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Life Science: Unit 7

Introduction to Microbiology: Lessons

Lesson 1: Going Viral

Lesson Objective: Scholars discover that while the causes and severity of pandemics may vary, they are most frequently caused by viruses. Materials Needed

- For each scholar: computer, **Visualizing the History of Pandemics** by Visualist Capitalist

Prep

- Materials Prep:
  - Send scholars a link to **Visualizing the History of Pandemics**.

What are scholars doing in this lesson?

- Scholars study the history of pandemics and complete a KWL chart in their Lab Notebooks. This opens up a conversation about the causes of pandemics, which leads to the reveal of this unit's Essential Question: Why do pandemics tend to be viral rather than bacterial?

Do Now

- Follow the **Do Now plan**.

Launch

- Show scholars **this image**.
  - Define **outbreak**, **endemic**, **epidemic**, and **pandemic**.
- Explain that in this unit, scholars will be focusing on pandemics. Ask: What do you already know about pandemics?
  - Have scholars record their answers to this question in the “What I Know” columns in the KWL charts in their lab notebooks. Then, have scholars share out.
- Tell scholars that today, they will be studying the history of pandemics and filling out the rest of their KWL charts!

Activity

- Scholars explore the **Visualizing the History of Pandemics** webpage and fill out the “What I Want to Know” and “What I Learned” columns in the KWL charts in their Lab Notebooks.

Discourse Debrief activity:

- Ask: What do you “Want to Know” about pandemics?

[**Tip:** Chart scholars’ questions in a class “Parking Lot” to return to and answer throughout the unit. The Parking Lot is a space in the classroom for scholars to continually ask questions and write ideas about a given topic as their knowledge develops throughout a unit of study.]

- Ask: What did you “Learn” about pandemics today?
- Ask follow-up questions to press scholars about the causes of pandemics. Scholars should identify that more pandemics have viral causes than bacterial and that those pandemics with bacterial causes generally happened a very long time ago.

[**Tip:** If scholars ask additional questions throughout Discourse that are unrelated to the objective, continue to add them to the Parking Lot! Revisit this chart at the end of Discourse during each class to check off questions that have been answered.]

Introduce the Essential Question:

- Introduce the Essential Question: Why do pandemics tend to be viral rather than bacterial?
- Scholars draft initial answers to the question independently in their Lab Notebooks during the last 5 minutes of class.

Accountability (Lab Notebook)

- The scholars’ KWL chart will serve as the Exit Ticket for Lesson 1.

Scoring

- Score scholars on a 1–4 scale (below expectations through exceeding expectations) based on classwork. Do not penalize scholars for initial misconceptions about contentâ€” rate them on effort and synthesis of information.

Lesson 2: The WHO?

Lesson Objective: Scholars understand that the severity of a pandemic is dependent on many factors, including the disease's incubation period, infectious period, case fatality rate (CFR), and R_0.

Materials Needed

- For the teacher: posterized **Modeling the Spread of Disease Data Tracker**, 1 marker, 1 phenolphthalein dropper bottle
- For each scholar: 1 cup filled with water
    - One scholar per class will have 1 sodium hydroxide bead dissolved in their cup.
        - Note: The scholar who has this cup (patient zero) should be kept a secret until Discourse.

Prep

- Intellectual Prep:
    - Review reading material:
        - **What Is R_0?: Gauging Contagious Infections** by Healthline
        - **Understanding R_0** by Khan Academy
- Materials Prep:
    - Posterize the **Modeling the Spread of Disease Data Tracker**. Record the names of your scholars in each class in the "Giver" column.
    - Fill cups with the same amount of water (water should not exceed one-third of the cup's volume). Fill enough cups so that each scholar will have one. Then, number the cups with a permanent marker.
    - Place one sodium hydroxide bead in one cup per class period and let it dissolve. Take note of which cup the bead is placed in for each class. Scholars should not know who has the sodium hydroxide bead in their cup of water.

What are scholars doing in this lesson?

- Scholars learn about the spread of a pandemic by mixing cups of water (which represent body fluids) with other scholars. While only one scholar will be "infected" at the beginning of the activity, many of them will be infected by the end of it. After the activity, scholars will use an indicator to determine who is infected and analyze data from the activity to determine how the disease spread. Afterward, they consider what makes one outbreak more severe than another and are introduced to R_0, incubation period, infectious period, and case fatality rate.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: How can a handful of isolated cases of a disease escalate into a pandemic?
- Ask: Why is it important for scientists to track the spread of diseases, even those that seem isolated to a specific area?
- Define **epidemiologist** and tell scholars that today, they will study how it's possible that what begins as an outbreak in one area can intensify so quickly.

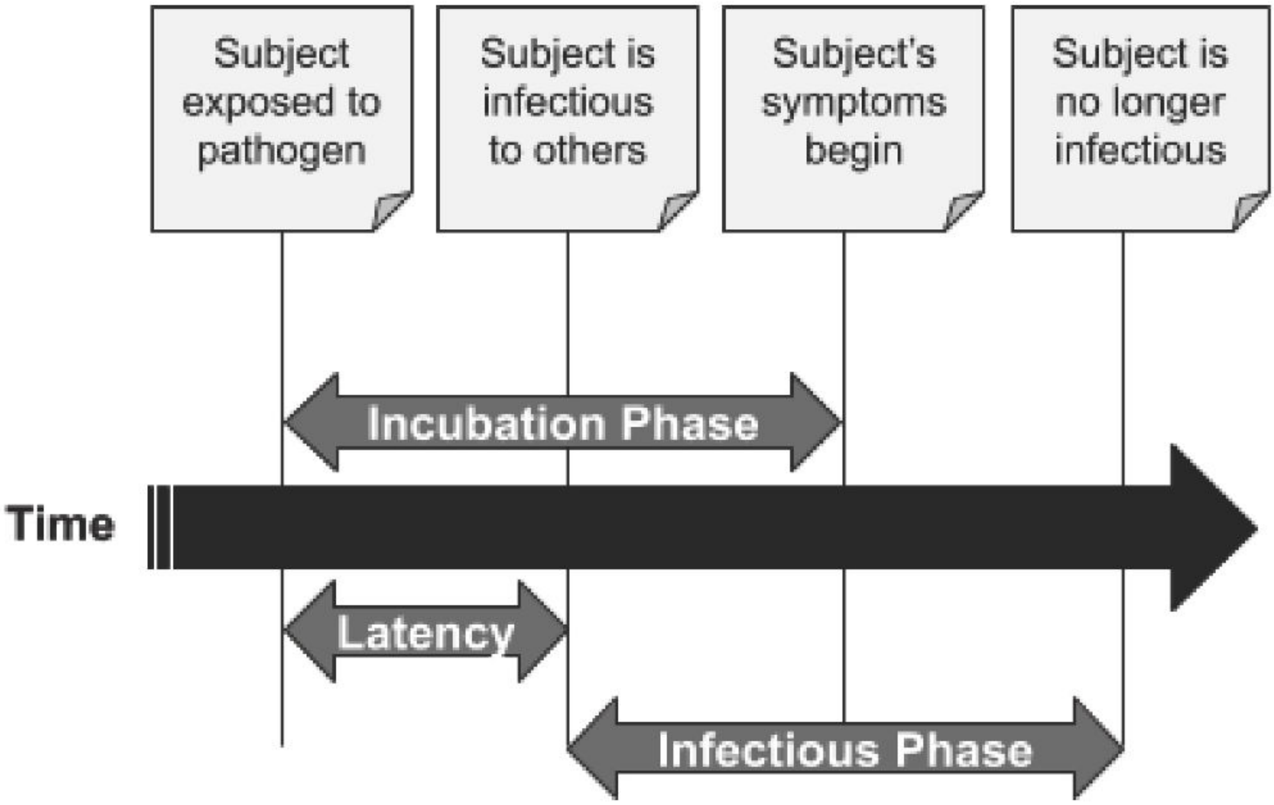
Activity Adapted from Modeling the Transmission of an Infectious Disease, North Arizona University, **CC BY-NC-SA 3.0 US**

- Scholars model in real time how a disease can unknowingly spread throughout a population.
    - Distribute one cup per scholar.
    - Read the activity directions in Lab Notebooks with scholars.
        - Scholars will mingle and swap "body fluids" with others, mixing their water together to mimic the usual handshakes, coughs, sneezes, etc., that would occur in normal friendly interactions. Throughout the course of the activity, scholars will unknowingly spread a "disease" (represented by the invisible sodium hydroxide) to an ever-growing percentage of the class.
    - Facilitate the activity and record "givers" and "receivers" for each round on the **data tracker**.
- After the activity is complete, teachers will add a few drops of phenolphthalein to each cup to see if scholars have been infected with the unseen disease.
- Tell scholars that only one person was initially "infected." Then, have scholars work in groups to try to track the path of the infection using the Work Space in the Lab Notebooks. They may be surprised to see that in just a few short exchanges, a significant portion of the class was exposed!

Discourse Debrief activity:

- Have two to three groups share their paths of infection.
    - Ask: Why can it be challenging for epidemiologists to track the spread of a disease?
        - After scholars discuss this question, reveal the scholar who was **patient zero**.
- Ask: How would the results be different if everyone chose the number of contacts they had?

- Ask: How would the results be different if you only had a 50% chance of contracting the disease after being exposed?
    - Define **susceptibility**.
- Define **mode of transmission** and ask: What modes of transmission might lead to the spread of body fluids in real life?
    - Scholars should determine that body fluids can be spread through both direct (touching the person) or indirect contact (coughing, sneezing, touching an infected surface).
- Ask: What other factors might impact the spread of a disease?
    - After scholars share their initial ideas, define **R_0** (pronounced "R-naught"), **infectious period**, and **incubation period**.
        - Ask: What was the R_0 of the disease in our activity?
            - Scholar responses may vary. Some scholars may argue that the R_0 was approximately 1 because each infected individual spread the disease to 1 person per round. Others may argue that the R_0 was higher because some infected individuals spread the disease to many people over many rounds. Allow scholars to debate about this to better understand that R_0 is not a static value since it is dependent on so many factors.
        - Ask: How might the number of infected individuals at the end of our activity have been different if those individuals knew they were sick?
            - Show scholars the image below:



- Ask: How do the lengths of the incubation and infectious phases impact the spread of disease?
    - Scholars should determine that if an incubation phase ends after the infectious phase begins, there is a higher likelihood that it will spread to more people because the infected individuals will spread it unwittingly.

Make broader connections:

- Ask: You studied many pandemics yesterday. Which outbreaks stood out to you as being the most severe?
    - Tell scholars that the perception of COVID-19's severity changed drastically over time and that at first, the public perception of COVID-19 was that the media was sensationalizing the virus and that it was not as severe as the seasonal flu.
        - Ensure you make a distinction between seasonal flu and pandemic flu with scholars.
    - Show scholars the following data:

Disease	R_0	Case Fatality Rate
Seasonal Flu	1.3	0.1%

COVID-19	2–2.5	1–3%

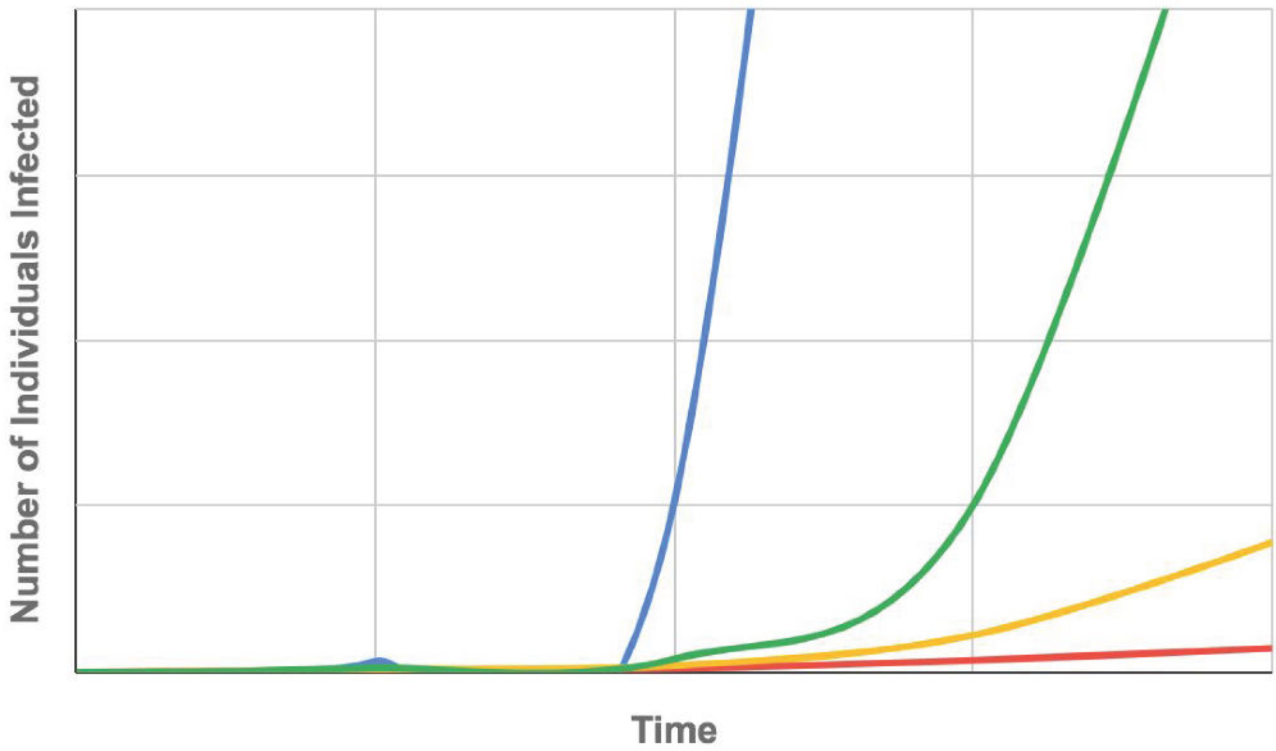
- Define **case fatality rate**. Then, ask: Based on this data, why might COVID-19 have caused a shutdown whereas the seasonal flu has not?
    - Scholars should describe that because it has a greater R_0 and longer incubation period, COVID-19 can spread much more quickly than the seasonal flu. They should also point out that even though COVID-19's CFR seems low, it is considerably more deadly than seasonal flu.

Accountability (Exit Ticket) Figure 1 contains data from past pandemics. Figure 2 indicates the number of individuals affected by these pandemics.

Figure 1

Disease	Incubation Period	R_0	Case Fatality Rate
Ebola	2–21 days	2	50%
Measles	10–12 days	16	25%
SARS	2–7 days	3.5	11%
Smallpox	7–17 days	6	40%

Figure 2



1. Which disease is most likely represented by the **blue** data graphed in Figure 2? Explain and justify your response using evidence and your knowledge of science. [3]

Measles is represented by the blue data graphed in Figure 2 because it has the greatest exponential growth, and measles has a considerably higher R_0 than the other diseases do. A disease's R_0 is the approximate number of individuals that an infected person will spread the disease to, meaning that the higher the R_0 value, the more rapidly a disease will spread.

Scoring Award points as follows:

1. Award one point for each of the following:

    - Identifying that the blue data represents measles
    - Specific evidence from Figure 1 or 2 that supports their claim
    - Scientifically accurate justification/reasoning that ties their evidence to their claim

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Lesson 3: Tree of Life

Lesson Objective: Scholars understand that there are many types of microorganisms and that not all of them are harmful to other living organisms. They also can differentiate between eukaryotic and prokaryotic life. Materials Needed

- For the class: 20 microscopes, printed **Microorganism Information Cards**, the **Common Microorganisms Microscope Slide Set** from Carolina Biological Supply Company (or a similar set with various microorganisms)

Prep

- Intellectual Prep:
  - **Taxonomy and the Tree of Life** by Khan Academy
- Materials Prep:
  - Print the **Microorganism Information Cards** in color.
  - Create a station for each organism. At each station, include:
    - 1 microscope
    - the station's respective microscope slide
    - the station's respective **Microorganism Information Card**

What are scholars doing in this lesson?

- Scholars visit different stations to learn about various microorganisms. At each station, they will view a microscope slide and read a brief information sheet to learn more about each organism. Scholars will quickly learn that there are many different types of microorganisms and that not all of them cause disease.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: What causes infectious disease?
  - Define **microorganism**.
  - Ask: What do you know about microorganisms?
    - Have scholars write the answer to this question in the "What I Know" column of the KWL charts in their Lab Notebooks. Then, call on two to three scholars to share out.
- Tell scholars that the idea that diseases were caused by microorganisms was extremely controversial until French scientist Louis Pasteur proved it in the 19th century.
  - Define **germ theory of disease**.

- Tell scholars that there is a vast number of microscopic species, all with their own unique characteristics.
    - Define **taxonomy** and show scholars **this image** by Britannica.
        - Show scholars **this image** from ResearchGate to demonstrate how organisms are classified according to their specific taxonomic rankings.
            - Tell scholars that because many microorganisms have cross-kingdom characteristics; some taxonomic rankings do not include the category.
- Ask: What do you already know about microorganisms?
    - Have scholars record their answers to this question in the “What I Know” columns in the KWL charts in their lab notebooks. Then, have scholars share out.
- Tell scholars that today, they will be taking a closer look at microorganisms to discover how these tiny living things vary in big ways!

Activity

- Scholars visit the various microorganism stations. As they do this, they will:
    - View each microorganism’s microscope slide and information sheet
    - Fill in the “What I Want to Know” and “What I Learned” columns of the KWL chart in their Lab Notebooks

Discourse Debrief activity:

- Ask: What surprised you as you studied various microorganisms?
    - Scholars should share details that showcase how these tiny organisms are much more complex than they imagined.
        - Show scholars the **Can Slime Mould Solve Mazes? | Earth Lab Video** by BBC Earth Lab (2 minutes, 32 seconds).
            - Explain to scholars that microorganisms display a stunning variety of structures and behaviors that help them survive. It's easy to write off microorganisms as "simple" creatures due to their size, but in fact, they have adapted to their environments just like every other creature on Earth.
- Have scholars share out what they learned from visiting the stations. Then, ask: How are these organisms similar? How are they different?

- Ask: How did the organisms you looked at today vary in size and structure?
    - Show scholars some of the following videos to demonstrate that microorganisms can be either **unicellular** or **multicellular**:
        - Unicellular organisms:
            - **Paramecium Bursaria Video** by my.microscopic.world (30 seconds)
            - **Ciliate in the Genus Blepharisma Video** by microbialecology (30 seconds)
            - **Ciliate in the Genus Stentor Video** by microbialecology (30 seconds)
            - **Ciliate in the Genus Spirostomum Video** by microbialecology (30 seconds)
        - Multicellular organisms:
            - **Volvox (Algae) Video** by my.microscopic.world (30 seconds)
            - **Eudorina (Algae) Video** by my.microscopic.world (30 seconds)
            - **Giant Green Hydra (Hydra Viridissima) Video** by my.microscopic.world (30 seconds)
- Ask: Do all unicellular organisms have nuclei?
    - Show scholars the **Cyanobacteria & Ciliate in the Genus Frontonia Video** by microbialecology (30 seconds) and explain one is eukaryotic, while the other is prokaryotic.
    - Define **eukaryotic** and **prokaryotic**.
    - Show scholars these Wikimedia images of **the structures of ciliates** and **the structures of cyanobacteria:**
        - Ask: Which organism is eukaryotic? Which organism is prokaryotic? Explain.
            - Scholars should identify that the ciliate is eukaryotic because it has nuclei, whereas the cyanobacteria is prokaryotic because it does not have a nucleus.

Make broader connections:

- Ask: Are all microorganisms a danger to our health?
    - Scholars will explain that although some microorganisms are a danger to our health, many have beneficial uses for humans and other living organisms as well.
        - Scholars should understand that there are countless beneficial or neutral types of bacteria present in the human microbiome. Tell scholars that on an average day, they have between 500 and 1,000 different species of

bacteria living on/inside their bodies. Add that there are three times as many bacterial cells than human cells in their bodies right now.

- Define **pathogen**.

Accountability (Exit Ticket) The diagram below depicts a cell and its structures.

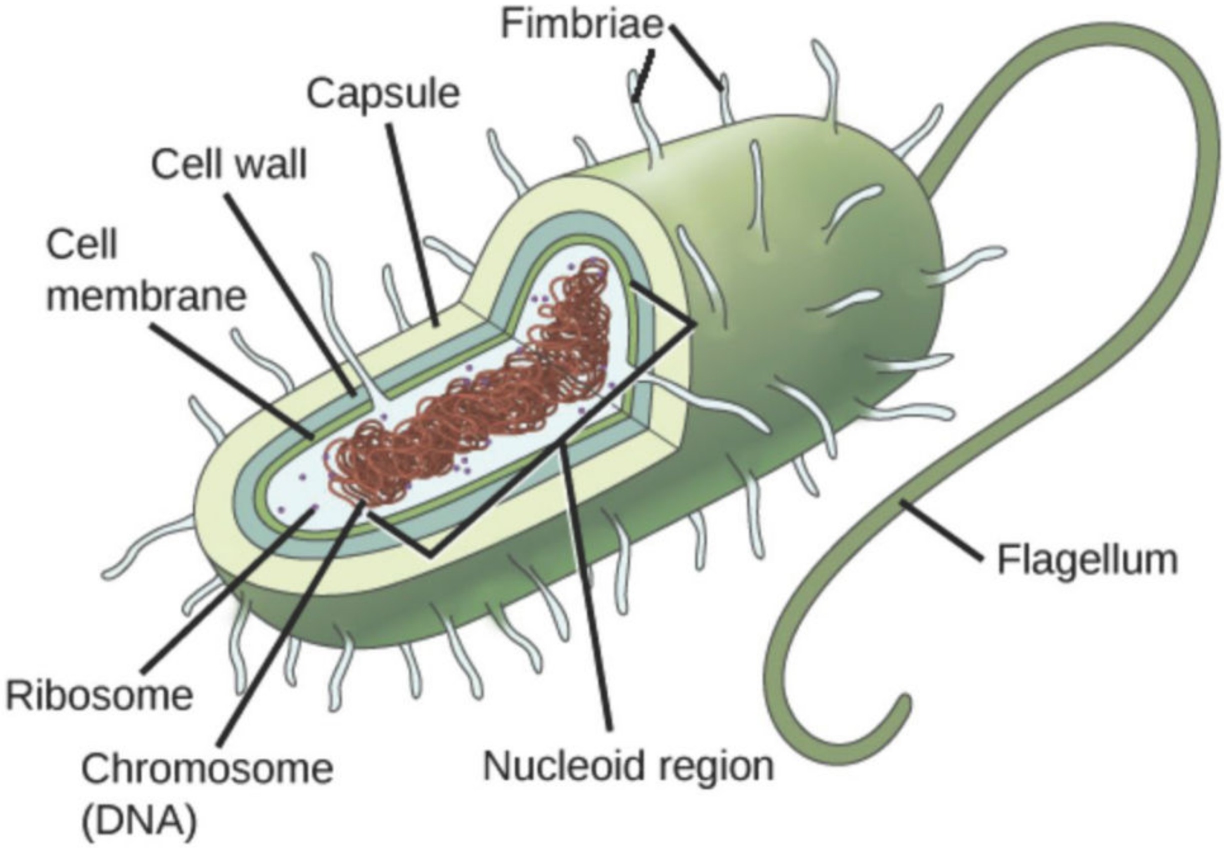

Image Credit: **Khan Academy**, modified from "**Figure 4.5**" by OpenStax College, Biology, **CC BY 3.0**

1. Is the cell represented above eukaryotic or prokaryotic? Explain. [2]

The cell represented above is prokaryotic because it does not have a nucleus.

2. Aaliyah says, “Cheese is made using bacterial cultures. If we want to avoid the next pandemic, we should stop eating cheese so the bacteria doesn’t get inside of us!” Evaluate the accuracy of Aaliyah’s statement. [2]

Aaliyah’s statement is inaccurate because the bacteria in cheese is perfectly safe for human consumption. While it is true that some bacteria cause infectious diseases, this is not true of all bacteria.

Scoring

1. Award one point for each of the following:

   - Identifying that the cell is prokaryotic

- Explaining that the cell does not have a nucleus

2. Award one point for each of the following:

    - Identifying Aaliyah's statement as inaccurate
    - A scientifically accurate explanation

Lesson 4: "Germs"

Lesson Objective: Scholars understand the similarities and differences between bacteria and viruses as they study their major structures and their functions. Materials Needed

- For each group: 1 microslide viewer, 1 harmful bacteria microslide, 1 virus microslide, the **Viral Structures** handout, the **Bacterial Structures** handout

Prep

- Intellectual Prep:
    - **Are Viruses Dead or Alive?** by Khan Academy
    - **Bacteria VS Virus** by ResearchGate
- Materials Prep:
    - Print color copies for each group:
        - **Viral Structures**
        - **Bacterial Structures**

What are scholars doing in this lesson?

- Scholars will be completing a lab in which they view microslides in order to compare the structures and functions of bacteria to those of viruses. Scholars will discover the similarities and differences between the two.

Do Now

- Follow the **Do Now plan**.

Launch

- Define **virus** and **virology**. Then, read **A Brief History of Virology**, adapted from Wikimedia, with scholars.
- Tell scholars that because of the invention of different scientific tools (like the electron microscope), we have learned much about such pathogens as viruses. However, because they are so small, they are not visible under classroom microscopes. Because of this, scholars will

be exploring the structures of viruses and bacteria by viewing zoomed-in images called microslides!

Lab

- Scholars view the microslides and complete the analysis questions in their Lab Notebooks. As they do this, they compare the structures of viruses and bacteria to better understand their similarities and differences.

Discourse Debrief experiment:

- Show scholars **this diagram** of different types of viruses and their structures.
    - Define **virus** and **virion**. Tell scholars that while the terms “virion” and “virus” have different meanings, they are often used interchangeably in the scientific community and, for simplicity, will be in this unit as well.
    - Review analysis question 2 with scholars.
        - Scholars should identify that all viruses pictured have a **genome** that contains either DNA or RNA and a protein **capsid** that covers the genome.
- Show scholars **this prokaryotic cell diagram** of a bacterium.
    - Define **bacteria** and **bacterium**.
        - Review analysis question 3 with scholars.
            - Ask: In what ways does a bacterium differ from a virus?
                - Scholars should identify that a bacterium has membrane-bound organelles, whereas a virus does not.
            - Ask: Knowing that viruses do not have organelles, how else might they be different from bacteria?
                - Press scholars to explain that because they do not have organelles, viruses cannot undergo life processes with their structures alone, such as growth, reproduction, synthesis of usable energy, and maintenance of homeostasis.
            - Show scholars this image depicting the characteristics of life:

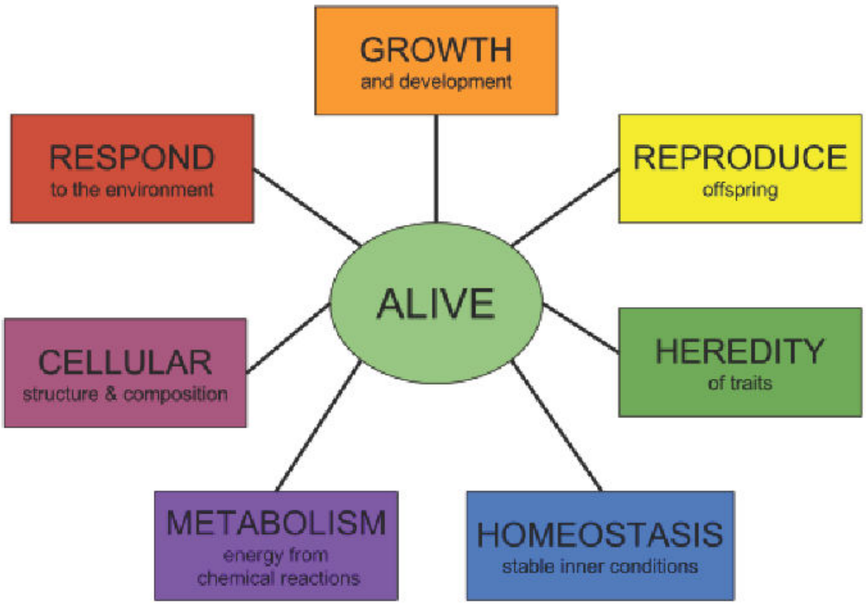

Image Credit: Chris Packard, CC BY-SA 4.0, via Wikimedia Commons

- Ask: Based on these defining characteristics of life, are viruses alive?
    - After scholars debate this, tell them that this discussion happens frequently in the scientific community because categorizing them as alive would change how we define life. Then, tell scholars that for this reason, scientists have classified viruses in a category between living and nonliving and are frequently described as inert.

Accountability (Exit Ticket)

1. The left column of the table below contains characteristics that may describe bacteria, viruses, or both. Select the pathogens that each characteristic applies to by circling the answer choice in the column on the right. [6]

considered living organisms	**bacteria only** **viruses only** **both bacteria and viruses**
require a host for reproduction	**bacteria only** **viruses only** **both bacteria and viruses**
unicellular	**bacteria only** **viruses only** **both bacteria and viruses**

contain genetic material	**bacteria only** **viruses only** **both bacteria and viruses**
show evidence of neither respiration nor metabolism	**bacteria only** **viruses only** **both bacteria and viruses**
do not contain a nucleus	**bacteria only** **viruses only** **both bacteria and viruses**

Scoring

1. Award one point for each correct response.

Lesson 5: Molecular Hackers (Two Days)

Lesson Objective: Scholars learn how bacteria and viruses replicate.

- **By the end of day one, scholars should understand that bacteria do not undergo mitosis to reproduce and instead engage in binary fissionâ€" a process that is considerably faster than the cell cycle and the reason why bacteria reproduce so quickly.**
- **By the end of day two, scholars will understand how viruses use the cellular mechanisms of their hosts to replicateâ€" often at a significantly faster rate than bacteriaâ€" by using processes such as reverse transcription, the lysogenic cycle, and the lytic cycle.**

Materials Needed

- Day One:
  - For each group: anchor chart paper, flip chart markers
  - For each scholar: computer
- Day Two:
  - For each scholar: computer

Prep

- Intellectual Prep:
    - **Prokaryotic Binary Fission vs. Eukaryotic Cell Cycle Video** by scienceclassisgreat (14 minutes, 53 seconds)
    - **Bacterial Binary Fission** by Khan Academy
    - **Viral Replication: Lytic vs Lysogenic** by Khan Academy
- Materials Prep:
    - Day Two:
        - Send the following links to scholars:
            - **The Viral Life Cycle** by LibreTexts
            - **Lytic vs. Lysogenic – Understanding Bacteriophage Life Cycles** by Technology Networks

What are scholars doing in this lesson?

- On day one, scholars learn that some unicellular organisms such as bacteria undergo a process called binary fission instead of mitosis because they do not have a nucleus. Scholars also create anchor charts, which describe how binary fission occurs. On day two, scholars participate in a research activity to study how viruses replicate through processes such as the lytic cycle, the lysogenic cycle, and reverse transcription.

Day One

Do Now

- Follow the **Do Now plan**.

Launch

- Show scholars this image of onion cells:

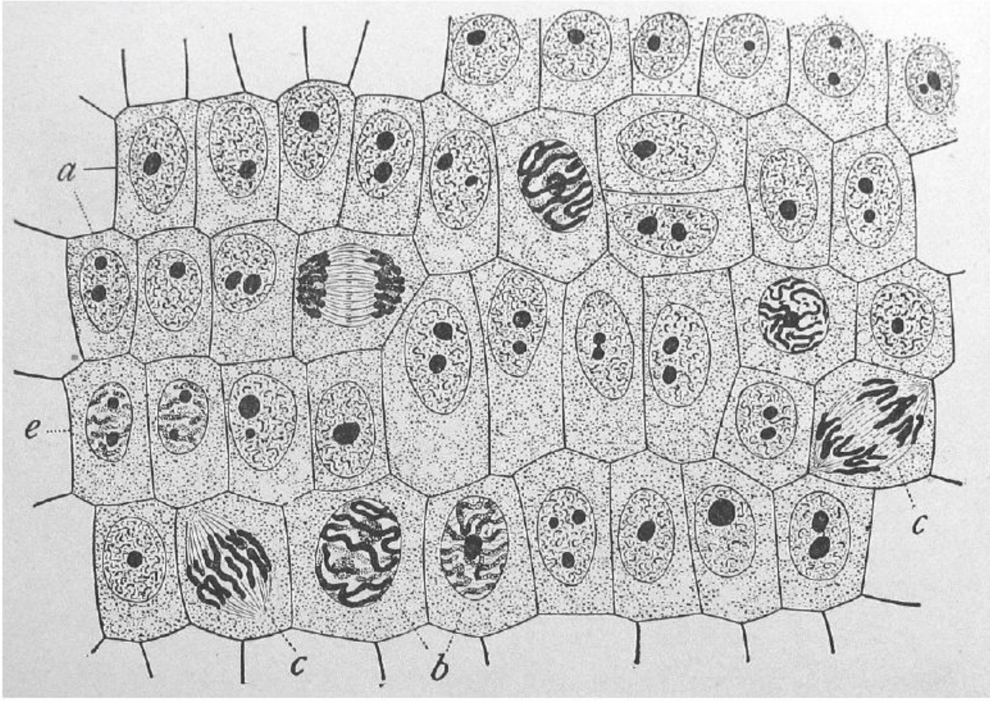

Image Credit: **[Edmund Beecher Wilson](#)**, public domain, via Wikimedia Commons

- Tell scholars that the cells shown are from a single slice of onion. Then, ask: Why do they all look so different?
    - Ask: What do you already know about cell division?
    - Show scholars the **Mitosis in a Unicellular Organism Video** by my.microscopic.world (30 seconds).
    - Ask: Do you think bacteria use mitosis in order to reproduce? Why or why not?
        - Scholars should explain that because prokaryotic organisms do not have nuclei, they will not be able to reproduce in the same way.
- Tell scholars that prokaryotes reproduce through a process known as binary fission and that today, they will be studying binary fission and presenting their findings to the class.

Activity

- Scholars research binary fission on their computers and create informational posters about this process in their groups.

Discourse Debrief activity:

- Have two to three groups share their anchor charts.
  - Define **binary fission** and show scholars the **Binary Fission in Bacteria Video** by Microbial Zoo (1 minute, 2 seconds).
    - Note: While scholars should have a conceptual understanding of binary fission, they do not to memorize all of its steps.

Make connections to the Essential Question:

- Tell scholars that binary fission takes significantly less time than the cell cycle, which allows bacteria to efficiently colonize inside of other organisms. Then, show scholars a portion of the **Bacterial Pathogenesis: How Bacteria Cause Damage Video** by Professor Dave Explains (4:35–7:30).
  - Ask: How do bacteria cause disease?
    - Scholars should explain that bacterial disease is primarily caused by the natural by-products they produce, such as toxins, enzymes, gas, and acid.
      - Note: Although it isn't central to the lesson's objective, there's an interesting takeaway here that will change how scholars view microorganisms: Bacteria and other microorganisms aren't "out to get us." They're just trying to survive and reproduce like any other species!

Accountability (Exit Ticket) The diagram below depicts the microorganisms *H. pylori* and *P. ostreatus*:

H. pylori

Image Credit: [Ali Zifan](), [CC BY-SA 4.0](), via Wikimedia Commons

P. ostreatus

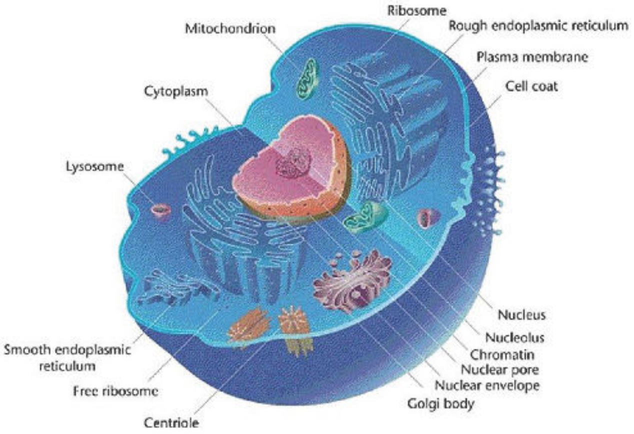

Image Credit: [Mediran](), [CC BY-SA 3.0](), via Wikimedia Commons

1. Do both of these organisms reproduce using the same processes? Use evidence from the information provided and explain your reasoning. [3]

These organisms do not reproduce using the same processes. *H. pylori* reproduces using binary fission because it is prokaryotic, whereas *P. ostreatus* reproduces using mitosis because it is eukaryotic.

2. Based on your understanding of viral structure, how do you think viruses replicate? Explain your reasoning. [4]

I think viruses use a process similar to binary fission to replicate. Viruses do not have a nucleus but do have genetic material, similar to bacteria. This makes me believe that viruses cannot undergo mitosis and must instead undergo binary fission like bacteria do or a process similar to it.

Scoring

1. Award one point for each of the following:

    - Identifying that H. pylori reproduces using binary fission
    - Identifying that P. ostreatus reproduces using mitosis
    - Evidence from the diagram that supports their claims

2. Score scholars on a 1–4 scale (below expectations through exceeding expectations). Do not penalize scholars for initial misconceptions about contentâ€" rate them on effort and writing. Look for the following when scoring scholar responses:

    - A clear claim that answers the question
    - Specific evidence collected from the activity or their prior knowledge that supports the claim
    - Justification/reasoning that ties the evidence to the claim
    - High effort shown in writing, with complete sentences and proper grammar/punctuation seen throughout the response

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Day Two

Do Now

- Follow the **Do Now plan**.

Launch

- Have scholars recap what they learned yesterday.
    - The cell cycle is used by eukaryotic cells to replicate through mitosis.
    - Prokaryotes such as bacteria utilize binary fission to replicate, a process that is significantly faster than mitosis.
    - Bacteria colonize in organisms through binary fission. When they cause disease in these organisms, it is primarily due to the natural by-products they produce such as toxins, enzymes, gas, and acid.
- Tell scholars that today, they will be studying how viruses produce **progeny**.

Activity

- Scholars conduct research using the provided links and answer the analysis questions in their Lab Notebooks, which are focused on viral replication. Scholars will learn about the following processes:
    - The lytic cycle
    - The lysogenic cycle
    - Reverse transcription

Discourse Debrief activity:

- Ask: How do viruses replicate?
    - Chart scholar responses. Ensure scholars describe the **lytic cycle**, **lysogenic cycle**, and **reverse transcription**. Press scholars to understand that these processes are not opposites but instead work in conjunction with one another in many cases.

Make connections to the Essential Question:

- Ask: How is the replication of viruses different from the replication of bacteria?
    - Press scholars to describe that bacteria do not require a host for replication, whereas viruses do.
        - Ask: What specialized structures do bacteria and viruses have to support their respective modes of replication? Explain.
            - After scholars share their initial responses, show them part of the **COVID-19 Animation: What Happens If You Get Coronavirus? Video** by Nucleus Medical Media (0:41–2:43) to demonstrate how viral structures allow them to “hack” host cell machinery in order to replicate.
- Ask: Why might it be a greater challenge to produce medications that eliminate viral infections than it is to produce medications that eliminate bacterial infections?
    - Press scholars to explain that since viral replication happens inside host cells, it is challenging to create a medication that stops viruses from replicating without also damaging the host’s cells. They should also be able to explain that because bacteria reproduce outside of the host’s cells, it would be easier to create a medication that targets bacteria without causing harm to the host’s own cells.

Make broader connections:

- Ask: How might cell **lysis** due to viral infection impact an organism?
    - Scholars should explain that viruses make organisms sick by killing cells or disrupting cell function. They should also be able to make a connection between the symptoms of a disease and the cell damage that occurs.

- Ask: If a virus primarily affects your respiratory system, what symptoms do you predict would be associated with its infection?
    - Scholars may describe the following symptoms: runny nose, cough, shortness of breath, congestion.
    - To provide a current real-world example, tell scholars that COVID-19 is a respiratory illness and show them the **What are the symptoms of COVID-19?** section of the World Health Organization's website.

Accountability (Exit Ticket) The following is adapted from **AP® Biology Curriculum Framework 2012–2013**:

Environmental factors influence the phenotypic expression of an organism's genotype. In humans, weight and height are examples of complex traits that can be influenced by environmental conditions. However, even simple single gene traits can be influenced by the environment; for example, flower color in some species of plants is dependent upon the pH of the environment.

Some organisms possess the ability to respond flexibly to environmental signals to yield phenotypes that allow them to adapt to changes in the environment in which they live. Environmental factors such as temperature or density can affect sex determination in some animals, while parthenogenesis (a form of asexual reproduction) can be triggered by reproductive isolation. Plant seed dormancy can increase the survival of a species, and some viruses possess both lysogenic and lytic life cycles.

1. Why is the possession of both lysogenic and lytic life cycles beneficial to some viruses? [1]
    1. Lytic infection alone involves integration, whereas lysogeny may not require integration.
    2. Lysogeny allows a virus to become more widespread in the environment by allowing replication through lytic infection to take place at a more opportunistic time.
    3. The lytic cycle replicates a large number of viruses quickly and results in the destruction of the infected cell and its membrane.
    4. In lysogenic cycles, the spread of the viral DNA occurs through usual prokaryotic reproduction.
2. Which statement most accurately summarizes the replication of bacteria and viruses? [1]
    1. Bacteria replicate through mitosis, while viruses replicate through meiosis.
    2. Both bacteria and viruses replicate by utilizing mitosis.
    3. Viruses depend on a host for replication, whereas bacteria do not.
    4. Both viruses and bacteria replicate through binary fission.
3. Reverse-transcriptase inhibitors (RTIs) hinder the activity of reverse transcriptase. How might RTIs impact a retrovirus such as HIV? Explain and justify your response. [3]

RTIs would prevent a retrovirus such as HIV from replicating. Reverse transcriptase is an enzyme that converts viral RNA into DNA during the process of reverse transcription. If the activity of reverse transcriptase were inhibited, reverse transcription could not take place, and the retrovirus could not use the host's cells to replicate its DNA.

Scoring

- Award one point for a correct response.
- Award one point for a correct response.
- Award one point for each of the following:
    - Identifying that RTIs would prevent the virus from being able to replicate
    - Connecting reverse transcriptase to reverse transcription/the conversion of viral RNA into DNA

- Explaining why reverse transcription is essential to replication

---

Lesson 6: Fighting Back!

Lesson Objective: Scholars understand that the immune system consists of many biological structures and processes that protect against disease. They can also describe how innate and adaptive immune responses work. Materials Needed

- For each group: 1 **Immune System Game** set (playing cards printed on different colors of cardstock, 1 body bag [paper lunch bag with body outline attached], 1 coin, 1 paper clip, snack-sized resealable plastic bags to keep each type of playing card organized, 1 gallon-sized resealable plastic bag for storing each kit)

Prep

- Intellectual Prep:
    - **Types of Immune Responses** by Khan Academy
    - **Role of Phagocytes in Innate or Nonspecific Immunity** by Khan Academy
- Materials Prep:
    - Prepare the materials as described in the **Immune System Game** instructions.

What are scholars doing in this lesson?

- Scholars play a game to learn about the specialized structures and defense mechanisms of the human immune system.

Do Now

- Follow the **Do Now plan**.

Launch

- Have scholars recap what they learned about how pathogens cause disease.
- Ask: What defenses does our body have against pathogens?
    - Have scholars share their understandings of what the immune system is, taking note of (but not correcting) misconceptions.
        - Define **immune system**.
- Tell scholars that today, they will play a game to model how the human immune system works!

Activity The **Immune System Game** by Kirsten A. Work, Melissa A. Gibbs, Erich J. Friedman. The American Biology Teacher. 77(5), 382-390, (1 May 2015)

- Scholars play the **Immune System Game** to better understand how the immune system works. As they play the game, they will be exposed to the following terms: macrophage, T cell, B cell, antibodies, adaptive immune system, and innate immune system.
- After the game is over, allow scholars to discuss the questions in their Lab Notebooks:
    - What is the difference between an innate and an adaptive immune response?
    - What defenses does your body have against pathogens?
    - How was the immune response different when there was a bacterial infection versus a viral infection?

Discourse Debrief activity:

- Review question 1 with scholars.
    - Have two to three groups share their responses. Then, define **innate immune response** and **adaptive immune response**.
    - Create a T-chart on the board to record notes around innate and adaptive immune responses.
- Review question 2 with scholars.
    - Have two to three groups share their responses. Then, ask scholars to list these defenses in the appropriate column of the T-chart.
        - Define **phagocytes**, **lymphocytes**, **antibodies**, and **antigens**.

Make broader connections:

- Show scholars this image of a person whose hand was cut, became infected, and began to swell:

Image Credit: LucyHAE, CC BY-SA 3.0, via Wikimedia Commons

- Ask: Does this swelling indicate that the immune system is functioning normally or abnormally?
  - Scholars should explain that this swelling is normal and is occurring as a result of an **inflammatory response**.
  - Show scholars the **Does a Strong Immune System Make Colds Worse? Video** By SciShow (3 minutes, 20 seconds) to allow them to make a stronger connection between symptoms and immune responses.

Make connections to the Essential Question:

- Ask: If your body has an immune system, why do you still sometimes need a doctor to prescribe you medication when you are sick?
  - Define **antibiotic** and **antiviral**. Explain that antibiotics kill bacteria, while antivirals stop the replication of viruses.
    - Ask: Knowing this, why might it be a greater challenge to "cure" a viral infection than a bacterial infection?
      - Press scholars to explain their answers. Try to elicit that unlike antibiotics, antiviral medications don't destroy their target but rather inhibit the growth of the virus to allow your immune system to fight off the infection.

Accountability (Exit Ticket) The word bank below contains several terms related to the immune system.

Antigens Innate **Phagocytes** **Antibodies**

________ ______________ ____________ ________

Adaptive Immune System Lymphocytes Pathogens

1. Use the word bank to fill in the blanks and complete the sentences below. [4]

The *immune system* consists of many biological structures and processes that protect against disease. *Innate* immunity utilizes mucous membranes, the skin, and stomach acid to keep out disease-causing microbes called *pathogens*. When this first line of defense is not effective, *phagocytes* detect and engulf pathogens in order to destroy them. They will then take proteins or peptide chains called *antigens* from the pathogen they destroyed and attach them to their surface. This triggers a(n) *adaptive* response. This response is dependent on two different types of *lymphocytes*: B cells and T cells. If pathogens have not yet infiltrated cells, B cells produce *antibodies*, proteins that attach to antigens and trigger a humoral response.

Scoring

- Award points as follows:
    - Four points for eight correct responses
    - Three points for six to seven correct responses
    - Two points for four to five correct responses
    - One point for two to three correct responses
    - Zero points for zero to one correct response

Lesson 7: Stopping the Spread

Lesson Objective: Scholars learn that herd immunity results when the proportion of individuals who are immune to a disease is high enough to resist its spread within a population, and that herd immunity can be achieved through vaccination or previous infection. Materials Needed

- For the teacher: stickers (blue, green, and red), **Herd Immunity: The Game Poster**
- For each scholar: 1 role card

Prep

- Materials Prep:
    - Posterize the **Herd Immunity: The Game Poster** from the Extra Resources Folder.

[**Tip:** If you laminate the data table and use dry erase markers, it can be reused.]

- Print the **Herd Immunity: The Game Role Cards** from the Extra Resources Folder in color and cut them out. Make enough copies of each card so that one scholar from each class can be a doctor, one scholar from each class can be patient zero, and the other scholars in each class can be civilians.
- Note: Role cards can not be reused once played with due to the use of stickers.

- Intellectual Prep:
    - **What is Herd Immunity? Video** by Microbiology Society (3 minutes, 7 seconds)

What are scholars doing in this lesson?

- Scholars physically model how herd immunity can be achieved by playing a game.

Do Now

- Follow the **Do Now plan**.

Launch

- Define **vaccine** and show scholars the **How Do Vaccines Work? Video** by TED-Ed (4 minutes, 35 seconds).
- Tell scholars that today, they will be playing a game in order to better understand why vaccines are so important.

Activity

- Scholars will play a game to model how herd immunity can be achieved through acquisition of an infectious disease or vaccination:
    - Read the activity directions in the Lab Notebook with scholars.
    - Distribute **Role Cards** to scholars and begin the game.
    - In the game, scholars will play the inhabitants of a small town. They will model the outbreak of an infectious disease (represented by stickers). The simulation will reset multiple times, and before each round begins, the town's doctor will have the opportunity to administer vaccines to some of the townspeople. Scholars will observe firsthand how the spread of disease changes when a greater percentage of the townspeople are vaccinated against the virus.

Discourse Debrief activity:

- Ask: At what point in the game did you notice that the spread of the disease began to slow down?
    - Scholars should look at the table that you used to track the data throughout the game and make conclusions about the percentage of individuals that must be immune in order to prevent the spread to other susceptible people within the population.
        - Define **immunity** and **herd immunity**.
- Ask: How can herd immunity be achieved?
    - Scholars should explain that herd immunity is achieved when a large amount of the population is immune due to either vaccinations or recovery.

- Ask: What was the R_0 of the disease in the game we just played?
    - Scholar responses may vary. Some scholars may argue that the R_0 was approximately 1 because each infected individual spread the disease to one person per round. Others may argue that the R_0 was higher because some infected individuals spread the disease to many people over many rounds. Allow scholars to debate about this and reinforce that R_0 is not a static value since it is dependent on so many factors.
        - Ask: How might the results have been different if the R_0 was higher?
            - After scholars share their predictions, show scholars this **How Herd Immunity Works** simulation by Research on Complex Systems Brockmann Lab. Manipulate the reproductive number and discuss the results.
- Ask: How does vaccination impact herd immunity?
    - After scholars share their thoughts, use the **How Herd Immunity Works** simulation again to manipulate the vaccination rate and discuss the results.
    - Then, show scholars the **Watch How the Measles Outbreak Spreads When Kids Get Vaccinated – and When They Don't** by The Guardian and discuss.
        - Display **Herd Immunity: Why Your Vaccinations Help Others Animation** if scholars need another visualization of how vaccinations impact herd immunity.

Make broader connections:

- Ask: Scientists need time to develop a vaccine when a new disease enters the population. It often takes years to develop a new vaccine, but that doesn't mean the population is helpless until then. There are still steps that everyone can take to reduce the spread of the disease until a vaccine is developed and tested.
- In 2020, everyone has been a part of the attempts to slow the spread of COVID-19. As scientists scrambled to develop a vaccine, health officials called on world leaders and their citizens to stay inside to help slow the spread of the disease in order to "flatten the curve."
    - Show scholars the image below:

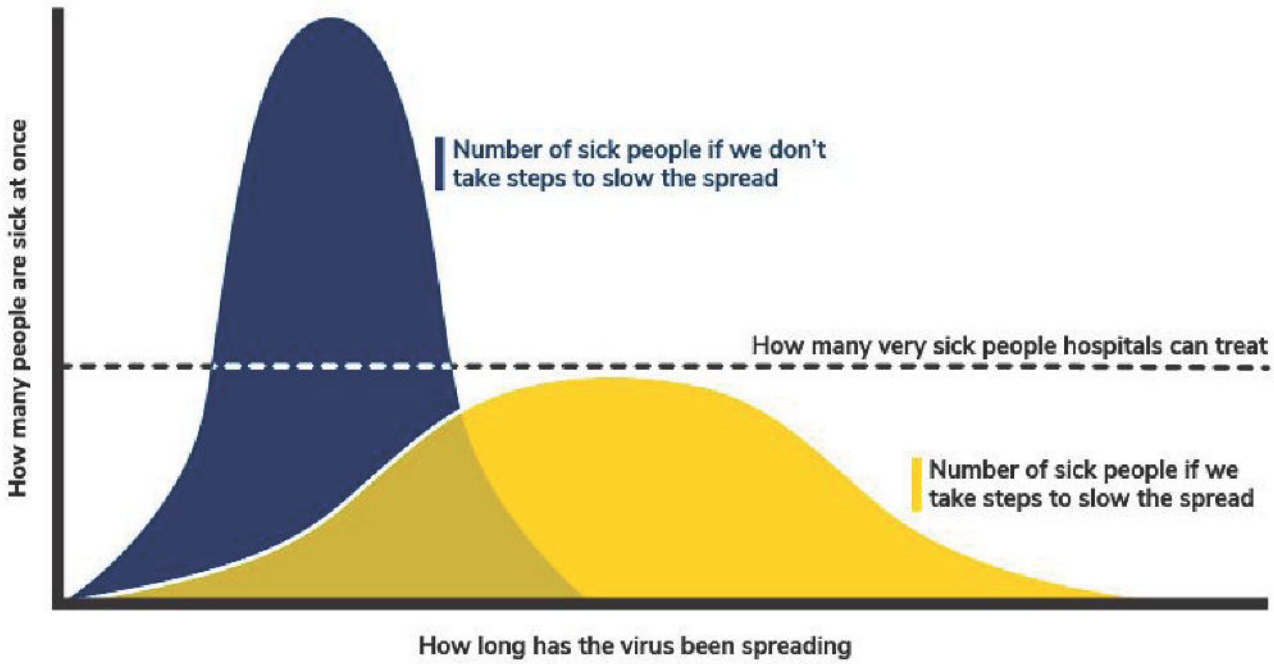


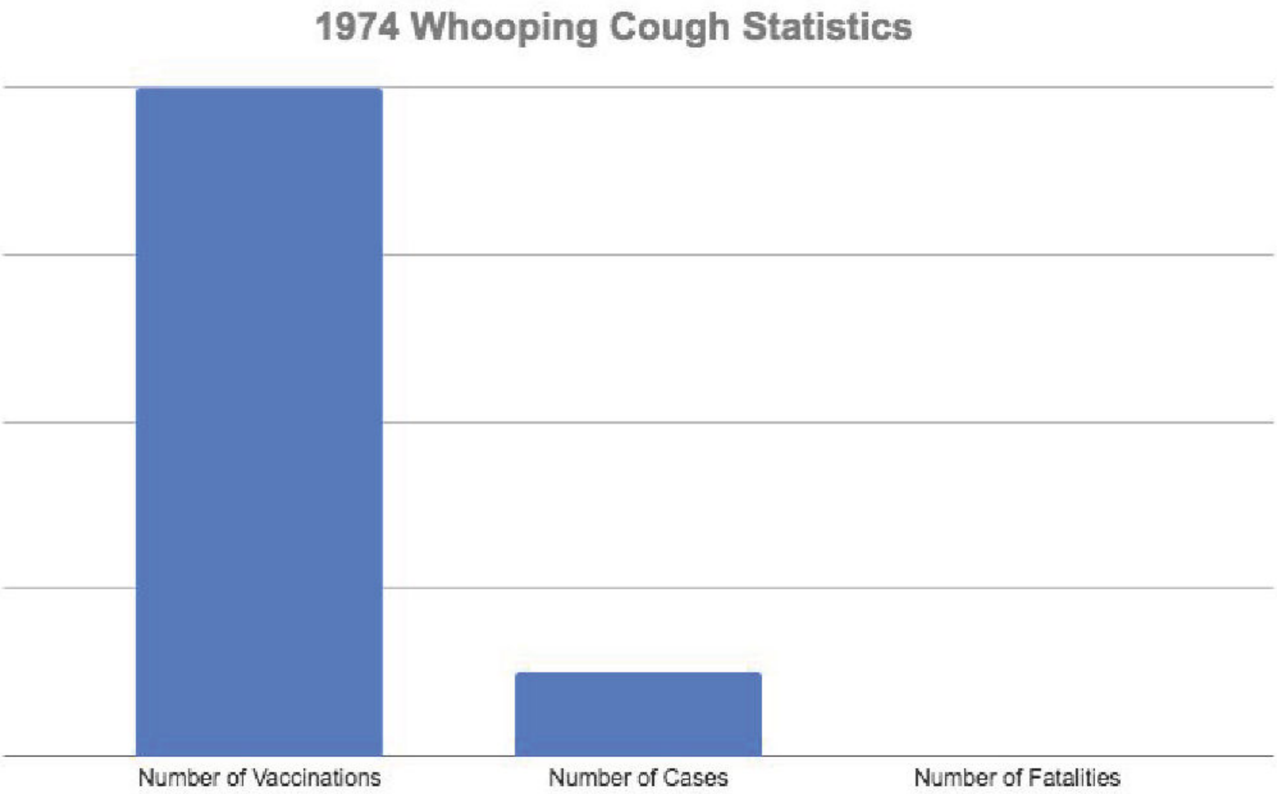
Image Credit: **Michigan Medicine University of Michigan, adapted from the Centers for Disease Control and Prevention**

- Ask: How does "flattening the curve" benefit the population?
    - Scholars should explain that flattening the curve would help countries' medical infrastructures keep up with increasing demand.
    - Explain that even with the curve flattened, a similar number of people were still predicted to be infected with COVID-19. The main difference between the blue and yellow regions on the graph is along the x-axis, meaning that if the curve is flattened, the infections will simply occur over a longer period of time. This would allow hospitals to treat a smaller number of patients at a time, making it less likely that they would run out of hospital beds and other important equipment and supplies.

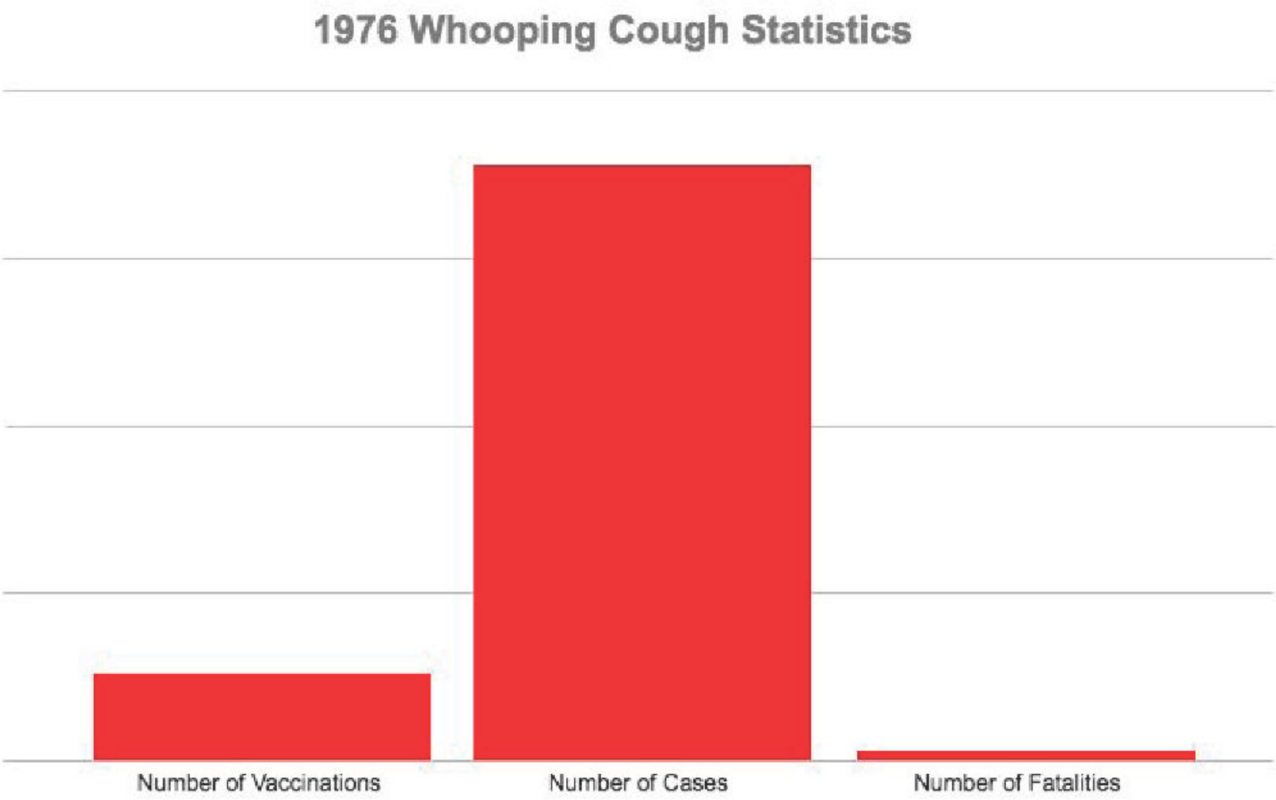
- Then, ask: Why isn't the goal to just reduce the number of COVID-19 cases as much as possible? Aside from that being unrealistic, might there be any benefit to a large number of individuals contracting COVID-19 in the absence of a vaccination?
    - Scholars should make connections to herd immunity.
        - Note to scholars that recovering from an infection often leaves you immune to future infection but not always: whether individuals will be immune to a virus after contracting it is dependent on both the individual and the virus.

Accountability (Exit Ticket) Directions: Read "**The Importance of Vaccinations**" by Family Doctor.

The graph below represents the number of vaccinations, cases, and fatalities related to whooping cough in Japan for the year 1974.



1. Using the information provided, make a prediction of what the data might have looked like in the year 1976 by completing the blank graph below. [2]



2. Explain and justify your response to Question 1. [2]

If the number of vaccinations decreased from 80% to 10%, the number of cases would increase. This is because there would no longer be herd immunity to the disease, and it would again begin to spread rapidly.

Scoring

1. Award one point for each of the following:
    - A considerable decrease in the number of vaccinations
    - A reasonable increase in the number of cases and fatalities in comparison to the number of vaccinations
2. Award one point for each of the following:
    - An accurate explanation of their data
    - Connecting their predictions to the importance of herd immunity

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Lesson 8: Survival of the Fittest (Three Days)

Lesson Objective: By the end of day one, scholars can articulate how disease is a vehicle that drives natural selection. By the end of day two, scholars learn that natural selection acts upon viruses despite being nonliving due to mutation, which causes them to evolve. By the end of day three, scholars learn that the *overuse* of antibioticsâ€" drugs designed to stop harmful bacteriaâ€" leads to the evolution of bacteria, causing them to become antibiotic resistant.

Materials Needed

- Day One:
    - For the teacher: 4 hot plates, 1 Bunsen burner (or alcohol burner), 4 beakers, water, glass beads, heat-resistant gloves, 4 bottles of agar, B. cereus broth, E. coli broth, petri dishes (2 per group), 4 pipettes, 1 permanent marker, goggles, gloves, apron, disinfectant wipes
    - For each group: 14 individually packaged isopropyl alcohol cleansing wipes, 1 petri dish of B. cereus, 1 petri dish of E. coli, 2 forceps, 2 of each antibiotic disc, 2 control discs, 1 permanent marker, clear tape, disinfectant wipes, 2 **Disc Placement Guides**
    - For each scholar: gloves, goggles, apron
- Days Two and Three:
    - For each group: 2 metric rulers, group's prepared petri dishes from day one, 2 **Disc Placement Guides**
    - For each scholar: gloves, goggles, apron

Prep

- Intellectual Prep:
    - **The Essential Role of Retroviruses in Evolution | Ethan W Taylor | TEDxHighPoint Video** by TEDx Talks (18 minutes, 16 seconds)

- **Evolution of Viruses** by Khan Academy
- **Antibiotic/Antimicrobial Resistance (AR/AMR)** by Centers for Disease Control and Prevention

- Materials Prep:
    - Day One:
        - Send scholars the following links:
            - **Timeline: The Evolution of Life** by New Scientist
            - **Did the Microbiome Help Drive Human Evolution?** by STAT
        - Print two copies of the **Disc Placement Guide** for each group.
        - Follow the instructions on pages 8 and 9 in the **Antibiotic Sensitivity Teacher's Manual*** by Carolina Biological Supply Company to prepare the materials for day one. Please note the following:
            - *Hard copies of the Teacher's Manual are included in the kits. If you wish to access online Carolina Biological upply Company resources, create a login and retrieve the redemption code once the kit is ordered.
            - Steps 11 and 12 call for a water bath. Instead, use the **Melting the Agar Procedure** in the Extra Resources Folder.
            - Prior to adding the bacterial solutions to the petri dishes, use a permanent marker to draw an arrow pointing upward on the outside of the bottom of the dish. This will allow scholars to better identify the placement of the antibiotic discs as they set up their experiment and record their data.
            - Scholar procedures have been altered to eliminate materials that have high safety risks (e.g., they will be using alcohol wipes instead of Bunsen burners to disinfect forceps between use). Review the scholar procedures in the Lab Notebook for additional information.
    - Day Two:
        - Send scholars a link to **Why It Takes so Long to Develop a Coronavirus Vaccine** by The Hill.

What are scholars doing in this lesson?

- Scholars participate in a three-day lab to discover how bacteria become antibiotic resistant. In the meantime, on day one scholars will discuss how pathogens are vehicles for natural selection in other organisms. On day two, scholars will discuss how viruses themselves mutate. By day three, scholars will review the results of their lab and find that antibiotic resistance occurs when bacteria evolve.

Day One

Do Now

- Follow the **Do Now plan**.

Launch

- Show scholars **this Pinterest image**, and tell them that this was the first phylogenetic tree drawn by Charles Darwin in 1837.
- Tell scholars that since then, phylogenetic trees have undergone many revisions and now look very different. Then, show scholars **this New York Times image**.
- Allow scholars to explore **Timeline: The Evolution of Life** by New Scientist.
    - Have scholars share out their findings. Press scholars to explain that all life on earth evolved from prokaryotic cells, similar to the bacterial cells they have been studying during this unit!
- Tell scholars that over the course of the next three days, they will be more deeply studying the relationships between viruses, bacteria, and evolution.

Activity

- Scholars work to complete the procedure in their Lab Notebooks to set up a lab that they will be revisiting over the next two days. In the lab, they will observe antibiotics' effect on bacterial growth.
- Then, they consider the following discussion questions:
    - What is the purpose of the control disc?
    - Why is it important to sterilize the forceps between each use?
    - What do you expect to see if the bacteria are sensitive to an antibiotic?
    - What do you expect to see if the bacteria are resistant to an antibiotic?

Discourse Debrief activity:

- Review discussion questions 3 and 4 with scholars. Then, tell them that over the course of the next two days, they will be gathering data to formulate conclusions about bacteria's antibiotic sensitivity.

Make broader connections:

- Tell scholars that despite having many ways to treat disease (such as antibiotics), bacteria and viruses have played a crucial role in evolution.
- Read the **Did the Microbiome Help Drive Human Evolution?** by STAT with scholars.
    - Ask: How have bacteria shaped the evolution of other organisms?

- Show scholars by The Atlantic (2 minutes, 15 seconds).
    - Ask: How have viruses contributed to human evolution?
        - As scholars explain that 8 percent of the human genome is from endogenous retroviruses, tell them that this can only occur if viral replication and insertion occurs in the germline. Then, ask scholars to explain why this is the case.
- Ask: What is the driver of evolution in organisms?
    - Define **natural selection**.
        - Ask: How might viral and bacterial infections be related to natural selection?
            - Scholars should explain that when a new pathogen is introduced into a population, members of the population that are able to resist or fight off the infection (due to their physical condition or DNA) are likely to live longer and go on to reproduce more.

Accountability (Exit Ticket) The image below shows a process known as insertional mutagenesis, in which a mouse genome is impacted by a virus.

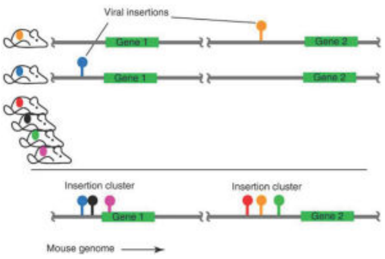

Image Credit: **Springer Nature**

1. Which of the following is a direct effect of insertional mutagenesis on the mouse? [1]
    1. Genetic recombination would occur due to the exchange of genetic material between different organisms during meiosis.
    2. The virus replicates using the host DNA machinery, resulting in the destruction of the infected cell and its membrane.
    3. Transcription and translation would be altered due to the insertion of additional base pairs.
    4. None of the above
2. Describe the role that pathogens such as virions and bacteria play in the evolution of other organisms. Explain and justify your response. [3]

Pathogens play a role in human evolution through natural selection. When a pathogen is introduced to a population, members of the population that are able to resist or fight off the infection are likely to live longer and go on to reproduce more. This will result in those beneficial traits becoming more common within the organisms' populations.

Scoring

1. Award one point for a correct response.

2. Award one point for each of the following:

    - An accurate claim, which describes the role pathogens play in evolution
    - A clear explanation of the phenomenon described in the claim
    - A justification, which explains how this phenomenon leads to the evolution of a population

---

Day Two

Do Now

- Follow the **Do Now plan**.

Launch

- Ask scholars to recap what they learned yesterday.
    - Viruses and bacteria have played key roles in the evolution of living organisms, including humans.
- Tell scholars that over the course of the next two days, we will be taking a closer look at how natural selection impacts the evolution of viruses and bacteria.

Activity

- Scholars collect data for the antibiotic resistance lab following the procedure in their Lab Notebooks. Then, they consider the discussion question:
    - The clear area around the antibiotic discs is called a “zone of inhibition.” Why do you think the clear area is called that?
    - What does today’s data indicate about the bacteria’s sensitivity to these antibiotics?

Discourse Debrief activity:

- Review the discussion question with scholars.
    - Scholars should explain that the clear area indicates that the antibiotic is inhibiting bacterial growth.

Make broader connections:

- Remind scholars that while antibiotics are not effective on viruses, there are antivirals and vaccinations that can stop their spread. Then, ask: Why are antivirals and vaccinations sometimes more challenging to produce than antibiotics?

- Ask: So far, we have discussed the evolution of other creatures in response to viruses. But what about the viruses themselves? Can viruses evolve?
    - Allow scholars to debate about this. They should come to the conclusion that because they have genetic material that must replicate, and in some cases endure reverse transcription, mutations can occur just like they would in any other DNA or RNA. Because their genetic information can be changed by mutations, natural selection acts upon them, allowing them to evolve despite being nonliving.
    - Show scholars the **How Do Mutations Affect the Development of Coronavirus Vaccine? Video** by TRT World Now (1 minutes, 9 seconds).

Make connections to the Essential Question:

- Read "**Why It Takes so Long to Develop a Coronavirus Vaccine**" by The Hill with scholars.
    - Ask: How does this add to your understanding of why pandemics tend to be viral rather than bacterial?
        - Scholars should be able to explain that because viruses mutate quickly, it is harder to develop vaccines and achieve herd immunity. Press scholars to make a connection between how vaccinations work and why frequent mutations present a challenge for the development of a vaccine.

Accountability (Exit Ticket) The following is an excerpt adapted from **AP® Biology Curriculum Framework 2012–2013**:

When genetic information changes, the results may be observable changes in the organism. At the molecular level, these changes may be the result of mutations in the genetic material, the effects of which may be seen during protein synthesis.

Transcription, mRNA processing and translation are imperfect. Errors can occur and may alter phenotypes. However, these errors are random and are not heritable except in the case of RNA viruses where the random errors change the genetic information of the virus.

Environmental factors can affect the degree of, or the probability of, errors in the information and processing. Genetic variations at the genome level, when expressed as phenotypes, are subject to natural selection.

1. Select the statement that best describes why changes in some viral genomes occur. [1]
    1. Mutations in DNA and recombinations during meiosis are sources of variation.
    2. Mitosis passes a complete genome from the parent cell to daughter cells.
    3. Errors in mitosis or meiosis can result in changes in phenotype.
    4. Errors during reverse transcription are integrated into the host genome and become transcribed and translated for the assembly of new viral progeny.
2. Newscasters on a popular news broadcasting channel were discussing the impact of natural selection on viruses, and the following claim was made: "We do not need to worry about COVID-19 evolving because viruses are nonliving. Only living organisms can evolve." Assess the scientific accuracy of this claim. Explain and justify your response. [3]

This claim is scientifically inaccurate because while it is true that viruses are nonliving, they do have genetic material that can mutate. If these mutations are beneficial to the virus, natural selection may cause these mutated traits to become more abundant and the virus may evolve over several generations.

Scoring

1. Award one point for a correct response.
2. Award one point for each of the following:

    - Stating that this claim is scientifically inaccurate
    - Explaining that viruses are capable of mutation
    - Connecting mutations to evolution

Day Three

Do Now

- Follow the **Do Now plan**.

Launch

- Have scholars recap what they learned yesterday.

    - Despite being nonliving, viruses mutate and evolve due to natural selection.

- Tell scholars that today, they will collect their final round of data for the antibiotic resistance lab and formulate conclusions.

Activity

- Scholars collect their final round of data for the antibiotic resistance lab. Then, they answer the analysis questions in their Lab Notebooks to formulate conclusions:

    - How can you tell if an antibiotic is sensitive or resistant to an antibiotic? Explain your reasoning.
    - Based on your data, fill in the table below as to whether each type of bacteria is sensitive (S) or resistant (R) to each type of antibiotic.
    - Why did the overall effectiveness of the antibiotics differ between the bacterial species you tested? Explain your reasoning.

Discourse Debrief experiment/activity:

- Have two to three groups share their response to analysis question 1.

    - Scholars should explain that the areas where bacterial growth is occurring are cloudy and that the growth is seen everywhere except for some of the antibiotic discs, where some have clear rings (called a "zone of inhibition"). They should also explain that there is a zone of inhibition if the bacteria is sensitive to the antibiotic, but there is no zone of inhibition and the bacteria grow up to the edge of the antibiotic if they are resistant.

        - Define **antibiotic resistance**.

- Display exemplar scholar work for analysis question 2.
    - Exemplar scholar work should have concluded the following:

Bacteria	Penicillin	Genta.	Ampicillin	Chlora.	Strept.	Tetra.
E. coli	R	S	S	S	S	S
B. cereus	R	S	R	S	S	S

- Review analysis question 3 with scholars.
    - Scholars should conclude that the effects were similar for both species for all antibiotics except for ampicillin, which was effective against E. coli but not B. cereus because B. cereus is resistant to ampicillin.
- Return to the antibiotic resistance lab experimental question and ask: Why do we need so many types of antibiotics?
    - Scholars should explain that bacteria have the ability to become antibiotic resistant.

Make broader connections:

- Show scholars **The Evolution of Bacteria on a "Mega-Plate" Petri Dish (Kishony Lab) Video** by Harvard Medical School (1 minute, 54 seconds).
    - Ask: How can bacteria become antibiotic resistant?
        - Press scholars to form a connection between natural selection and the evolution of bacteria. Ensure they understand that no individual bacterium evolves but that instead, the bacteria that can survive the increasing antibiotic doses survive and reproduce, while the bacteria that cannot withstand the antibiotic perish.

Make connections to the Essential Question:

- Ask: If both viruses and bacteria can evolve and present challenges for treating infectious disease, why do pandemics more typically have viral causes?
    - Scholars should explain that viral mutations happen much more frequently due to the nature of their replication, and that this presents a challenge to create a vaccine in the first place, causing them to spread rapidly.
- Show scholars **How Can We Solve the Antibiotic Resistance Crisis? Video** by TED-Ed (6 minutes, 22 seconds). Ask:
    - What human activity causes antibiotic resistance?

- How can we prevent the evolution of antibiotic resistant bacteria?
    - By the end of this discourse, scholars should understand that the overuse of antibiotics leads to antibiotic resistance.

Accountability (Exit Ticket) According to “Leading Antimicrobial Drug-Resistant Diseases” by *NIH MedlinePlus Magazine*:

Mycobacterium tuberculosis is the bacterium that causes tuberculosis (TB). TB is an often-severe airborne disease caused by a bacterial infection. TB typically affects the lungs, but it also may affect many other organs of the body. It is usually treated with a regimen of several drugs taken for six months to two years, depending on the type of infection. In most cases, TB is treatable. However, some bacteria are becoming resistant to the two most potent TB drugs. This is known as multidrug-resistant TB (MDR TB).

1. Describe why some bacteria such as Mycobacterium tuberculosis become antibiotic resistant. [2]

Some bacteria become antibiotic resistant because the individual microorganisms are able to survive the application of antibiotics due to favorable mutations and other genetic differences. Those bacteria that survive will continue to grow and multiply, passing their DNA on to their offspring and creating new populations of evolved antibiotic-resistant bacteria.

Scoring

1. Award one point for each of the following:
    - Explaining why some bacteria survive the initial application of the antibiotic
    - An explanation of how antibiotic resistance occurs

Lesson 9: #WashYourHands

Lesson Objective: Scholars learn that some products available to eliminate microorganisms are more effective than others due to the structural differences between viruses and bacteria.
Materials Needed

- For the teacher: 3 bowls, water, gloves, goggles, dish soap, ground pepper, hand sanitizer
- For each group: chart paper, flip chart markers
- For each scholar: computer

Prep

- Intellectual Prep:
    - **Why Soap Works** by The New York Times

What are scholars doing in this lesson?

- Scholars use a model to discover how soap works and investigate whether it is more effective than hand sanitizer.

Do Now

- Follow the **Do Now plan**.

Launch

- Tell scholars that as whole cities and countries shut down due to COVID-19 outbreaks, many consumers rushed to stores to purchase items that they believed would protect them from the quickly spreading virus. During this unprecedented time, stores across the globe frequently sold out of hand sanitizer before liquid hand soap.
    - Ask: Why do you think hand sanitizing products sold out of stores faster than soap?
        - Ask: Is one of these products more effective than the other at keeping individuals safe from a viral outbreak?
        - Tell scholars that today, they will investigate to find the answer!

Research

- Scholars work in groups to research to evaluate the efficacy of soap and hand sanitizer by following the directions in their Lab Notebooks:
    - Groups formulate hypotheses to answer the experimental question, “Is soap or hand sanitizer more effective than the other at keeping individuals safe from a viral outbreak?”
    - Scholars use their computers to research this question and take notes in their Lab Notebooks.
    - Groups use chart paper to communicate their findings.

[**Tip:** As a scaffold, you may offer scholars two to four websites on which to conduct their research.]

Discourse Debrief activity:

- Two to three groups present their findings to the class.
- Scholars discuss the findings to formulate conclusions as a class. Use the following questions to move the conversation if needed:
    - Were your original hypothesis accurate? Why or why not?
    - How does soap work?
    - How does hand sanitizer work?
    - Is one of these products more effective at eliminating the novel coronavirus than the other? Why or why not?
        - Scholars should be able to explain that soap breaks down viral structures as the running water washes them down the drain. They should also be able to explain that while sanitizer can also break down viral structures, its effectiveness is dependent on many factors (such as its percentage of

alcohol and how much sweat/grease is on your hands) and that it does not remove viruses in the same way running water does.

- Model the effectiveness of water alone, soap, and hand sanitizer by demonstrating **this experiment**:
    - Fill three bowls with water.
    - Sprinkle ground pepper flakes all over the surface of the water in each bowl.
        - Tell scholars that in this model, the surface of the water in the bowl represents our skin and the pepper represents the viruses on our skin.
    - Wet your finger with water only and use that finger to touch the pepper flakes floating in the first bowl.
        - Scholars will observe that the pepper flakes remain unchanged.
            - Ask: Did water alone have any effect on the virus? Explain.
    - Dip your finger in hand soap and then use that finger to touch the pepper flakes floating in the second bowl.
        - Scholars will observe that the pepper flakes spread apart.
            - Ask: Did soap have any effect on the virus? Explain.
    - Dip your finger in hand sanitizer and then use that finger to touch the pepper flakes floating in the second bowl.
        - Scholars will observe that the pepper flakes spread apart.
            - Ask: Did hand sanitizer have any effect on the virus? Explain.
    - Show scholars **How Soap Kills the Coronavirus Video** by Vox(3 minutes, 44 seconds).

Make broader connections:

- Show scholars **this diagram** of a virus.
    - Ask: How does soap destroy a virus's structures?
        - Scholars should be able to explain that the lipid envelope and protein capsid are "pulled apart" due to the molecular structure of soap and how it interacts with fats and proteins.

- Show scholars this Pinterest diagram of a bacterium:
    - Ask: Based on its structures, can soap destroy a bacterium in the same way it destroys a virus?
        - Scholars should determine that because they have different structures, the bacterium may not be "pulled apart" by soap in the same way.
            - Tell scholars that regular hand soap and running water works by washing bacteria down the drain but does not destroy them.

Make connections to the Essential Question:

- Tell scholars that some soaps are antibacterial while others are not. Then, ask:
    - Do you think antibacterial soap would be more effective at eliminating the novel coronavirus than the other? Why or why not?
        - Scholars should conclude that since it is a virus, not a bacterium, antibacterials will not have any added effect on the novel coronavirus.
    - Would the spread of COVID-19 be easier to stop if it was caused by bacteria instead of viruses? Why or why not?
        - Scholars should conclude that if COVID-19 was caused by bacteria, it would be easier to stop because bacteria can be eliminated more easily.
- Scholars have five minutes to answer the question in their Lab Notebooks. This will count as the Exit Ticket for today.

Accountability (Lab Notebook)

1. During the COVID-19 outbreak, Saleem went to the store to pick up some items to help protect himself from the quickly spreading virus. He found there were three options to choose from: hand sanitizer, antibacterial soap, and regular soap. Is one of these items more effective at protecting him from a viral outbreak than the others? Explain and justify your response. [3]

Possible Exemplars:

Soap would be more effective at protecting Saleem from COVID-19 than hand sanitizer would be. This is because soap destroys viruses by rupturing them as the water washes them off your hands and down the drain, whereas hand sanitizer does not completely break down and remove the viruses on your hands. It would not matter whether the soap was antibacterial or not because viruses are different from bacteria, so either type of soap would do the job effectively as long as Saleem washes his hands properly!

Plain soap and water would be the best option for Saleem. The unnecessary use of antibacterial products could lead to more bacterial evolution, making more bacteria resistant to them. Also, for hand sanitizer to work, it must have enough alcohol, and if it doesn't, it won't kill the virus. Plus, over time, repeated use can irritate the skin.

Scoring

1. Award one point for each of the following:

    - Identifying that soap is more effective than hand sanitizer at eliminating viruses
    - Explaining that antibacterial soap and regular soap are similarly effective, and/or highlighting the potential dangers of the unnecessary use of antibacterial products
    - A scientifically accurate reason for why the product(s) identified as more effective work better than the other(s)

Lesson 10: Fake News

Lesson Objective: Scholars can clearly explain why pandemics tend to be viral rather than bacterial and provide relevant evidence from the unit. Materials Needed

- For each scholar: a copy of the **Final Project Rubric**, computer

Prep

- Materials Prep:
    - Print/send scholars copies of the **rubric** in advance of class.

What are scholars doing in this lesson?

- Scholars answer the question through the composition of a written response. They include supporting evidence from several lessons to strengthen their arguments.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: What are some things you heard about COVID-19 that turned out not to be true?
    - Tell scholars that some information passed around on social media and news outlets can be misleading or not based on scientific evidence. Then, ask: Why might this happen?
- Explain to scholars that this is their opportunity to educate others about pandemics! In this lesson, they will compose written responses that answer the Essential Question.
- Outline the essay format and share the rubric.
    - Review each section of the **rubric** together and ensure scholars understand the assignment.

Activity

- Using the project rubric as a guide, scholars begin writing essays to answer the unit's Essential Question!
- As scholars are working, circulate and ask them how they are incorporating evidence from the unit into their materials. Study scholar work and identify any lingering misconceptions, pausing to coach scholars and help them update their notes as needed. (At this point in the unit, these should be rareâ€" if you identify a misconception, make a plan to round back with the scholar[s] before the final exam to allow them extra opportunities for practice.)

Presentations

- Scholars present their work to the class.
    - Scholars evaluate each presentation and offer positive and constructive feedback.
        - If time allows, scholars can use copies of the rubric to perform peer and/or self evaluations.

Accountability (Essays)

Grade scholar projects. Look for evidence of writing with best effort and give feedback on explaining claims with strong support from scientific knowledge learned throughout the unit.

- Directions: Compose an essay that answers the Essential Question. Support your argument by including information about the scientific concepts you learned throughout the unit and explaining their connection to the Essential Question.

Scoring

- Score scholars out of six points using the provided rubric.

Unit Vocabulary

Vocabulary List

- **outbreak**
- **endemic**
- **epidemic**
- **pandemic**
- **epidemiologist**
- **patient zero**
- **susceptibility**
- **mode of transmission**
- **R_0**
- **infectious period**

- **incubation period**
- **case fatality rate (CFR)**
- **microorganism**
- **germ theory of disease**
- **taxonomy**
- **unicellular**
- **multicellular**
- **eukaryotic**
- **prokaryotic**
- **pathogen**
- **virus**
- **virology**
- **virion**
- **genome**
- **bacteria**
- **bacterium**
- **binary fission**
- **progeny**
- **lytic cycle**
- **lysogenic cycle**
- **reverse transcription**
- **lysis**
- **immune system**
- **innate immune response**
- **adaptive immune response**
- **phagocyte**
- **lymphocyte**
- **antibody**
- **antigen**
- **inflammatory response**
- **antibiotic**
- **antiviral**
- **vaccine**
- **immunity**
- **herd immunity**
- **evolution**
- **natural selection**
- **antibiotic resistance**