1 *The Full Course*

INVESTIGATION

2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students use a model to explore the cause-and-effect relationship between the inappropriate use of antibiotics and the phenomenon of the evolution of antibiotic resistance. As they use the model, students use mathematical representations to support their analysis of patterns and trends in the results and to develop explanations for how and why the population of bacteria is changing. These explanations are based on the differential survival and reproduction of resistant bacteria when antibiotics are present in their environment (the human body they are infecting).

Prepare to teach the unit by reviewing the *Quick Start to Issues and Science*, found at the front of this Teacher Edition. This guide breaks down the resources and equipment needed to teach the unit. It calls out critical planning tools including the *NGSS Overview*, the *Phenomena, Driving Questions, and SEPUP Storyline* overview and the *SEPUP Scoring Guides*. For more detailed information on the program as a whole, see the "Issues and Science Program Overview" section of the *Teacher Resources*.

If this is your **first** SEPUP unit, read through "Planning for First-Time Users," found on the last page of the *Quick Start*.

Teacher's Note: This unit assumes that students have already completed the *Issues and Life Science* REPRODUCTION unit or other unit about genetics, specifically about how mutations lead to genetic variation.

NGSS CORRELATIONS

Performance Expectations

Working toward MS-LS4-4: Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

Working toward MS-LS4-6: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Disciplinary Core Ideas

MS-LS4.B Natural Selection: Natural selection leads to the predominance of certain traits in a population, and the suppression of others.

MS-LS4.C 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

Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings.

Developing and Using Models:

Develop and use a model to predict and/or describe phenomena.

Use and/or develop a model of simple systems with uncertain and less predictable factors.

Using Mathematics and Computational Thinking: Use mathematical representations to describe and/or support scientific conclusions and design solutions.

Crosscutting Concepts

Patterns: Patterns can be used to identify cause and effect relationships.

Cause and Effect: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Common Core State Standards—Mathematics

6.SP.B.5: Summarize numerical data sets in relation to their context.

6.RP.A.1: Understand the concept of a ratio, and use ratio language to describe a ratio between two quantities.

Common Core State Standards—ELA/Literacy

RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

INVESTIGATIVE PHENOMENA AND SENSEMAKING

Investigative Phenomena, Sensemaking

Humans can change the way species look or behave, including bacteria.

Students begin their sensemaking about evolution and natural selection by using a model to explore what happens when a person doesn't finish taking all of their prescribed antibiotics. Students begin to figure out that this affects the bacteria's environment, which can lead to changes in the population of bacteria.

WHAT STUDENTS DO

Students model the effects of antibiotics on a population of disease-causing bacteria during an infection. Students toss number cubes to determine whether an infected individual remembers to take the prescribed daily dose of antibiotics, which in turn affects the size and antibiotic resistance of the bacterial population in the patient. Students keep track of and graph the population size of the remaining bacteria, depending on their resistance to antibiotics. Students consider the effect of changing the chemical environment on the survival of bacteria with varying levels of antibiotic resistance.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  1 Scoring Guide: ORGANIZING DATA FOR ANALYSIS (ODA)
  Driving Questions Board cards and instructions

- *For each pair of students*
  1 set of 50 disks: 20 green, 15 blue, 15 orange
  4 colored pencils (including green, blue, and orange)
  1 number cube

- *For each student*
  1 Student Sheet 1.1, "Bacteria Graph"
  1 Scoring Guide: ORGANIZING DATA FOR ANALYSIS (ODA) (optional)

The ORGANIZING DATA FOR ANALYSIS (ODA) Scoring Guide can be found in the Assessment tab in the back of this Teacher Edition. Students can find "Keeping a Science Notebook" in Appendix E: Literacy Strategies in the Student Book.

The Driving Questions Board cards and instructions can be found in the front pouch of your printed Teacher Edition or as a download on the "Tools and Resources" page in your online Teacher Portal.

Student Sheet 1.1 has the axes drawn with tick marks and lines where the title, key, and axes labels should go. For students who need more scaffolding, consider filling in any or all of these blank lines before making copies.

TEACHING SUMMARY

GET STARTED

1. Engage students' interest by introducing the issue used to drive the learning in this unit.

   a. Have students read the vignette that opens the unit.
   b. Identify the societal issue that students will explore in the unit.
   c. Begin a Driving Questions Board.

2. Initiate students' sensemaking about evolution through a scenario of a sick person taking antibiotics.
   a. Ask students if they've ever taken an antibiotic when they've been sick.
   b. Have students read the scenario and the introduction.

DO THE ACTIVITY

3. (LITERACY) Introduce or review the use of a science notebook.

   Explain your expectations for the type and organization of students' notebooks.

4. Student pairs use a model to simulate taking antibiotics as prescribed or not as prescribed.
   a. Introduce students to the model by reviewing the box titled "A Bacterial Infection."
   b. Direct students to the Procedure.

5. (ODA QUICK CHECK) Students graph the results of their simulations.
   a. (MATHEMATICS) Distribute Student Sheet 1.1, "Bacteria Graph."
   b. Introduce or review the SEPUP Assessment System.
   c. Provide an overview of the Scoring Guides.
   d. Explain the expectations for student growth over time.

BUILD UNDERSTANDING

6. Students share their graphs and discuss them as a class.
   a. Ask two or three pairs to share and explain their graphs.
   b. Instruct students to answer Analysis item 1 individually in their science notebooks.

7. As a class, students discuss Analysis item 2.
   a. Students complete Analysis item 2.
   b. Have the groups you've identified share their explanations with the class.
   c. Pose questions to get students thinking about evolution and cause and effect.

8. The class revisits the Driving Questions Board.
   a. Tell students to complete Analysis items 3 and 4 in their science notebooks and then discuss their responses in their groups.
   b. Add students' new questions to the Driving Questions Board, and review them as a class.

TEACHING STEPS

GET STARTED

1. Engage students' interest by introducing the issue used to drive the learning in this unit.
   a. Have students read the vignette that opens the unit.

Anchoring Phenomenon

The vignette with Sasha and her family visiting the zoo and noticing a bird with an unusual bill is related to the front cover photo on the Student Book. After reading the text, have students examine the photo and/or read the description of the photo on the back cover. Ask them to generate some questions about the phenomenon presented in the vignette. If students are not familiar with the term *phenomenon* (or its plural form, *phenomena*), explain that a *phenomenon* is an observable fact or event. In this unit, student will investigate phenomena related to how populations change over both short and long periods of time. They will construct explanations and models based on disciplinary core ideas and crosscutting concepts related to evolution.

   b. Identify the societal issue that students will explore in the unit.

Defining Issues

Have students read the description of what they will investigate in this unit (following the vignette) and discuss how the unit may or may not answer their questions. Most importantly, identify that students will investigate the issue of how people are affected by and affect evolution.

   c. Begin a Driving Questions Board.

Driving Questions Board

In SEPUP, the Driving Questions Board elicits students' initial wonderings about the unit issue and the investigative phenomena; the class is then prompted to revisit the Driving Questions Board throughout the unit. Ideally, student questions generated at the start of each learning sequence can be condensed through class discussion into a unified driving question. As a scaffold to teachers who are new to this teaching strategy, driving questions cards are provided for each learning sequence and can be displayed as the unified driving question.

The driving questions are also identified on the Phenomena, Driving Questions, and SEPUP Storyline overview found in the NGSS and Common Core tab in the back of this Teacher Edition.

This activity starts a sequence of learning around the first driving question: How are humans affecting evolution? Students will revisit this question in the final sequence of the unit. Pose the question, and have students share their initial ideas.

2. Initiate students' sensemaking about evolution through a scenario of a sick person taking antibiotics.

   a. Ask students if they've ever taken an antibiotic when they've been sick.

      Follow this question by asking them if they can remember any specific instructions they received from their doctors about taking the antibiotic. Elicit students' ideas about the reasons for these instructions and whether they have always complied.

   b. Have students read the scenario and the introduction.

      Emphasize that doctors always instruct their patients to finish the full course of antibiotics; in this activity, students will use a model to understand why this instruction is so important. Emphasize that antibiotics are chemical substances that kill or inhibit the growth and reproduction of bacteria and other kinds of infectious agents, with the exception of viruses.

DO THE ACTIVITY

3. (LITERACY) Introduce or review the use of a science notebook.

   Explain your expectations for the type and organization of students' notebooks.

   Keeping a science notebook helps students keep track of data; record predictions, hypotheses, and questions as they investigate; process ideas; build scientific writing skills; and write lab reports. Keeping a Science Notebook in Appendix E of the Student Book provides suggested guidelines.

Teacher Resources
Science Notebook

4. Student pairs use a model to simulate taking antibiotics as prescribed or not as prescribed.

   a. Introduce students to the model by reviewing the box titled "A Bacterial Infection."

      In this model, bacteria are represented by plastic disks. The relative resistance to antibiotics is indicated by the color of the disk. Whether or not a person remembers to take the antibiotic on a given day is represented by the number on the cube; this represents uncertainty or unpredictability in the model.

b. Direct students to the Procedure.

Consider bringing the whole class together after one round to ensure that they understand the model. Provide support for students as they implement Procedure Steps 1–6.

5. (ODA QUICK CHECK) Students graph the results of their simulations.

a. (MATHEMATICS) Distribute Student Sheet 1.1, "Bacteria Graph."

Quick Checks

Have students use this Student Sheet to complete Procedure Step 7. In addition, point out the "Scatterplot and Line Graphing Checklist" in Appendix C in the Student Book, and review it with your class as necessary. While the Next Generation Science Standards (NGSS) expect students to be proficient at making this kind of graph by the end of fifth grade, some students may need reminding or the additional scaffolding provided on this Skill Sheet.

SEPUP Assessment System

b. Introduce or review the SEPUP Assessment System.

Explain that the graph assigned in Procedure Step 7 is the first assessment in this unit and that you will use it to introduce the SEPUP Assessment System to your students.

c. Provide an overview of the Scoring Guides.

Before assigning the assessment, distribute the ORGANIZING DATA FOR ANALYSIS (ODA) Scoring Guide, and use it to model how the system works. Point out the levels in the first column of the Scoring Guide. Tell students that these levels are the same for all Scoring Guides and range from 0 to 4. Review the descriptions of each level. For example, a Level 4 response is "complete and correct" in all Scoring Guides. Point out that the scores (0–4) are based on the quality of students' responses and do not correspond to letter grades. Allow students to refer to the Scoring Guide as they prepare their answers. Be sure they understand that the Scoring Guides do not include the specific content students must provide in their responses; rather, the guides explain the overall expectations for responses at various levels of performance on the task.

d. Explain the expectations for student growth over time.

Explain to students that they aren't expected to always produce complete and correct work on their first attempts. Instead, they should work toward developing consistent Level 3 and Level 4 answers as they become more proficient with the concepts (both disciplinary core ideas and crosscutting concepts) and the science and engineering practices being assessed. It is not necessary (or even expected) that an "A" student will always write Level 4 responses, especially at the beginning of the course or when they are introduced to a new Scoring Guide. For a sample Level 4 response, see the Sample Student Response to Student Sheet 1.1 at the end of this activity.

Let students know that they will not be formally assessed on their graphs at this time. Rather, this item is a Quick Check, which is an opportunity for you to gauge students' ability to organize data for analysis.

BUILD UNDERSTANDING

6. Students share their graphs and discuss them as a class

   a. Ask two or three pairs to share and explain their graphs.

   Select pairs whose graphs show different results, depending on when and how often they skipped a dose of antibiotics.

   b. Instruct students to answer Analysis item 1 individually in their science notebooks.

   Check that students are able to answer this straightforward question and that they are using their notebooks to record their ideas. They can reference the graphs on Student Sheet 1.1.

7. As a class, students discuss Analysis item 2.

   a. Students complete Analysis item 2.

   This Analysis item asks students to provide an explanation for their findings. Give students time to discuss this question in their groups. Circulate throughout the room, and identify two or three groups to share their explanations. Look for groups who have different yet plausible explanations to generate a productive class discussion.

   b. Have the groups you've identified share their explanations with the class.

   This question serves to set the stage for the next several activities. Do not expect all students to have a well-thought-out explanation at this point.

   c. Pose questions to get students thinking about evolution and cause and effect.

   Dr. Torres said that the bacteria are evolving; ask students what the doctor meant by that. This question will elicit some initial student thinking about evolution.

   Other questions to pose: What if the initial population had included only sensitive bacteria? What if the antibiotic had not been introduced? How would things differ? These questions all emphasize cause and effect. The crosscutting concept of *cause and effect* will be introduced formally in the next activity; introducing the term here will help students begin to understand this kind of relationship. For example, having only sensitive bacteria present when a person starts taking an antibiotic will cause all of those bacteria to be eliminated.

8. The class revisits the Driving Questions Board.

   a. Tell students to complete Analysis items 3 and 4 in their science notebooks and then discuss their responses in their groups.

      These items encourage students to think about the effects that humans have on populations around them, and vice versa.

   b. Add students' new questions to the Driving Questions Board, and review them as a class.

      Let students know that throughout the unit, they will apply their understanding of evolution to these questions.

STRATEGIES FOR TEACHING DIVERSE LEARNERS

Below are suggestions for differentiating instruction and assessment in this activity for diverse learners in your classroom:

Teacher Resources
Differentiated Instruction

- Students with learning disabilities: Work through the model as a whole class prior to groups working through it on their own. Student Sheet 1.1 has the axes drawn with tick marks and lines where the title, key, and axes labels should go. For students who need more scaffolding, consider filling in any or all of these blank lines before making copies.
- English learners: Introduce a class word wall for the EVOLUTION unit as a visual reminder of the new key scientific terms and to make these words easily accessible. Consider adding an explanatory picture or diagram for some (or all) of the terms.
- Academically gifted students: Have students conduct additional trials and describe the variation between them.

These icons, ● ● ●, indicate where you can formatively assess students' proficiency with the three dimensions: ● = SEP, ● = DCI, ● = CCC.

SAMPLE RESPONSES TO ANALYSIS

● ● 1. Describe what happened when you or a classmate did the following:

   a. Remembered to take the antibiotic according to the instructions

      When I remembered to take the antibiotic, the bacteria were eliminated completely by the time the medicine was finished. None of the bacteria were able to increase to high levels.

b. Missed several doses of the antibiotic

When I forgot to take the antibiotic, the bacteria were able to remain, especially the bacteria that are highly resistant to the antibiotic. Even though the least-resistant bacteria were killed off, the highly resistant bacteria were able to increase in number and remain in the body.

2. Provide an explanation for these results.

   Hint: How do bacteria differ, and what is happening to the bacteria when they are exposed to antibiotics in their environment?

   Students' responses will likely vary. A sample response is shown here:

   Antibiotics help your body fight off an infection by killing or reducing the bacteria. A small number of bacteria in any population in your body may not be affected by the antibiotic as quickly. These bacteria have something that makes them more resistant to the antibiotic, and they continue to reproduce and grow. Completing the full course of the antibiotic as prescribed helps make sure that these bacteria do not survive and, therefore, won't make you ill or infect anyone else.

3. Explain how people are affecting populations of bacteria when they take an antibiotic.

   People are changing the population of bacteria by getting rid of it entirely if they take the full course of antibiotics. If they don't take the full course, they are changing the type of bacteria in their body by getting rid of bacteria that are not resistant and leaving behind resistant bacteria.

4. **Revisit the issue:** What questions do you have about other ways that humans affect or are affected by other changing populations?

   Students' responses will likely vary. A sample response is shown here:

   Are we changing the populations of plants and animals around us by something we are doing to the environment? Are we affecting the crops we grow by the way we grow them? Are we affecting other people?

5. **Reflection:** Have you or any of your family members ever taken an antibiotic? If so, did you follow the instructions? How did this activity affect how you will take antibiotics in the future?

   Students' responses will likely vary. A sample response is shown here:

   We have taken antibiotics, and we usually follow the instructions. But once when I felt better after only two days, I stopped taking the medicine. From now on, I'll know why I should finish it all.

REVISIT THE GUIDING QUESTION

What happens when a person does not take antibiotics as prescribed?

When a person doesn't take antibiotics as prescribed, any bacteria that are more resistant to the antibiotic can stay alive and reproduce. Eventually, the highly resistant bacteria may become the most common in the body, and the person can remain sick. The bacteria they pass on to other people are more likely to be the resistant type.

ACTIVITY RESOURCES

KEY VOCABULARY

antibiotic

BACKGROUND INFORMATION

BACTERIAL RESISTANCE

Bacteria, both beneficial and harmful, live within the human body. Infections occur when the size of a population of harmful bacteria (either indigenous or introduced) grows too large. Since they were discovered in the 1930s, antibiotics have been extremely successful in fighting bacterial infections. The antibiotic used depends on the microbe causing an infection. Today, many antibiotics are less effective because resistant bacterial strains have become more prevalent. These strains have evolved due to natural selection in an environment that includes antibiotics. This can occur when some bacteria in the population have genetic variations that naturally confer some resistance to these medicines. It takes only a small number of resistant microbes within a population to lead to an increase in resistant microbes. As the rest of the bacterial population is killed off, the resistant bacteria face no competition and can reproduce more successfully. As a result, increased use of antibiotics can lead to the development (evolution) of resistant strains.

The possibility that disease-causing organisms could become resistant to treatment with antibiotics was first observed in 1943, when penicillin was being developed for use. It was during the second clinical trial of penicillin that one of the 15 patients died from a strep infection because the microbe had become resistant to the antibiotic. Today, there are antibiotic-resistant strains of many different disease-causing microbes, including *Streptococcus pneumoniae* (which causes ear infections and meningitis), *Mycobacterium tuberculosis* (which causes tuberculosis), *Haemophilus influenzae* (which causes respiratory infections), and *Neisseria gonorrhoeae* (which causes gonorrhea). More than 90 strains of *Staphylococcus aureus* bacteria, a common cause of hospital staph infections, are now resistant to penicillin. Some microbes, including those that cause staph and tuberculosis, have evolved multi-drug resistance, increasing concerns about our ability to fight these infections as these strains spread.

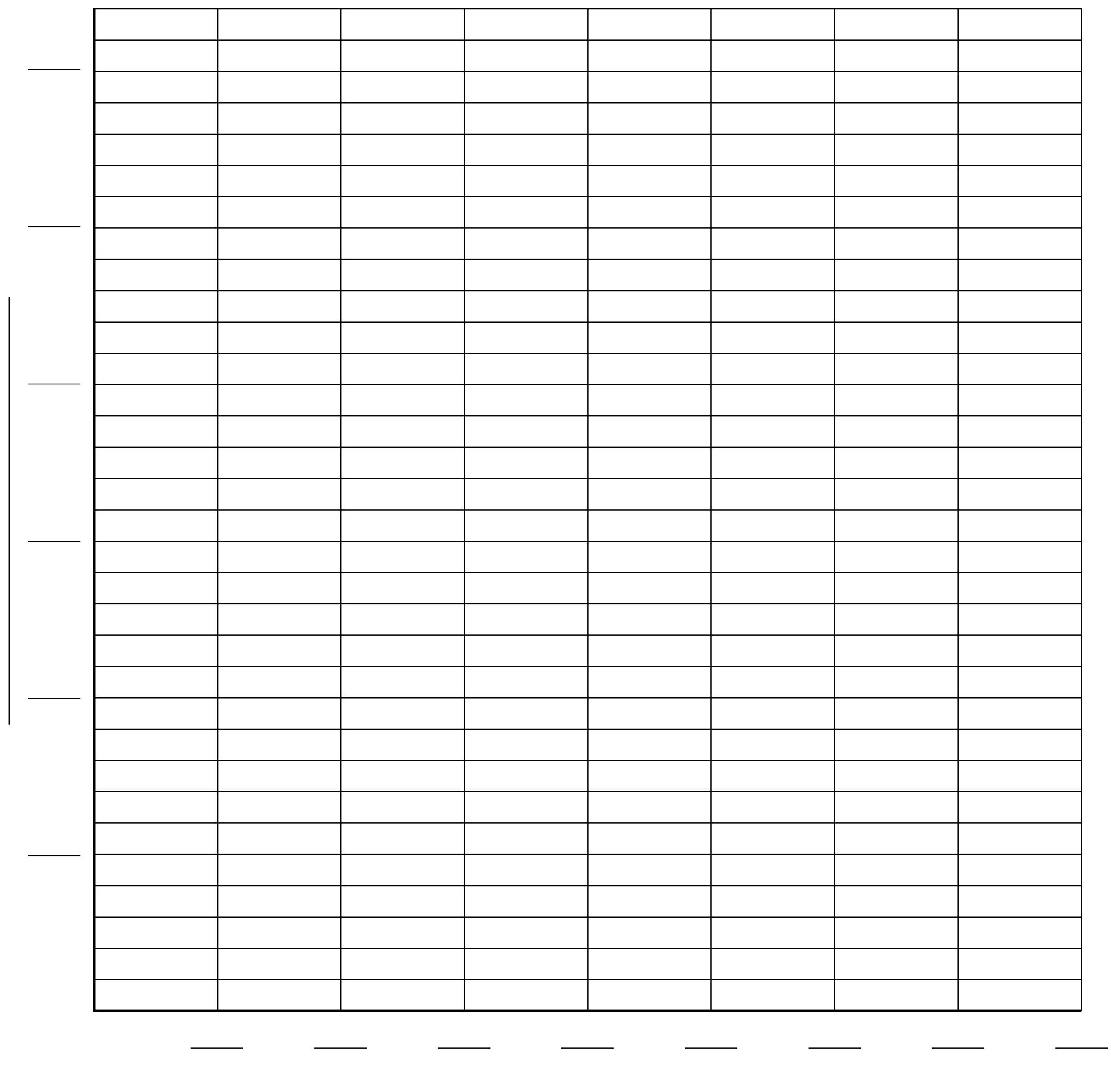
This is one reason that it is important to reduce the unnecessary use of antibiotics and other antibacterial agents. Overprescribing and misuse contribute to the problem, and many health care providers are more carefully monitoring their patients' use of antibiotics. Some researchers are also recommending that the routine use of antibacterial soaps and other such products be reduced.

Patients have played, and continue to play, an important role in the developing crisis. Many people who have been given prescriptions start feeling better after a few days and stop taking the antibiotic—but all the microbes may not yet have been killed, especially those with more antibiotic resistance. These still-living resistant bacteria then reproduce. This increases their population and increases the chance of their causing future infections that cannot be treated with a typical course of antibiotics. However, this crisis is not due to patients alone. Health care policies have also contributed. In some countries, many antibiotics are available without a prescription, and thus the opportunity for misuse in these areas is even greater. In some cases, doctors have prescribed antibiotics unnecessarily, either as a placebo or because patients demand them. As more and more antibiotics are prescribed, the non-resistant strains are killed, allowing the population size of the resistant strains to increase, especially as they are passed from individual to individual.

Name______________________________ Date____________

STUDENT SHEET 1.1

BACTERIA GRAPHS



Key

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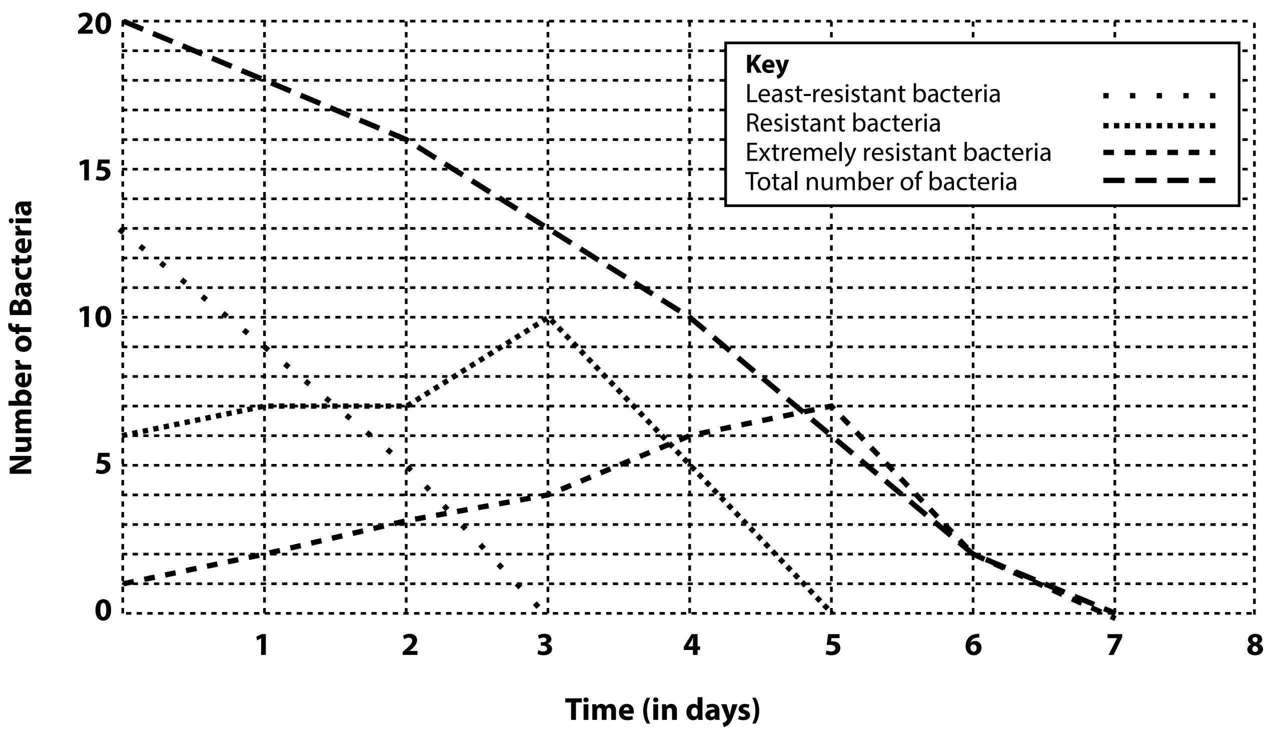
Name *Sample student response 1* Date____________

STUDENT SHEET 1.1

BACTERIA GRAPHS

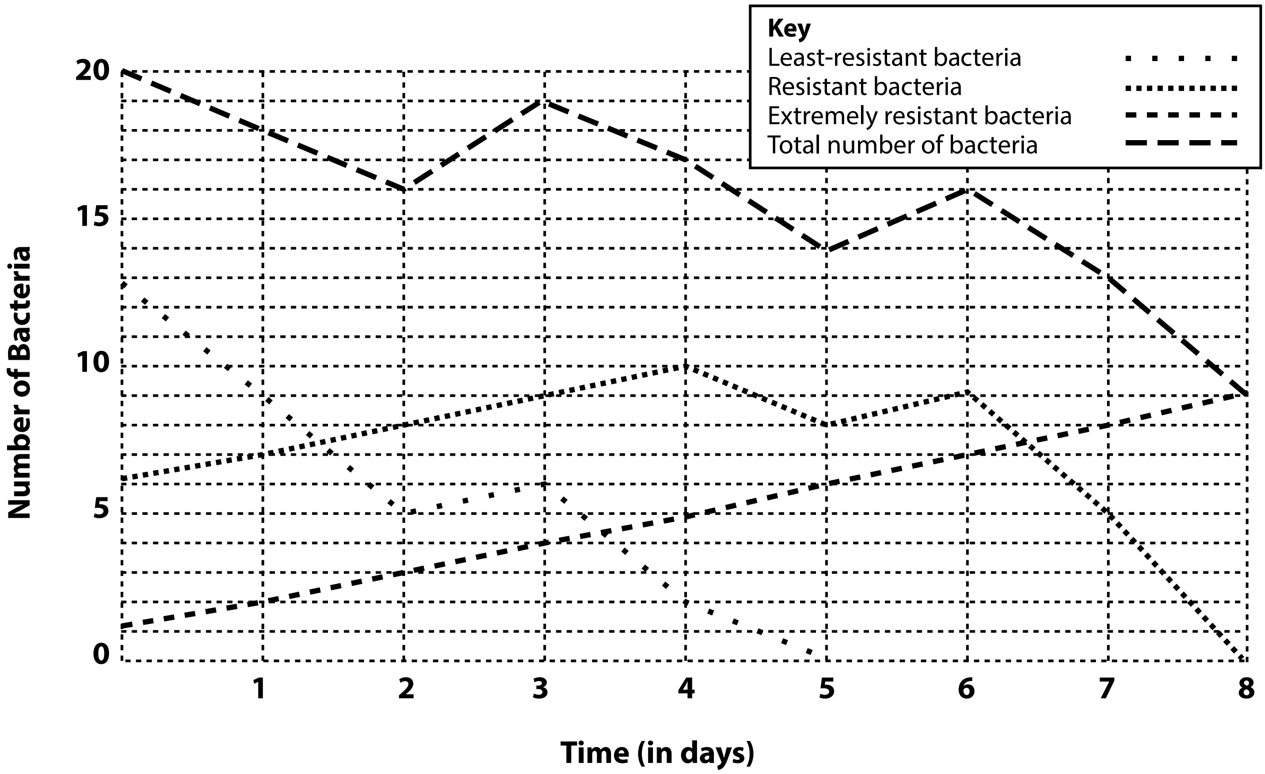


Toss number	Least-resistant bacteria	Resistant bacteria	Extremely resistant bacteria	Total
Initial	*13*	*6*	*1*	*20*
1	*9*	*7*	*2*	*18*
2	*5*	*8*	*3*	*16*
3	*0*	*9*	*4*	*13*
4	*0*	*5*	*5*	*10*
5	*0*	*0*	*6*	*6*
6	*0*	*0*	*2*	*2*
7	*0*	*0*	*0*	*0*
8				

Name *Sample student response 2* Date

STUDENT SHEET 1.1

BACTERIA GRAPHS



Toss number	Least-resistant bacteria	Resistant bacteria	Extremely resistant bacteria	Total
Initial	*13*	*6*	*1*	*20*
1	*9*	*7*	*2*	*18*
2	*5*	*8*	*3*	*16*
3 (forgot)	*6*	*9*	*4*	*19*
4	*2*	*10*	*5*	*17*
5	*0*	*8*	*6*	*14*
6 (forgot)	*0*	*9*	*7*	*16*
7	*0*	*5*	*8*	*13*
8	*0*	*0*	*9*	*9*

ORGANIZING DATA FOR ANALYSIS (ODA)

When to use this Scoring Guide:

This Scoring Guide is used when students are organizing data into tables, graphs, or other displays that can help them analyze and interpret the data.

What to look for:

- Response includes a title or other brief description of the data.
- Response presents the data logically and effectively, including appropriate units and labels.

Level	Description
Level 4 Complete and correct	The student • clearly describes what the data set represents* AND • presents the data using logical and effective displays (e.g., tables, graphs, charts, figures) to allow for analysis and detection of patterns and relationships.
Level 3 Almost there	The student • describes what the data set represents* AND • uses mostly effective displays (e.g., tables, graphs, charts, figures) to present the data and allow for analysis and detection of patterns and relationships.
Level 2 On the way	The student presents the data with some attempt at organization.
Level 1 Getting started	The student presents the data with little or no organization.
Level 0	The student's data are missing, illegible, or irrelevant to the goal of the investigation.
x	The student had no opportunity to respond.

* with a descriptive title, caption, or introduction, as appropriate

NGSS OVERVIEW

EVOLUTION

Performance Expectation MS-LS4-1: Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

Performance Expectation MS-LS4-2: Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

Performance Expectation MS-LS4-3: Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.

Performance Expectation MS-LS4-4: Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

Performance Expectation MS-LS4-5: Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

Performance Expectation MS-LS4-6: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Performance Expectation MS-LS3-1: Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **Investigation: The Full Course** Students use a model to explore the cause-and-effect relationship between inappropriate use of antibiotics and the phenomenon of the evolution of antibiotic resistance. As they use the model, students use mathematical representations to support their analysis of patterns and trends in the results and to develop explanations for how and why the population of bacteria is changing. These explanations are based on the differential survival and reproduction of resistant bacteria when antibiotics are present in their environment (the human body they are infecting).	MS-LS4.B MS-LS4.C	Analyzing and Interpreting Data Developing and Using Models Using Mathematics and Computational Thinking	Patterns Cause and Effect	Mathematics: 6.SP.B.5 6.RP.A.1 ELA/Literacy: RST.6-8.3
2. **Modeling: Hiding in the Background** Students use a model to explain how a change in the environment—a change in predation—can cause changes in trait frequency within a population of prey. Students analyze and interpret data from their model using mathematical representations in their explanations.	MS-LS4.B MS-LS4.C MS-LS2.A	Analyzing and Interpreting Data Developing and Using Models Constructing Explanations and Designing Solutions Using Mathematics and Computational Thinking	Cause and Effect Patterns	Mathematics: 6.SP.B.5 6.RP.A.1 ELA/Literacy: RST.6-8.3

EVOLUTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
3. **Role Play: A Meeting of Minds** Students develop an understanding of Darwin's Theory of Natural Selection and use it to explain why species change over time. They learn why this explanation has prevailed by listening to arguments supporting Darwin vs. Lamarck. They use the theory to explain how a change in the environment causes a change in trait frequency from one generation to the next.	MS-LS4.B MS-LS4.C MS-LS3.B	Constructing Explanations and Designing Solutions Engaging in Argument from Evidence	Cause and Effect Patterns	ELA/Literacy: RST.6-8.2 WHST.6-8.2
4. **Modeling: Battling Beaks** Students use a model to simulate the role of genetic mutations in natural selection. They discover that mutations provide the variation on which natural selection acts. Some mutations cause traits that have the effect of enhancing an organism's survival in its current environment. Students explain that individuals possessing these adaptive traits survive to have relatively more offspring. Thus, these traits become proportionally more common in the next generation. This activity provides an opportunity to assess student work related to Performance Expectation MS-LS4-4.	MS-LS4.B MS-LS4.C MS-LS2.A MS-LS3.B MS-LS3.A	Constructing Explanations and Designing Solutions Using Mathematics and Computational Thinking Developing and Using Models Analyzing and Interpreting Data	Cause and Effect Patterns Structure and Function	Mathematics: 6.SP.B.5 6.RP.A.1 ELA/Literacy: RST.6-8.3 WHST.6-8.2
5. **Modeling: Mutations: Good or Bad?** Students follow the inheritance of a hemoglobin mutation through two generations. Students identify patterns in their data and investigate the cause-and- effect relationship between environmental conditions and the frequency of a trait in a population. Based on their data collection and analysis, students construct explanations for how changes to a gene influence an organism's ability to survive and reproduce. Specifically, students use the example of hemoglobin to explain how structural changes to genes, or mutations, lead to changes in protein structure and function, and how this can lead to changes in the function of red blood cells, which, in turn, can affect survival of individuals with the mutation. This activity provides an opportunity to assess student work related to Performance Expectation MS-LS3-1.	MS-LS4.B MS-LS3.A MS-LS3.B MS-LS4.C	Developing and Using Models Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions	Structure and Function Cause and Effect Patterns Scale, Proportion, and Quantity	Mathematics: 6.RP.A.1 6.SP.B.5 ELA/Literacy: SL.8.1 SL.8.4

EVOLUTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
6. **Computer Simulation: Mutations and Evolution** Students continue investigating the inheritance and selection for the hemoglobin mutation using a computer simulation. Students use mathematical representations and analyze graphs to determine the distribution of the mutation in their population over time. Students manipulate different parameters to investigate multiple cause-and-effect relationships between environmental conditions and natural selection in their population. This activity provides an opportunity to assess student work related to Performance Expectation MS-LS4-6.	MS-LS4.C MS-LS4.B MS-LS3.A MS-LS3.B	Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions Asking Questions and Defining Problems Developing and Using Models	Cause and Effect Patterns Structure and Function	Mathematics: 6.RP.A.1 6.SP.B.5 ELA/Literacy: SL.8.1 SL.8.4
7. **View and Reflect: Origins of Species** Students explore and explain how one species of finch arriving on the Galapagos Islands 3 million years ago evolved into the current 13 species. They also explore how recent changes in the environment have selected for different beak shapes and sizes within a species, reinforcing cause-and-effect relationships. Students learn that evidence from the Galapagos finches supports scientists' assumptions that the same processes that operated in the past are operating today; thus, the same cause-and-effect relationships happening in Galapagos finches today also happened in the past.	MS-LS4.A MS-LS3.B MS-LS4.B MS-LS4.C	Constructing Explanations and Designing Solutions	Cause and Effect Patterns Connections to Nature of Science: Science Is a Human Endeavor	ELA/Literacy: RST.6-8.9 WHST.6-8.2
8. **Reading: History and Diversity of Life** Students obtain information through text and graphics about the history and diversity of life. They learn how life forms have evolved over time, with all organisms sharing a common ancestor. They build un their understanding of speciation and evolutionary trees as a way to represent evolutionary relationships, and they are introduced to the process of extinction.	MS-LS4.A	Constructing Explanations and Designing Solutions Obtaining, Evaluating, and Communicating Information	Patterns	ELA/Literacy: RST.6-8.7 WHST.6-8.2

EVOLUTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
9. **Laboratory: Fossil Evidence** Students examine actual fossils of four species representing a diversity of life forms that existed at different points in the past. Then they examine simulated stratigraphic data to detect patterns in the fossil record. They analyze and interpret these patterns to place the four species in chronological order and, thus, determine their relative ages.	MS-LS4.A MS-ESS1.C	Analyzing and Interpreting Data Constructing Explanations and Designing Solutions Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns Cause and Effect Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems	ELA/Literacy: RST.6-8.3
10. **Investigation: Fossilized Footprints** Students look for patterns in a set of fossilized footprints, a kind of trace fossil. They analyze the patterns to draw inferences about the organisms that left these traces, including the behavior and size of the organisms. They argue for the most plausible explanation for these patterns.	MS-LS4.A	Analyzing and Interpreting Data Engaging in Argument from Evidence Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns Cause and Effect Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems	ELA/Literacy: RST.6-8.3
11. **Investigation: Family Histories** Students analyze and interpret data to look for patterns in the evolution and extinction of families from three classes of vertebrates. They summarize how life forms have evolved over time, assuming that the same natural laws have always operated and will continue to operate in the future. This activity provides an opportunity to assess student work related to Performance Expectation MS-LS4-1.	MS-LS4.A	Analyzing and Interpreting Data Constructing Explanations and Designing Solutions Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems	Mathematics: 6.SP.B.5 ELA/Literacy: RST.6-8.7
12. **Investigation:** A Whale of a Tale Students compare anatomical structures in modern adult whales and embryos with fossil whales to construct an explanation about the evolutionary history and relationships of whales. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS4-2.	MS-LS4.A MS-ESS1.C	Constructing Explanations and Designing Solutions Analyzing and Interpreting Data Engaging in Argument from Evidence	Patterns Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems	Mathematics: 6.SP.B.5 ELA/Literacy: RST.6-8.7

EVOLUTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
13. **Investigation: Embryology** Students analyze and interpret skeletal and embryological images to identify patterns of similarities and differences across species that look very different as mature animals. Students identify patterns of similarities throughout developmental time to infer evolutionary relationships not obvious in the mature animals. This activity provides an opportunity to assess student work related to Performance Expectation MS-LS4-3.	MS-LS4.A	Analyzing and Interpreting Data	Patterns Structure and Function	ELA/Literacy: RST.6-8.7
14. **Talking it Over: The Sixth Extinction?** Students analyze and interpret patterns of large-scale extinctions over the entire history of Earth, and identify the five mass extinctions detected by scientists. Students compare the possible causes of those extinctions, and learn that there may be multiple causes. They analyze data on the current rate of extinction and engage in argument based on evidence about whether there is currently a sixth mass extinction caused by human activity.	MS-LS4.A MS-ESS3.C MS-LS4.D MS-LS4.B	Analyzing and Interpreting Data Engaging in Argument from Evidence Asking Questions and Defining Problems	Patterns Cause and Effect Stability and Change Connections to Nature of Science: Science Knowledge Assumes an Order and Consistency in Natural Systems Connections to Nature of Science: Science Addresses Questions About the Natural and Material World	ELA/Literacy: RST.6-8.7 WHST.6-8.9
15. **Reading: Bacteria and Bugs: Evolution of Resistance** Students obtain information about four types of organisms that have evolved resistance to chemical control methods. Students identify the cause-and-effect relationship between human activity and the evolution of resistance to chemical controls, and they consider whether this pattern is likely to continue in the future. They conclude by using the principles of natural selection to explain the phenomenon of the evolution of antibiotic resistance.	MS-LS4.B MS-LS4.C	Obtaining, Evaluating, and Communicating Information Constructing Explanations and Designing Solutions	Cause and Effect Patterns	ELA/Literacy: RST.6-8.1 WHST.6-8.9

EVOLUTION (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
16. **Investigation: Manipulating Genes** Students obtain and synthesize information from multiple sources about technologies that people have used over time to change the traits of organisms to make them more useful or desirable to people. They evaluate this information for its accuracy, reliability, and bias. They consider the impact of this technology on people and other organisms. The activity provides an opportunity to assess student work related to Performance Expectation MS-LS4-5.	MS-LS4.B MS-LS4.D	Obtaining, Evaluating, and Communicating Information	Cause and Effect Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology Connections to Nature of Science: Science Addresses Questions About the Natural and Material World	ELA/Literacy: WHST.6-8.2 WHST.6-8.8
17. **Project: Superbugs and Other Ways Humans are Affecting Evolution** Students synthesize their understanding of evolution by natural selection to communicate to an audience of peers and community members one important thing they have learned about how evolution has shaped and continues to shape life on Earth.	MS-LS4.B MS-LS4.C MS-LS3.B	Obtaining, Evaluating, and Communicating Information	Cause and Effect	ELA/Literacy: WHST.6-8.2

PHENOMENA, DRIVING QUESTIONS AND SEPUP STORYLINE

EVOLUTION

EVOLUTION

Unit Issue: How people can affect and be affected by evolution.

Anchoring Phenomenon: Populations change over time. Some changes take place over very long time periods, while others take place over observable time periods. People can cause and be affected by these changes. Examples include: there are more life forms now than there were in the past; some kinds of organisms have gone extinct, like large dinosaurs; organisms that are harmful, like some bacteria and pests, have developed resistance to our methods of eliminating them. Students generate and answer questions such as: How have populations changed over time? What caused these changes? How are people affected by and affecting evolution? Are people causing a mass extinction?

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
Humans can change the way species, including bacteria, look or behave.	How are humans affecting evolution?	What happens when a person does not take antibiotics as prescribed? (Activity 1)	1 [14, 15, 16, 17]	MS-LS4-4 MS-LS4-6	Some bacteria are more resistant to antibiotics than others, and because of that, can become more abundant over time.
Populations change over time.	How do populations change over time?	How does the environment affect an individual's probability of survival and successful reproduction? (Activity 2)	1, 2, 3, 4, 5, 6	MS-LS4-4 MS-LS4-6 MS-LS3-1	Some traits increase an individual's chance of survival in a specific type of environment.
		How does natural selection happen? (Activity 3)			Natural selection is the process by which some traits become relatively more common in a population over time.
		What role does genetic variation play in the process of natural selection? (Activity 4)			Variation in traits is caused by mutations, and mutations are passed on to offspring; the frequency of the trait in the population depends on the environment.
		How do mutations affect survival? (Activity 5)			The sickle cell mutation is harmful when a person has two copies because it affects the structure and function of red blood cells; it is beneficial when a person has one copy in an environment with malaria.
		Why does sickle cell trait frequency vary across the world? (Activity 6)			The frequency of the sickle cell trait depends on two environmental variables—the frequency of malaria and the availability of health care.

PHENOMENA, DRIVING QUESTIONS AND SEPUP STORYLINE

EVOLUTION (continued)

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
Evidence of species that no longer exist can be found in fossils.	What information can we learn from fossils?	How do new species evolve? (Activity 7)	7, 8, 9, 10, 11, 12, 13	MS-LS4-1 MS-LS4-2 MS-LS4-3	Natural selection happening over a short period of time leads to changes in trait frequency in a population; when it happens over a long period of time, populations with different traits may evolve into separate species.
		How are the diverse species living today related to one another and to the species that once lived on Earth? (Activity 8)			Speciation is a continual process that has resulted in many life forms and billions of species, most of which have gone extinct; all species are related to one another, sharing either a recent or distant ancestor.
		What kind of evidence do fossils provide about evolution? (Activity 9)			Fossils provide evidence for evolutionary relationships of organisms that lived in the distant and recent past.
		What other kinds of information can we get from fossils? (Activity 10)			Fossils can also provide information about the habits, traits, and environments of extinct organisms.
		What can you learn about evolution by comparing the fossil records of fish, mammals, and reptiles? (Activity 11)			Life forms have evolved over time, with some life forms having been relatively more abundant in the past, and other life forms becoming relatively more abundant more recently.

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

EVOLUTION (continued)

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
		How did whales evolve? (Activity 12)			Whales, despite sharing superficial similarities with fish, are aquatic mammals that evolved from terrestrial relatives; this evolutionary history is informed by fossil evidence and evidence from embryos.
		How can embryos provide evidence about evolutionary relationships? (Activity 13)			Embryos can reveal evolutionary relationships that are not apparent in the adult organisms.
Humans can change the way species look or behave, including bacteria.	How are humans affecting evolution?	Is the current rate of extinction typical? (Activity 14)	1, 14, 15, 16, 17	MS-LS4-4 MS-LS4-5	People are affecting evolution by causing a significantly higher rate of extinction than in the past.
		What is the evidence that resistance to chemical controls is evolving in other types of organisms? (Activity 15)			People are affecting evolution by changing selection pressure on organisms that cause problems for us; the evolutionary responses of these organisms can lead to additional problems for us.
		How have humans manipulated genes in other organisms? (Activity 16)			People have manipulated genes and, therefore, evolution of organisms for thousands of years, most recently through genetic engineering.
		How are humans affecting and affected by evolution? (Activity 17)			There are many ways humans are affected by and affecting evolution, and understanding evolution by natural selection is important for understanding and anticipating these processes.

UNIT OVERVIEW

EVOLUTION

Unit Issue: How people can affect and be affected by evolution.

Anchoring Phenomenon: Populations change over time. Some changes take place over very long time periods, while others take place over observable time periods.

Listed below is a summary of the activities in this unit. Note that the total teaching time is listed as 29–34 periods of approximately 45–50 minutes (approximately 6-7 weeks). There are no suggested activities to skip in this unit as skipping an activity in this case would mean losing key NGSS elements of the unit, e.g. the opportunity to practice elements of the PE prior to the activity that assesses it.

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
1. **Investigation: The Full Course** Students model the effects of antibiotics on a population of disease-causing bacteria during an infection. Students toss number cubes to determine whether an infected individual remembers to take the prescribed daily dose of antibiotics, which in turn affects the size and antibiotic resistance of the bacterial population in the patient. Students keep track of and graph the population size of the remaining bacteria depending on their resistance to antibiotics. Students consider the effect of changing the chemical environment on the survival of bacteria with varying levels of antibiotic resistance.	Antibiotic resistance, changing environment LITERACY MATHEMATICS	Prepare Student Sheet(s).	ODA QUICK CHECK Proc.	2
2. **Modeling: Hiding in the Background** Using toothpicks of two colors, students simulate the effect of prey coloration on predation rates by birds. They calculate and graph the changing frequencies of worm colors over successive generations. Students consider how this model is similar to the antibiotic scenario in the previous activity.	Traits, variation, population MATHEMATICS	Prepare Student Sheet.	ODA PROC. AID A1	2
3. **Role Play: A Meeting of Minds** Students role-play an imaginary meeting between Charles Darwin, Jean-Baptiste Lamarck, a modern-day science reporter, and a middle school student. In the role play, Darwin and Lamarck present and compare their explanations for how a change in a species occurs. Students learn that Darwin's explanation has been accepted as the Theory of Natural Selection and that this theory is essential to our understanding of evolution.	Natural selection, trait, variation, populations, evolution LITERACY	Prepare Student Sheet	EXP A3	1–2

EVOLUTION (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
4. **Modeling: Battling Beaks** Students simulate the effect of natural selection on an imaginary forkbird species. Genetic mutations, represented by tosses of a number cube, introduce variation into the population. Differential survival and reproduction of particular types of forkbirds changes the composition of the population over time. At the close of the activity, the class discusses the role of variation in the process of natural selection.	Natural selection, evolution, trait, variation, mutation, genes	Buy any dry O-shape cereal, prepare plastic forks (break off tines)	MOD QUICK CHECK A4 EXP A5 (Assessment of PE MS-LS4-4)	2
5. **Modeling: Mutations: Good or Bad?** Students follow the inheritance of a hemoglobin mutation through two generations. They investigate the effects of environmental conditions (incidence of malaria, survival rates, and resource availability) on the increase or decrease of the trait.	Natural selection, trait, variation, mutation, genes evolution, genes, structure/ function	Prepare Student Sheets.	MOD A3 (Assessment of PE MS-LS3-1)	2
6. **Computer Simulation: Mutations and Evolution** Students use a computer simulation to extend their investigation around the inheritance of the hemoglobin mutation. The simulation first extends their data from the previous activity through 30 generations. Then students are able to adjust the environmental conditions to see how access to resources and the prevalence of malaria influence the distribution of the hemoglobin gene over time.	Evolution, natural selection, population, trait, variation, cause and effect, computer simulation	Arrange access to computers with Internet access.	EXP A2 (Assessment of PE MS-LS4-6)	2
7. **View and Reflect: Origins of Species** Students watch a video segment on the evolution of Galapagos finches. They learn about Darwin's original discovery of the finches and how the birds contributed to his ideas about natural selection. They also learn about recent research done by Peter and Rosemary Grant over several decades, who documented the phenomenon of evolving beak size. They use a viewing guide to help them understand speciation and natural selection in the Galapagos finches.	Evolution, speciation, diversity LITERACY	View video, prepare Student Sheet.	EXP A1	1–2

EVOLUTION (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
8. **Reading: History and Diversity of Life** Students read text and examine graphs and charts to obtain information about both a brief history of life on Earth and a glimpse at the diversity of life on Earth today, as well as in the past. Stop to Think questions guide them through the reading to develop an understanding of the dynamic nature of life on Earth.	Evolution, speciation, diversity, extinction LITERACY	Prepare Student Sheet.	COM QUICK CHECK A4	1–2
9. **Laboratory: Fossil Evidence** Students examine and describe four types of fossils from various localities and geologic time periods. Students then examine four simulated drill cores, representing a fictional series of rock layers found in different parts of the world. The fossils in the drill cores are the same four fossils they examined. Based on the fossils contained within the layers, students are asked to determine how the layers in each locality correlate to the layers from the other localities. They are then challenged to use this fossil evidence to construct a timeline showing the relative timespans of each species represented by the actual fossils.	Fossils, paleontology, geologic time scale, evolution	Prepare Student Sheet.	AID A2	2
10. **Investigation: Fossilized Footprints** Students interpret fossilized footprint evidence that is presented to them in stages. Through this process, they develop their skills at distinguishing observations from inferences, and at modifying hypotheses in light of new evidence. They also learn about other kinds of evidence that can be gathered from fossils, such as behavior.	Trace fossils, paleontology, evidence versus inference, evolution LITERACY		ARG PROC. QUICK CHECK A3	1–2
11. **Investigation: Family Histories** Students draw and compare double bar graphs showing changes in the numbers of fossil families in the fish, reptile, and mammal classes over geologic time. From this evidence, they can conclude that both speciation and extinction have occurred in all classes of vertebrates for as long as each class has existed. Students discuss how this evidence provides further support for a branching model for evolution.	Evolution, speciation, extinction, classes, evolutionary tree		AID A1 (Assessment of PE MS-LS4-1)	2

EVOLUTION (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
12. **Investigation: A Whale of a Tale** Students investigate how fossil history provides another line of evidence for evolution. They compare the skeleton of a living whale to fossils of its extinct ancestors and use anatomical differences to arrange the skeletons in order. Students apply the theory of natural selection to whale evolution, using anatomical adaptations to infer the habitats and lifestyles of extinct species.	Evolution, speciation	Prepare Student Sheet.	EXP A4 (Assessment of PE MS-LS4-2)	2
13. **Investigation: Embryology** Students first examine six species to identify bones with homologous structures and functions. Although the fully formed limbs appear different on the outside, students are able to identify similarities at the skeletal level. Students then examine embryological development of limbs and notice many similarities between different species. Finally, students then examine development of whole embryos of different species to infer evolutionary relationships.	Evolution, embryos, embryology	Prepare Student Sheet, organize cards.	AID A3 (Assessment of PE MS-LS4-3)	2
14. **Talking it Over: The Sixth Extinction?** Students examine a graph showing rates of extinction over time and identify episodes where rates of extinction were well above the background rate of extinction. They match information on cards about the five major extinction events identified by scientists to the graph. They also summarize the possible causes for these extinctions. Students then read about rates of extinction since 1500 and examine possible causes for those extinctions. Students consider whether there is currently a sixth mass extinction due to humans and, if so, whether people should do anything to prevent it.	Extinction, extinction events, evidence and trade- offs	Copy Student Sheet.	ARG A2 E&T QUICK CHECK A4	2

EVOLUTION (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
15. **Reading: Bacteria and Bugs: Evolution of Resistance** Students read about four types of organisms that cause problems for people, the use of chemicals to control those organisms, and how the organisms ultimately develop resistance to these chemicals. Students draw connections to the evolution of antibiotic resistance introduced at the start of the unit.	Evolution, natural selection, resistance LITERACY	Prepare Student Sheet.	EXP A2	1
16. **Investigation: Manipulating Genes** Students search a collection of websites for information about one or more technologies that people have developed to affect traits of organisms. They summarize the key points from at least two sources and synthesize the information. They evaluate each source according to a set of criteria. Students share the results of their research with their peers. Finally, students consider the possible trade- offs of using these technologies.	Genetic engineering, genetically modified organism, selective breeding, artificial selection	Arrange Internet access; prepare Student Sheet.	COM A2 (Assessment of PE MS-LS4-5) E&T A3	2–3
17. **Project: Evolution and Us** Students develop a presentation or visual display to help scientists convince the public that learning about and understanding evolution is directly relevant to people's lives. They share this presentation or visual display within the classroom (and may also share it outside of the classroom).	Evolution, natural selection	Gather supplies for presentations/visual displays.	COM PROC.	2

This book is part of SEPUP's *Issues and Science* 17-unit multi-year course. The units are designed to allow for custom sequencing to meet local needs. For more information about these units, see the SEPUP and Lab-Aids websites listed at the bottom of this page.

- Land, Water, and Human Interactions
- Geological Processes
- Earth's Resources
- Weather and Climate
- Solar System and Beyond
- Ecology
- Body Systems
- From Cells to Organisms
- Reproduction
- Evolution
- Biomedical Engineering
- Energy
- Chemistry of Materials
- Chemical Reactions
- Force and Motion
- Fields and Interactions
- Waves

Additional SEPUP instructional materials include:

- SEPUP Modules: Grades 6–12
- *Science and Sustainability*: Course for Grades 9–12
- *Science and Global Issues: Biology*: Course for High School Biology

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