SUCCESS ACADEMY EDUCATION INSTITUTE

Life Science:
Unit 7

Introduction to Microbiology: Introduction

Purpose: The Why, What, and How of This Unit

Essential Question: Why do pandemics tend to be viral rather than bacterial?

Unit Storyline Synopsis: Scholars engage with the Essential Question by considering what causes pandemics and how they vary in severity. They will be asked to define what makes one pandemic more serious than another. Is it the case fatality rate? The incubation period? The R_0? How can we quantify the toll a pandemic takes on its affected population? Scholars already know about microorganisms and may think they understand them, but they will quickly realize as they study taxonomy that microorganisms come in many forms and not all of them result in illness.

After taking a closer look at various microorganisms, they will study the structure and function of the two pathogens that most frequently cause disease in humans: bacteria and viruses. They will learn how pathogens infect organisms at the microscopic level, using the host's own biological processes, and based on this information, scholars will consider why pandemics more frequently have viral causes. Is it their structure? Is it how they infect hosts? Is it how hosts respond? Then, scholars will consider how (or if!) these pathogens can be stopped by studying immunity.

At the end of the unit, scholars apply their understanding of pathogens as they study how bacteria and viruses evolve through natural selection. They also learn that pathogens themselves are vehicles of natural selection in other living organisms and have greatly impacted the trajectory of their evolution. Finally, scholars conclude the unit by composing written responses to share their newfound knowledge of viruses, bacteria, and the spread of pandemics.

Why This Unit? Scholars study a real-world problem that has recently upended their day-to-day lives: the spread of disease. During the COVID-19 outbreak, inaccurate information about the disease has

spread through social media and news outlets alike. But how can scholars evaluate all of the information being thrown at them and make reasonable conclusions about the truth behind global crises like these? In this unit, scholars uncover the science behind pandemics like COVID-19. They build upon their prior knowledge of genetics and biology to better understand the behavior of pathogens like viruses and bacteria, as well as their spread. The discoveries made and connections drawn in this unit will benefit scholars greatly as they prepare for high school– and college-level science.

What Is the Bottom Line?

Big Idea: Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.

- Homeostatic control systems in species of microbes, plants, and animals support common ancestry.
- Disruptions at the molecular and cellular levels affect the health of the organism.
- Plants, invertebrates, and vertebrates have multiple nonspecific immune responses.
- Mammals use specific immune responses triggered by natural or artificial agents that disrupt dynamic homeostasis.

Big Idea: Heritable information provides for continuity of life.

- DNA, and in some cases RNA, is the primary source of heritable information.
- Genetic information is stored in and passed to subsequent generations through DNA molecules and, in some cases, RNA molecules.
- DNA replication ensures continuity of hereditary information.
- Genetic information in retroviruses is a special case and has an alternate flow of information: from RNA to DNA, made possible by reverse transcriptase, an enzyme that copies the viral RNA genome into DNA. This DNA integrates into the host genome and becomes transcribed and translated for the assembly of new viral progeny.
- Genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a protein.

Big Idea: The processing of genetic information is imperfect and a source of genetic variation.

- Bacteria divide by binary fission, allowing for rapid evolution.
- DNA mutations can be positive, negative, or neutral based on the effect or the lack of effect they have on the resulting nucleic acid or protein and the phenotypes that are conferred by the protein. Whether or not a mutation is detrimental, beneficial, or neutral depends on the environmental context. Mutations are the primary source of genetic variation.
- Errors in DNA replication can cause mutations in the DNA.
- Changes in genotype may affect phenotypes that are subject to natural selection. Genetic changes that enhance survival and reproduction can be selected by environmental conditions.
- Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts.
- Viruses have highly efficient replicative capabilities that allow for rapid evolution and acquisition of new phenotypes because they replicate via a component assembly model, allowing one virus to produce many progeny simultaneously via the lytic cycle.

- RNA viruses lack replication error-checking mechanisms and thus have higher rates of mutation.
- The reproductive cycles of viruses facilitate transfer of genetic information because viruses transmit DNA or RNA when they infect a host cell. Some viruses are able to integrate into the host DNA and establish a latent (lysogenic) infection. These latent viral genomes can result in new properties for the host, such as increased pathogenicity in bacteria.

How do Next Generation Science Standards practices and crosscutting concepts support mastery of the Big Ideas? Science and Engineering Practices highlighted in this unit:

- **Analyzing and Interpreting Data**
- **Engaging in Argument from Evidence**
- **Obtaining, Evaluating, and Communicating Information**

Crosscutting Concepts highlighted in this unit:

- **Structure and Function**
    - Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural structures/systems can be analyzed to determine how they function.
- **Patterns**
    - Macroscopic patterns are related to the nature of microscopic structure.
    - Graphs, charts, and images can be used to identify patterns in data.
    - Patterns in rates of change and other numerical relationships can provide information about natural systems.
    - Patterns can be used to identify cause-and-effect relationships.

Safety

Plan carefully for safety in all lessons. The top safety risks in this unit include:

- Lesson 2 involves the use of phenolphthalein. Review all safety information and the Safety Data Sheet for **phenolphthalein** to ensure proper safety precautions are taken before conducting this lesson. Note that only teachers should use the phenolphthalein in this lesson. Ensure that scholars wear proper personal protective equipment (PPE) as indicated in this lesson.
- Lesson 2 involves the use of sodium hydroxide. Review all safety information and the Safety Data Sheet for **sodium hydroxide** to ensure proper safety precautions are taken before conducting this lesson. Ensure that scholars wear PPE as indicated in this lesson.
- In Lesson 8, teachers will prepare an experiment that requires an open flame. Ensure that teachers are aware of the risks associated with using the flame and understand how to conduct the experiment safely. Work with your manager to develop clear directions and ensure teachers are aware of all necessary safety precautions that must be taken.

- In Lesson 8, teachers will use a hot plate. Ensure that teachers are aware of how to work with hot materials safely to avoid accidentally burning themselves, as well as what to do should they burn themselves. All materials should be handled with oven mitts as there is no way to see whether materials are too hot to touch. Ensure that teachers wear proper PPE as indicated in this lesson. Ensure hot plates are turned off at the end of the preparation. Check glassware for chips or cracks before placing on a hot plate as the heat can cause the glass to shatter if already damaged.
- In Lesson 8, scholars will be working with E. coli and B. cereus broth cultures grown in nutrient agar and placing antibiotic disks. Review all safety information for the following to ensure proper safety precautions are taken before conducting these lessons. The E. coli and B. cereus broth cultures used in this activity are classified by the CDC as BSL-1 (low risk microorganisms). Review the safety guidelines for BSL-1 microorganisms from **Carolina Biological Supply Company** and from pages 30–32 of the **Centers for Disease Control and Prevention's Biosafety in Microbiological and Biomedical Laboratories**. Ensure that scholars wear proper PPE as indicated in this lesson.
    - Some scholars may be allergic to one or more of the antibiotics being used. Ensure you are aware of all scholar allergies and do not expose scholars to allergens.
    - Review all safety information and the Safety Data Sheet for **nutrient agar** to ensure proper safety precautions are taken before conducting this lesson.
- Lesson 8 involves the use of isopropyl alcohol wipes. Review all safety information and the Safety Data Sheet for **isopropyl alcohol wipes** to ensure proper safety precautions are taken before conducting this lesson. Ensure that scholars wear proper PPE as indicated in this lesson.

Important Note: These lesson plans highlight some of the safety risks you should be aware of while teaching these lessons. These safety suggestions are not meant to take the place of a formal science safety training. Please be sure to follow all safety rules from your district, as well as all local, state, and federal science safety guidelines.

Unit Storyline

Engage: Scholars investigate the history of pandemics as they are introduced to this unit's Essential Question: Why do pandemics tend to be viral rather than bacterial?

- **Lesson 1: Going Viral.** Scholars investigate the history of pandemics. As they take a closer look at their facts and figures, they notice that pandemics are caused by viruses more often than they are caused by bacteria.

Explore: Scholars discover how pandemics spread and begin to lay a foundation for answering the Essential Question by learning about taxonomy and digging deeper into the nature of microorganisms.

- **Lesson 2: The WHO?** Scholars are thrown into the world of epidemiology as they model the spread of a pandemic. As they learn about the different factors that influence their spread, they begin to consider what makes one outbreak more severe than another.
- **Lesson 3: Tree of Life.** Scholars are introduced to taxonomy and learn that microorganisms can come in various forms as they view microscope slides. They also learn that not all microorganisms cause illness and that many are actually beneficial to other living organisms.

Explain: Scholars learn that while viruses are nonliving and thus not classified as microorganisms, they are categorized as pathogens along with bacteria and other disease-causing microorganisms. They also learn about how viruses and bacteria replicate. Then, they get an in-depth look at the immune system and study how the spread of disease can be slowed by scientific innovations such as vaccinations, antibiotics, and antivirals. By the end of the Explain, scholars will understand how pathogens cause illness as well as the biological and scientific defenses we have to fight them.

- **Lesson 4: "Germs".** Scholars look at microslides in order to compare the structures and functions of bacteria and viruses. As scholars study their similarities and differences, they see that virusesâ€" despite being nonlivingâ€" have specific structures that allow them to infect their hosts.
- **Lesson 5: Molecular Hackers (Two Days).** How are such tiny pathogens capable of causing such major homeostatic disruptions? Scholars take a closer look at how bacteria undergo binary fission and viruses "hack" the biological processes of their hosts in order to replicate.
- **Lesson 6: Fighting Back!** Scholars study the immune system to better understand how these pathogens can be stopped. They also gain a better understanding of an illness's symptoms after seeing immune responses in action!
- **Lesson 7: Stopping the Spread.** Scholars learn that herd immunity is achieved when a sufficient amount of an affected population becomes immune to a disease and that this protects other members of the population who are not. They also understand that the least disruptive way to achieve herd immunity is through vaccination.

Elaborate: These lessons are designed to help scholars draw connections between the structures of pathogens and their survival. As scholars participate in a three-day lab to take a deeper look at antibiotic-resistant bacteria, they discover that disease is a vehicle of natural selection in other organisms and learn quickly that multicellular organisms are not the only life to evolve as a result of natural selection. Then, scholars study how and why the efficacy of good hygiene practices may vary.

- **Lesson 8: Survival of the Fittest (Three Days).** Scholars complete a three-day lab to learn how bacteria can become antibiotic resistant. As they do this, they learn that not only do viruses and bacteria evolve, they are also a mechanism for our own evolution as humans!
- **Lesson 9: #WashYourHands.** Scholars model how soap works and consider why various sanitizing products and medicines vary in their effectiveness at eliminating all pathogens.

Evaluate: Scholars use what they have learned throughout the unit to develop compelling responses to the Essential Question.

- **Lesson 10: Fake News.** Scholars synthesize their newfound knowledge and compose written responses to explain why pandemics are typically viral rather than bacterial.

Extra Resources

In addition to the resources linked throughout the guide, use the following materials to help you prepare to launch this unit with scholars:

- **Printable Exit Tickets**
- **Printable Lab Notebook**