It is important to emphasize that all viruses have a genome and a capsid, however only some have an envelope.
- Those with an envelope are called enveloped viruses while those without an envelope are called naked viruses. The figure can be used to explain these points.
Lecture

Slide Four: The genome

Important points:

- Viral genomes code for viral proteins. They are much smaller than either bacterial or eukaryotic genomes because the virus uses many of the host cell proteins to replicate. Viral proteins have unique structures that the immune system can recognize as foreign.

- Viral genomes can be either DNA or RNA.

Review with the students the central dogma of gene transcription.

Make sure these questions are answered:

Where will a virus whose genome is made of DNA have to go to replicate the DNA?

- To the nucleus.

Will it be able to use host machinery to replicate in the nucleus?

- Yes, because the host replicates DNA in the nucleus.

Then where will the DNA go to make protein?

- Into the cytoplasm.

Will it be able to use host machinery to make protein in the cytoplasm?

- Yes, because the host makes protein in the cytoplasm.

If the genome of a virus is made of RNA, where will that virus replicate its RNA?

- Not in the cytoplasm, because RNA isn’t made from RNA in cells, it is made from DNA.

So what will the virus have to do?

- It will have to make DNA from its RNA first.

Will it be able to use host machinery (proteins)?

- No, because host cells don’t make DNA from RNA, it will have to bring its own machinery with it.
Lecture

Once it has made the DNA and replicated it, what will it do?
- It will make RNA from the DNA to replicate its genome.

What else will it do?
- It will make protein from the RNA for its capsid and envelope.

It is important to review this process here so the students have a clear idea of how viruses function.

Slide Five: The capsid

Important Points:
- Both enveloped and naked viruses have **capsids** that encapsulate the genome of the virus.
  - The capsid is composed of **virally encoded proteins**, it does not contain **lipids**.
  - The capsid carries some viral proteins, which are not found in the host and are required for **viral replication**.

Ask the students whether they can think of one of the proteins that the capsid may contain if the virus is an RNA virus.
- It would contain the enzyme that makes the viral RNA into DNA inside the host cell nucleus.

Slide Six: The envelope

Important Points:
- **Enveloped** viruses have an envelope while **naked** viruses do not.
- The envelope is made of **viral proteins** plus **host cell membrane**. This means that enveloped viruses have membranes that resemble the host cell.
Ask the students:

Do you think the presence of an envelope affects how well the immune system will recognize the virus?

- Yes, the presence of the host cell membrane camouflages the enveloped virus from the immune system. In contrast, naked viruses lack this camouflage.

Slide Seven: Virus life cycle

The next few slides show how the genome, capsid and envelope of the virus are used in the viral life cycle.

For this introductory part of the curriculum the viral life cycle has been simplified to focus on attachment, entry, and exit. This will leave viral replication for Unit 4.4.

A major focus of this lesson is the notion that, like bacterial structures, each viral structure performs its own unique, and key, function.

Slide Eight: Attachment

Important Points:

- Both naked and enveloped viruses need to attach to their host cells before they can enter the cell.
- To do this they have receptors on their surface that act like ‘keys’ to interact with receptors on the host cell surface that act like ‘locks’.

Example: The slide shows HIV. HIV’s ‘key’ is the receptor protein gp120. Gp120 interacts with a ‘lock’ on the host cell surface called CD4. Cells of the immune system like T cells and macrophages have the CD4 ‘lock’. So, HIV can only infect cells with this kind of lock.
2. Lecture

- Other viruses have different keys that bind to different locks.

  *Example:* For example, H1N1 uses a receptor key called hemagglutinin (the H in H1N1). H1 bind to sialic acid sugars on epithelial cells in the respiratory tract. Different variants of H1N1 have different ‘H’ keys that attach to different kinds of sialic acid sugars. The different sialic acid sugars are on different cells in the respiratory tract. This enables different variants of H1N1 to infect different sites in the respiratory tract. For example the H1N1 that caused the Spanish flu of 1918 was able to infect the epithelial cells in the lower lungs, which is believed to be one of the reasons that this strain of flu was so deadly. That is why people were nervous about the 2009 H1N1. If it had been able to infect the lower lung too, it would have been much more deadly. However, it infected only the upper respiratory tract.

**Slide Nine: How naked viruses enter host cells**

**Important Points:**

- Some naked viruses release enzymes that punch holes in the host cell membrane.
  - The virus then injects its genome and other viral proteins into the host cell cytoplasm.
  - The genome will then enter the host cell nucleus and use its machinery to replicate.
- Some naked viruses are endocytosed by the host cell.
  - *Endocytosis* is a normal cellular process by which small particles are engulfed by host cell membrane and internalized. It differs from *phagocytosis*, which is used to internalize large particles like bacteria.
  - After being endocytosed the virus needs to punch its way out of the endosome so that it gets into the cytoplasm, using enzymes as described above. Then it too can enter the nucleus.

It is important that the students understand the difference between being in the cytoplasm and being inside the cell in the endosome.
Lecture

Slide Ten: How enveloped viruses enter host cells

Important Points:
- Because some of the viral envelope is composed of host cell membranes, some viruses can fuse their envelope with the host cell membrane.
  - This happens because both viral envelope and host cell membrane are mostly lipid. Think of it like two oil droplets in water fusing together.
  - The virus can then spill its capsid and genome into the cytoplasm.
- Other enveloped viruses are endocytosed by the host cell.
  - After being endocytosed the enveloped virus needs to get its genome into the cytoplasm like the naked virus did. It will fuse with the endosome, since the endosome is composed of lipid membrane too.
  - Once it is in the cytoplasm, it too can enter the nucleus.

Slide Eleven: How naked viruses exit host cells

Important Points:
- Naked viruses replicate and make new virus particles in the host cell cytoplasm.
- The cytoplasm fills with virus until it can't sustain it any more. Then the membrane bursts and the virus particles are released.
- This process is called cell lysis.

Ask the students what will happen to the cell after it has lysed.
- The cell will die. Infection with a naked virus always causes cell death.
- The cell debris will attract an immune response.
Lecture

Slide Twelve: How enveloped viruses exit host cells

Important Points:

- Enveloped viruses leave the cell in five distinct stages.
  1. Envelope proteins collect in areas of the host cell membrane.
  2. The capsid proteins are made in the cytoplasm and gather up the genome within them.
  3. They travel to the membrane where they attach to the inside of membrane in the region, where the envelope proteins have accumulated.
  4. The capsid buds off of the host cell gathering the envelope proteins with it as it goes.
  5. The envelope protein seals up to form a new virus particle.

- Whether or not the process of budding off causes the host cell to die depends on how fast the virus is replicating. If it is replicating slowly it may not cause cell death.

Slide Thirteen: Video and worksheet

Important Points:

- The goal of this activity is to reinforce for the students that a virus must infect a host cell in order to replicate and survive.
- This is in contrast with bacteria, that are usually free living – bacteria that infect host cells, such as Chlamydia, do so because the cells provide key nutrients, not because they need their replication machinery.

Have the students watch this short and highly engaging video (about 4 minutes) on how the flu infects cells of the respiratory tract.

The NPR video (5 min) can be found at the links below:

Have the students complete the worksheet in small groups.
This can be found in the materials folder for this lesson. It may be completed as homework if time is limited.
Wrap Up

Important points:

Ask the students:

What problem would an enveloped virus encounter as it buds out of the host cell? How could it solve that problem?

- Stimulate student discussion in the context of receptor keys specifically designed to bind to a lock on the host cell that it is trying to leave from.

How does the virus manage to leave? Why doesn’t it keep re-infecting the same cell?

- The goal is for students to realize that the same ‘lock and key’ receptors that allowed the virus to get into the cell in the first place could prevent the budding virus from leaving the cell.
- You want students to suggest that the budding virus might have to inactivate the host cell receptor before it can leave.
  - This point is explained in the next slide.

Important points:

In the case of Influenza virus like H1N1, one of the surface proteins is an enzyme neuraminidase (the N in H1N1). The enzyme can chew up sialic acid sugars on the host cell membrane that act as ‘locks’. This prevents the receptor ‘lock’ interacting with the hemaglutinin ‘key’ on the virus envelope. This means that the new viruses don’t re-infect the same cell. This is important because infecting a cell weakens it if it does not kill it. So a second round of infection would not be as effective in producing new virus as infecting new host cells.

Walk the students through the diagram, then ask them:

Why does influenza go to the trouble of having neuraminidase?

- To enter cells influenza must bind to a host receptor. The same entry receptors may then prevent budding off, so one way to solve this problem is for the virus to express a factor that cleaves the receptor. In influenza this factor is neuraminidase.
Wrap Up

What do you think would happen if the virus lost the neuraminidase?

- If it weren't able to inactivate the host cell receptor the virus would be unable to detach and look for other hosts to infect.
- If the virus were unable to infect another host and continue replicating, it would eventually die out.

An overall message is the complexity involved in trying to infect a host. At every step along the way the host is trying to prevent infection, while the infectious virus is trying to maximize its chances.

Homework

Have the students complete the Venn Diagram worksheet.

- This homework asks students to list the structural elements specific to bacteria and viruses, and those that they share. It also asks the students to indicate which of these elements are important and how each kind of microbe causes disease.
- The homework will provide the students with the opportunity to consolidate their understanding of the key structural and functional differences between microbe bacteria and viruses. These differences are important foundations for future concepts in this module.

Also have the students complete the virus structure worksheet if it is not finished in class.
OVERVIEW

Rationale: This lesson demonstrates that although we are covered in bacteria and exposed to viruses all the time, we rarely get sick. You will engage students in discussions that will develop the idea of sterility and the notion that the interior of the body is sterile while the exterior is non-sterile. This will involve the new concept that exterior is defined as the area in contact with the environment, not merely on the outside.
Based on these ideas, you will introduce the concept that our body has natural defenses designed to protect against infection, and that these defenses are either found on the non-sterile exterior or in the sterile interior.
This lesson covers the basic structures of the immune system by describing these structures as barriers that separate the host form the surrounding environment.

Do Now: This activity demonstrates that the outside of our body is colonized with bacteria, yet the inside is sterile. To begin to explore the ways that the body separates itself from the outside environment, students will present their knowledge of host defenses.

Lecture and Socratic Discussion: This will allow students an opportunity to hypothesize the functions of immune structures. Again, it will illustrate the relationship between structure and function. Students will realize that they know most of the immune structures, like skin and mucus.

Wrap Up: The wrap up emphasizes two points from the lesson: 1) Infections only occur when a microbe gets past an immune barrier 2) There are multiple layers of barriers, so if one fails there is another defense.

Lesson Plan

So Why Aren't We Always Sick? Our Bodies' Defenses.

1. Do Now (5 min):
Demonstrate that we are covered in bacteria: spit on a microscope slide. Emphasize that the inside is sterile!

2. Lecture/Discussion (20-25 min):
Lecture / discussion of immune system structure and anatomy.

3. Wrap Up (5 min):
Lead the students to address these questions: what diseases are you susceptible to if you remove a given immune barrier? Do you get sick every time your skin is broken?

4. Homework:
Remind students to study for a quiz during lesson 6.
Lesson 1.5

**Do Now**

The do now demonstrates that the outside of our body is colonized with bacteria, yet the inside is not.

**Do now**

- What does sterile mean?
- Is the human body sterile?

**Ask the students:**

**What does sterile mean?**

- An area can’t be sterile if it contains microbes in the environment.
- To be sterile an area needs to have separation from the environment.

**Is the human body sterile?**

- The inside of the human body is sterile.

**If non-sterile means containing microbes in the environment, what areas of the body are non-sterile?**

- The student should be encouraged not only to think in terms of the skin and the inside of the ear, but also to understand that the whole of the gastrointestinal tract from the mouth through the stomach and the gut to the anus is actually non-sterile, i.e. exposed to bacteria and viruses in the environment.

**Are there any areas of the body that aren’t exposed to microbes in the environment?**

- The students will be likely to say under the skin. Then develop the idea that the skin forms an important barrier between sterile and non-sterile parts of the environment.
- At this point it will be important to draw a parallel between the role of the skin and the role of the lining of the gastrointestinal tract as a barrier. The lining of the tract is composed of specialized cells called ‘epithelium’ that we will look at in detail shortly.

**Finally, bring up the question of the lungs:**

**Certainly the mouth and the nose are exposed to the environment and therefore non-sterile, but what about the inside of the lungs themselves?**

- They don’t form a tube connected at either end to the outside like the GI tract does. In fact the lungs are a special case - special mechanisms at the entry to the lungs keeps the inside sterile, which makes them particularly vulnerable to infection.
You will now discuss how specific immune barriers function. It is important that students become familiar with these structures because bypassing them is a key way in which a microbe becomes a pathogenic i.e. becomes able to cause disease.

**Slide One: The inside versus the outside of the body**

- The slide reinforces the notion that the gastrointestinal tract is just like the skin – it is in contact with the environment and therefore non-sterile.
- The lungs are protected and therefore largely sterile.

**Slide Two: Commensal bacteria**

**Important Points**

- This slide emphasizes the point that the outside of our body is a rich ecosystem consisting of many different species of microbe co-existing with us in a diverse ecosystem.
- The figures show bacteria on the skin (they do not cause disease).

**If possible, demonstrate that we are covered in bacteria:**

Use a microscope slide of saliva or a skin scraping to illustrate the point. Define the population of bacteria that exists in an ecosystem with us as commensal bacteria.

- **Commensal bacteria** cover our bodies and fill our intestines.
- In their ecosystem niche they are symbiotic because they perform useful tasks - like protecting us from dangerous bacteria and helping to digest our food.

**Ask the students:**

**Do you think commensal bacteria will cause disease?**

- Under normal conditions no, because this is a mutually beneficial symbiotic relationship there is no advantage if the bacteria cause disease.
- However there are exceptions, which will be discussed in later Units.
Remind the students that you can’t see a virus under a microscope and ask them whether they would expect the skin or saliva to contain viruses as well. Viruses need cells to survive and reproduce, and usually cannot exist for long on the outside. Nonetheless a population of viruses is to be expected, especially in the mouth where more living cells are found.

**Slide Three: Barriers**

*The barriers that keep microbes out of the sterile areas!*

What are they?

**Important points:**

- You will examine barriers in two contexts:
  1. The defenses that are present when the barrier is intact.
  2. The defenses that appear when a barrier is breached.

**Ask the students:**

*What are some important barriers?*

- If time permits have the students brainstorm a list before proceeding.
- You will consider them in order.

**Slide Four: Skin**

*Skin*

**Important points:**

- The skin is the largest organ of the body. It is composed of various layers of **epithelium**.

**Ask the students:**

*What does epithelium mean?*

- It describes a type of cell that is exposed to a different environment on its top surface compared with its bottom surface. The skin is very thick and made up of several layers of epithelium.

*Which surface will be sterile, top or bottom?*

- The bottom is sterile, while the top (outside) is covered in commensal bacteria.
2. Lecture and Socratic Discussion

What would cause the skin barrier to be breached or broken?
- Puncture wounds, bites or scrapes for example.

What would be the consequence?
- Commensal and other bacteria would now have access to a sterile environment.

Slide Five: Defensins

Important Points:
- The skin is not just composed of a physical barrier of cells, it is also covered with chemicals (defensins) that keep unwanted microbes in check.

Defensins may be important for supporting the symbiotic commensal bacteria and preventing other bacteria outcompeting them. In fact, many commensal bacteria have mutated to allow them to coexist with defensins while new arrivals will not have done so. Defensins are not only located on the skin, they are also found in the blood stream, where they kill any bacteria and fungus that enter the body.

Ask the students:
Are defensins likely to be effective against a commensal bacterium that has entered a cut in the skin vs. a non-commensal bacterium?
- No, because the defensins are on the skin, not in the blood or tissues.

Slide Six: Intestinal Epithelial cells

Important Points:
- Unlike the epithelium of the skin the epithelium of the gastrointestinal tract is only one layer thick.

Ask the students:
Why is epithelium in the gut one layer thick?
- Because this epithelium is not strictly for protection – it provides an important transport function that moves nutrients into the blood stream. Hence it needs to be exposed to the nutrients in the stomach and small intestine.
Lecture and Socratic Discussion

Thin epithelial membranes like those found in the gut are also found in the nose and lungs. The mucous membranes also perform other functions, including transferring oxygen in and carbon dioxide out.

Slide Seven: Mucous

Important Points:

- The epithelia of the gut, nose and respiratory tract need to be thin in order to perform their important functions, but this leaves them vulnerable to damage, and once damaged to infection.
- Mucous provides an additional layer of protection against microorganisms. It is a viscous fluid that sits on the outer layer of the epithelium.
- Mucous often works in conjunction with cilia. In this case some of the epithelial cells are modified to contain small hairs or cilia. The cilia beat to sweep the mucous and any bacteria stuck in it away from the epithelium surface. The picture shows what lung cilia look like.

Ask the students:

**Why might it be particularly important for lung epithelia to sweep the mucous away?**

- Because the lung needs to be kept sterile. In fact, the reason smokers are vulnerable to infection is because nicotine prevents the cilia from beating. Any mucous containing bacteria can't be swept away and swallowed so it enters the lungs, causing infection.

Slide Eight: Tears

Important Points:

- Like that of the lungs and gut, the thin epithelium of the eye performs an important function: in front of the pupil it is transparent so light can pass onto the retina. Mucous would not work here because it is too thick. The eye has developed another strategy: it continually bathes the eye in moisture – tears that lubricate the eye and also wash away any bacteria that land on the surface.
Lecture and Socratic Discussion

1. Tears have several functions:
   1. In healthy eyes the tears that keep the cornea wet contain enzymes that can dissolve bacteria cell walls.
   2. If an eye is irritated a second type of tears washes away the particle or irritant (like onion vapor) rapidly.
   3. Emotional tears don’t perform a protective role.

Slide Nine: Stomach acid

Important Points:

- The stomach is another thin epithelium with a transport function. It is also the gateway to the intestine, so it also acts to protect the intestine from excessive bacteria.

Ask the students:

Do you know how the stomach protects against bacteria and viruses?

- It makes acid to sterilize the stomach contents. The acid also contains enzymes that break down bacteria. Stomach acid is as strong as the acid in a car battery. This limits the possibility of a pathogen entering the small intestines.

- The processes that transport nutrients across the stomach epithelium are adapted to work under conditions of high acidity.

Slide Ten: What if microbes enter the sterile parts of the body?

Ask the students:

What do you know about serious burns? Do people normally survive? What do they usually die of?

- Burn victims usually die of serious infections. When the skin barrier is massively breached the body cannot protect against the onslaught of infection.

When can barriers be breached without necessarily resulting in death?

- Skin wounds, abrasions, etc. Under these conditions, where the influx of infection is not as massive, the body has a second set of barriers to protect the inside sterile environment. The next slides focus on these internal barriers.
2. Lecture and Socratic Discussion

Slide Eleven: Complement

**Complement**

The liver produces a chemical called complement that kills bacteria and other invading cells by punching holes in their membrane, and causing the invaders to leak.

Show the students the video link demonstrating complement.

**Important Points:**

- The liver produces a chemical called complement that kills bacteria and other invading cells by punching holes in their membrane, and causing the invaders to leak.

**Ask the students:**

**Why doesn’t the complement attack the host cells?**

- Look for the answer that it can recognize the host cell somehow. Host cells express an ‘antidote’ that inhibits complement. This antidote is species specific and it doesn’t protect bacteria, fungus and cells from other animals.

Slide Twelve: Phagocytes

**Phagocytes**

We have cells that are specialized to remove microbes by eating them.

Show the students the video of the macrophages eating a microbe.

**Important Points:**

- We have cells that are specialized to remove microbes by eating them.

**Ask the students:**

**What problem will the macrophages need to solve?**

- It will have to be able to identify what is an infectious microbe and what is a normal cell.

- Macrophages identify invading microbes with receptors on their cell surface. These receptors allow the macrophages to distinguish between microbes and host cells and then eat the microbes. Most infections stop here.

- However, if the infection persists other cells can be trained to specifically handle the microbe.
Lecture and Socratic Discussion

Slide Thirteen: B-cells and antibodies

Important Points:

- When other barriers of the immune system, like macrophages fail, other cells can be trained to inactivate the microbe.

Ask the students:

Do you remember from Bio 1 what B cells do to respond to a microbe?

- When B cells are trained they make antibodies. Antibodies are soluble proteins that specifically recognize invading microbes and mark them for destruction.
- B cells also use antibodies as receptors on their surface to recognize and target the invaders for phagocytosis.

Slide Fourteen: T-cells

Important Points:

- T cells can also be trained to respond to a microbe that has managed to evade the other barriers of the immune system.
- T cells also have unique receptors that allow them to recognize well-camouflaged invaders.

Ask the students:

What type of infection have we not yet considered?

- Intracellular pathogens including viruses, bacteria, and parasites.

Trained T cells can use their specific receptors to see microbes that live inside host cells, like viruses. The T-cells then coordinate an attack on the invader and kill infected host cells.
Wrap Up

Important points:

- Because there are so many levels of defenses, most microbes that have penetrated the external barriers will be removed easily by the immune cells. This is why we are rarely sick.

Ask the students:

If there are so many barriers why do we get sick at all?

- The level of exposure is important. For example as we saw in burn victims even non-pathogenic bacteria can cause serious illness if they gain access to the body in high numbers.

- Small numbers may be enough to cause disease. An example is the meningitis bacterium. Even very small numbers (thousands) produce enough potent toxin to cause disease.

- Pathogens can adapt so that they can bypass immune barriers. Pathogens adapt by constantly mutating. For example swine flu mutated so it could infect humans.

All of these strategies will be discussed in detail in later lessons.

Homework

Remind the students that the next class will be a quiz.