TEACHER LESSON PLAN

Lesson 3 – The Evolution of Disease: Viruses, Bacteria, and Immunity

LESSON QUESTIONS

- What are the similarities and differences between diseases caused by bacteria and viruses?
- What are two examples of ways disease-causing agents evolve?

LESSON OBJECTIVES

- Compare features of diseases caused by bacteria and viruses.
- Describe antibiotic resistance and antigenic drift as two examples of ways disease-causing agents evolve.

DOK 1 – 4

OVERVIEW

In this lesson, students develop a conceptual understanding of the relationship between disease agents and the body's response. As a class, students share ideas about how the body protects us from disease. They watch two animations about the human immune system and use the AEIOU strategy to engage with the video content (DOK2). This activity allows students to draw conclusions about why we still get sick despite this system being in place to protect us (DOK3). Working in small groups, students choose one viral and one bacterial disease to research (DOK1). They compare and contrast the viral and bacterial disease (DOK2) and as a class, discuss features including the treatments and preventions they discovered in their research to establish an understanding that different pathogens use different tactics to circumvent our immune systems. As a result, different types of treatments and preventions are needed.

Students then study antibiotic resistance and antigenic shift and drift in more detail. Students view 2 videos and again use the AEIOU strategy to engage with the video content (DOK2). Students work individually or in small groups to create concept maps related to these strategies and conclude the lesson with a writing assignment to tie together the concepts of disease, immunity, and the evolutionary "arms race" between pathogens and the human immune system (DOK4). An assessment worksheet offers an opportunity to present students with a series of questions layered to match the structure of the lesson's concepts.

LENGTH

Two to three 45-minute sessions

GLOSSARY TERMS

antibiotics, antibiotic resistance, antigenic drift, antigenic shift, bacteria, immune system, virus

STANDARDS

Next Generation Science Standards

- Disciplinary Core Ideas in Life Sciences
    - Structure and Function
        - In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.
    - Growth and Development of Organisms
        - Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.
        - Animals engage in characteristic behaviors that increase the odds of reproduction.
    - Interdependent Relationships in Ecosystems
        - Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
        - Growth of organisms and population increases are limited by access to resources.
    - Inheritance of Traits
        - Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

- Natural Selection
  - Natural selection leads to the predominance of certain traits in a population, and the suppression of others.

- Adaptation
  - Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

- Science and Engineering Practices

  - Asking Questions and Defining Problems
    - Ask questions that arise from careful observation of phenomena, models, or unexpected results to clarify and/or seek additional information.

  - Analyzing and Interpreting Data
    - Analyze and interpret data to provide evidence for phenomena.
    - Analyze and interpret data to determine similarities and differences in findings.

  - Constructing Explanations and Designing Solutions
    - Construct an explanation that includes qualitative or quantitative relationships between variables that predict and/or describe phenomena.

  - Engaging in Argument from Evidence
    - Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

  - Obtaining, Evaluating, and Communicating Information
    - Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.

- Crosscutting Concepts
    - Patterns:
        - Patterns can be used to identify cause-and-effect relationships.
        - Graphs, charts, and images can be used to identify patterns in data.
    - Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
        - Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.
    - Systems and System Models: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.
        - Systems may interact with other systems; they may have subsystems and be a part of larger complex systems.
    - Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.
        - Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.
        - Small changes in one part of a system might cause large changes in another part.
        - Stability might be disturbed by either sudden events or gradual changes that accumulate over time.
- Connections to the Nature of Science
    - Scientific Investigations Use a Variety of Methods
    - Science Knowledge is Based on Empirical Evidence

Common Core State Standards

- CCSS.ELA-LITERACY RST.6-8.7
  Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

- CCSS.ELA-LITERACY.RST.6-8.9
  Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

- CCSS.ELA-LITERACY.WHST.6-8.7
  Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

- CCSS.ELA-LITERACY.WHST.6-8.8
  Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

- CCSS.ELA-LITERACY.WHST.6-8.9
  Draw evidence from informational texts to support analysis, reflection, and research.

- CCSS.ELA-LITERACY.SL.6.1 ; CCSS.ELA-LITERACY.SL.7.1; CCSS.ELA-LITERACY.SL.8.1
  Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6/7/8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.2
  Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.

- CCSS.ELA-LITERACY.SL.7.2
  Analyze the main ideas and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue under study.

MATERIALS

- Computer with internet access

BACKGROUND FOR TEACHER

The main goal of this lesson is for students to understand that the human immune system is designed to protect us from disease-causing bacteria and viruses, and that these germs sometimes evolve in order to overcome our immune systems. Students

know germs and may realize them as a cause of disease. However, the way the body responds to disease is largely a black box for middle school students. Although the immune system is highly complex, the basic concepts are simple. Students will learn that a system called the immune system is tasked with fending off infections and disease. Students will know of evolution but may not realize that the principles apply to disease. In fact, disease is one area in which evolution can readily be seen "in action." For example, antibiotic resistance, which is well-documented, and of great concern to the medical community, arises because bacteria rapidly evolve to avoid the effects of antibiotics.

TEACHER NOTES

The over-arching question of this lesson is how do germs that cause diseases evolve and how does that affect the human immune system's ability to protect us? Although the immune system mechanisms are complex, for this lesson it is enough for students to understand that the body has defenses that will protect us from germs.

For your own reference, you may wish to review Unit 1 of our high school modules: The Human Immune System. Unit 1 provides a general overview of the immune system as well as in-depth information about the innate and adaptive immune systems.

Students should also be familiar with the general concept of evolution. For example, they will need a grasp of natural selection to understand that antibiotic resistance is an adaptation resulting from mutations in bacteria that allow them to survive.

The AEIOU strategy is a good way to reinforce learning from a video. Be sure to allow pauses for students to make notes on the video content, but do not let students take notes while they are watching. During the pauses, students complete one or more of the AEIOU items: A is an adjective to describe a part of the video they watched, E is an emotion about how they feel watching something in the video, I is an interesting thought or idea they saw or learned from the video, O is an "oh" moment that was unexpected or surprising, U is something that made them think "Um?" - a question they have about the content.

LESSON RESOURCES

- Lesson videos and animations:
    - *The Innate Immune System*
      https://vimeo.com/248009187

    - *The Adaptive Immune System*
      https://vimeo.com/248009441

- *Bugs on Screen*
  https://hms.harvard.edu/news/bugs-screen

- *Antigenic Drift: How the Influenza Virus Adapts*
  https://vimeo.com/248009839

- Lesson glossary
  https://vaccinemakers.org/sites/default/files/resources/MS.lesson%20glossary.lesson3-Final.pdf

- Student worksheet
  https://vaccinemakers.org/sites/default/files/lessons/MS.student.worksheet.lesson3-Final.pdf

- Additional resources that may be helpful:
  - Information on concept mapping:
    - Concept Maps reference page, Reading Rockets, https://www.readingrockets.org/classroom/classroom-strategies/concept-maps
    - Concept Maps reference page, UNC Learning Center, https://learningcenter.unc.edu/tips-and-tools/using-concept-maps/
  - A Look at Each Vaccine, vaccine and disease reference page, Vaccine Education Center at Children's Hospital of Philadelphia, https://www.chop.edu/centers-programs/vaccine-education-center/vaccine-details
  - VEC Vaccine Notes, VEC, https://www.chop.edu/parents-pack/vec-vaccine-notes
  - A Closer Look: How Viruses Change Over Time, Hilleman film.com, https://hillemanfilm.com/news/closer-look-how-viruses-change-over-time
  - The Innate Immune System, Kahoot!, https://create.kahoot.it/details/c619dfc6-19fb-47d1-bfda-62d7ac92951d?drawer=
  - The Adaptive Immune System, Kahoot!, https://create.kahoot.it/details/df39cc6f-051d-4507-a33e-f6cbafec3d96?drawer=
  - Additional Activity: Memory & Vaccines – Making the Connections, https://vaccinemakers.org/news-events/spotlight-memory-vaccines-making-connections

ENGAGE

1. Ask students to share ideas about how our bodies protect us from diseases.
2. Show the animations *The Innate Immune System* and *The Adaptive Immune System*.

3. Use the AEIOU strategy to reinforce learning related to the animation content.
4. Ask students to brainstorm why germs can still make us sick with this dedicated immune system protecting us.
5. Explain that this is the question the class will be working to understand in this lesson.

EXPLORE

1. As a class, review the lesson glossary terms.
2. Working in small groups, have students choose one viral and one bacterial disease from the following list, (or assign them):

Viral diseases	**Bacterial diseases**
Common cold	Anthrax
COVID-19	Cholera
Ebola	Diphtheria
Hepatitis B	*Haemophilus influenzae* type b (Hib)
Influenza	Lyme disease
Measles	Meningococcal
Mumps	Pertussis
Polio	Tetanus
Rabies	Tuberculosis
Rubella	Typhoid

   Groups explore online resources to characterize the features of these diseases, noting similarities and differences, such as symptoms, parts of the body affected, how it spreads, how it is treated, and how to prevent it. Ask them to note one interesting fact about each disease.
3. Guide students to create a graphic organizer (such as a T-chart or Venn diagram) to organize their information.
4. Have groups identify similarities and differences between the viral and bacterial diseases they researched.
5. Have groups present their findings to the class. If time is limited, have groups present the treatments and preventions and one interesting fact for each disease.

EXPLAIN

1. Have a class discussion specific to the types of treatments and preventions they learned about during their research. List the ideas on the board so the class can see them.
2. Guide the discussion to ensure that antibiotics are realized as a treatment for bacterial, but not viral, infections and that vaccination is mentioned as a prevention for viral or bacterial infections.

3. If the question isn't presented during the course of discussion, ask students why antibiotics and vaccines do not always work.
4. Show students the video *Bugs on Screen* and the animation *Antigenic Drift: How the Influenza Virus Adapts*.
5. Use the AEIOU strategy to reinforce learning related to the video and animation content.

ELABORATE

1. Students work in small groups to research either antibiotic resistance or influenza's genetic changes.
2. Students create a concept map or flow diagram to illustrate how their concept arises.
3. Encourage students to include in their concept maps the basic process of evolution (heritable variation, reproduction, selection).
4. Have students work in small groups or individually to use their concept maps and what they learned about the immune system to write a paragraph describing how the evolution of viruses and bacteria can affect our immune system's ability to protect us.

EVALUATE

Students work individually to answer the assessment questions on the student worksheet. Hand out these pages only after the other sections of the lesson are completed.

RUBRIC: STUDENT WORKSHEET

1. Name two diseases caused by viruses and two diseases caused by bacteria. Identify the virus or bacterium that causes it and give one fact about each disease.

- Answers will vary. Students will likely list information from their own research as well as the class presentations and discussion. Please refer to the "Resources" section for suggestions of where to confirm the accuracy of disease facts.

2. Name three diseases that cannot be cured by antibiotics and explain why antibiotics do not work against them.

- Any three viral diseases; students should explain in their answer that antibiotics can only treat bacterial and not viral infections.

3. Describe steps in the process by which bacteria could become resistant to an antibiotic.

- Antibiotic resistance: First a bacterium is exposed to an antibiotic. Next, a bacterium has a mutation that confers some resistance. This mutant has a selective advantage so more copies of it survive to the next generation. With continued exposure (selection pressure), all individuals will possess the mutation, and the bacteria will be resistant to the antibiotic and, therefore, the antibiotic will no longer work to effectively treat the disease.

4. Describe how a virus could evolve to continue infecting new populations of people.

- Antigenic drift and shift: As a virus reproduces, small genetic changes accumulate to make its surface proteins ("keys") change (antigenic drift). As these surface proteins change, antibodies against the virus do not work as well or at all, so the virus can infect someone who was previously immune. If these changes occur rapidly (antigenic shift), many people may be susceptible to the infection causing a pandemic.

5. If you were a germ, why would it be important to evolve?

- The human immune system has several different ways of defending the body against germs, and it can also learn to remember and recognize germs that previously caused an infection mounting a faster and stronger immune response during subsequent infections. By evolving, bacteria and viruses have a better chance of circumventing the immune system defenses.

6. Why is it important for our immune systems to be able to fend off germs in different ways?

- Disease-causing bacteria and viruses have different ways of entering and infecting our bodies. In addition, some can evolve to overcome our immune system defenses. By having different methods of defending itself, the body increases the likelihood that it can fight off different germs.