2 Hiding in the Background

MODELING

2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

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.

NGSS CORRELATIONS

Performance Expectations

Working towards 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 towards 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.

MS-LS2.A Interdependent Relationships in Ecosystems: In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.

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.

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

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

Crosscutting Concepts

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

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

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.

WHAT STUDENTS DO

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.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*

  1 Scoring Guide: ORGANIZING DATA FOR ANALYSIS (ODA)

  1 Scoring Guide: ANALYZING AND INTERPRETING DATA (AID)

  1 Visual Aid 2.1, “Worm Color Model”

* green or beige paper, cloths, or rugs (optional)

- *For each group of four students*
  - 2 paper bags
  - 50 green toothpicks
  - 50 beige toothpicks

- *For each student*
  - 1 clear plastic sandwich bag
  - 1 Student Sheet 2.1, "Worm Populations"
  - * 1 piece of graph paper
  - 1 Scoring Guide: ORGANIZING DATA FOR ANALYSIS (ODA) (optional)
  - 1 Scoring Guide: ANALYZING AND INTERPRETING DATA (AID) (optional)

* *not included in kit*

The "toothpicks" provided in the equipment kit are thin green and beige plastic rods. The activity requires 50 toothpicks of each color for each group of four students. Extras are provided to replace any that may become lost during the activity. Alternatives include dyed and undyed pasta. This activity is best conducted outdoors on green grass. The color and texture of healthy grass usually makes the green toothpicks slightly more difficult to see, providing more predictable results. However, this activity can also be conducted on concrete (preferably beige in color, similar to that of the beige toothpicks) or indoors in the classroom. If this activity is conducted in the classroom, you may wish to use either green or beige paper, cloths, or rugs to cover sections of the floor.

TEACHING SUMMARY

GET STARTED

1. Students are introduced to the Toothpick Worm Model.
   a. Introduce the scenario involving worms and birds that eat the worms.
   b. Ask students, "Which worms do you think are more likely to be eaten?"
   c. Ask students, "What do you think would happen to the color of the worm population over many generations, and why?"
   d. Inform the class that they will be testing their predictions with a population of green and beige "worms."

DO THE ACTIVITY

2. If you have not previously done so, introduce the SEPUP model for collaborative work.
   a. Introduce SEPUP's 4–2–1 model for collaborative work.

b. Clarify which situations are appropriate for collaboration and which are appropriate for working independently.

c. Introduce strategies for effective group interaction, and introduce the strategy "Developing Communication Skills," found in Appendix E in the Student Book.

3. Students groups model how toothpick-worm color affects the rate of survival.

a. Direct students to Procedure Steps 1–6, and model how to distribute and pick up the toothpicks.

b. (MATHEMATICS) Distribute Student Sheet 2.1, "Worm Populations," and model how to fill in the tables.

c. Instruct students to perform the simulation for Generation 1.

d. When students have completed the first generation, consider bringing the class together to discuss Generation 2.

e. (ODA ASSESSMENT) Instruct students to continue the simulation through Generation 3, and then graph their results in Procedure Step 12.

TEACHING STEPS

GET STARTED

1. Students are introduced to the Toothpick Worm Model.

a. Introduce the scenario involving worms and birds that eat the worms.

Ask students to imagine a population of worms in which there is some variation in color: some worms are lighter and some are darker. Birds eat these worms. Most of the birds that eat these worms are better at seeing lighter worms.

b. Ask students, "Which worms do you think are more likely to be eaten?"

Students are likely to predict the lighter worms because they are easier to find. Clarify that this means that the lighter worms have a lower chance of surviving; scientists use the term *probability of surviving*.

c. Ask students, "What do you think would happen to the color of the worm population over many generations, and why?"

Students are likely to state that the worm population would become darker over time. Accept all reasonable explanations at this point for why this might happen. At the end of this activity, students should be able to explain that the frequency of the worms that are more difficult to see will increase in the population due to their greater ability to survive and reproduce.

d. Inform the class that they will be testing their predictions with a population of green and beige "worms."

Point out that the green and beige toothpicks will represent the worms, and that students, themselves, will be the "birds."

Be sensitive to the fact that up to 8% of males are red-green colorblind and may not be able to distinguish the green and beige toothpicks very easily (although they may be capable of this due to differences in intensity of color). However, this is unlikely to have a major effect on the results of the simulation, since it is performed by groups of four students.

DO THE ACTIVITY

2. If you have not previously done so, introduce the SEPUP model for collaborative work.

   a. Introduce SEPUP's 4–2–1 model for collaborative work.

   Explain that many of the activities in this book use the SEPUP 4–2–1 cooperative learning model. Students work in groups of four or in pairs to share, discuss, compare, and revise their ideas and to conduct investigations and activities. In all cases, each individual student is responsible for contributing ideas, listening to others, recording and analyzing their results, and monitoring their own learning.

   b. Clarify which situations are appropriate for collaboration and which are appropriate for working independently.

   In science, collaboration is essential to the development of new ideas and to a better understanding of scientific concepts. However, scientists must publish only their own work and must give others credit when they build on others' ideas.

   c. Introduce strategies for effective group interaction, and introduce the strategy "Developing Communication Skills," found in Appendix E in the Student Book.

   Explain or model what productive group interactions and communication (both agreement and constructive disagreement) look like and sound like. For more information about group work, including optional Student Sheets to help support students' interactions, see the Facilitating Group Interactions section of Teacher Resources II, "Diverse Learners."

3. Students groups model how toothpick-worm color affects the rate of survival.

   a. Direct students to Procedure Steps 1–6, and model how to distribute and pick up the toothpicks.

      After scattering 25 beige and 25 green toothpicks on the ground, students should pick up a toothpick as soon as they see it and place it in their plastic bag. If students are working in groups of four, each of the four picks up the first 10 toothpicks they see. If there are fewer than four people in a group, they need to figure out how many toothpicks each person will pick up to equal 40.

   b. (MATHEMATICS) Distribute Student Sheet 2.1, “Worm Populations,” and model how to fill in the tables.

      Generation 1 begins with 25 beige and 25 green worms; this has been pre-filled in Row 1 of both tables. In Row 2, students record the number of worms that survived predation. You may wish to model this in the first table with, for instance, 7 surviving green worms.

      To represent reproduction, students multiply this number by 4—this represents each surviving adult worm having 4 offspring identical in color. (If your students have had the Reproduction unit, you can explain that the worms reproduce asexually.) Emphasize that green worms can produce only green worms, and beige worms can produce only beige worms. In this example, the 7 surviving green adults have 28 green offspring. This number goes in Row 3. To determine the total number of worms at the end of Generation 1, students add Rows 2 and 3. In this example, 7 + 28 = 35. This number is entered into Row 4.

   c. Instruct students to perform the simulation for Generation 1.

      Circulate among the groups to offer guidance where needed.

      Note that it is possible for students to collect all of the toothpicks of a particular color, reducing their population to zero and eliminating color variation from the population. If this occurs, no additional toothpicks of that color would be added to the population, and the next generation would be a column of zeros.

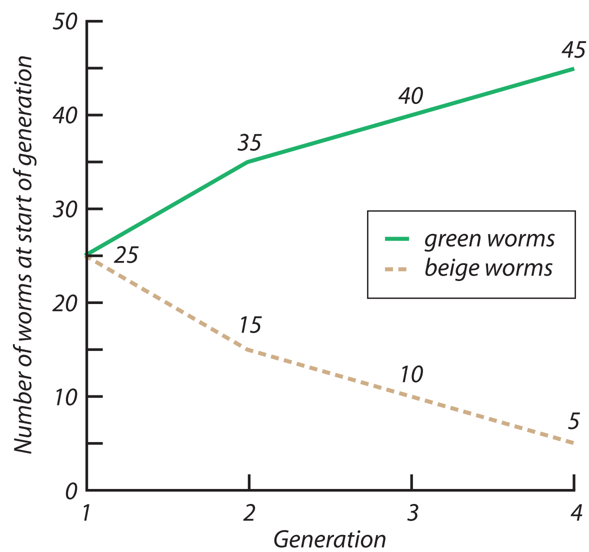
   d. When students have completed the first generation, consider bringing the class together to discuss Generation 2.

      To begin Generation 2, students begin with the number of green and beige worms remaining at the end of Generation 1 (i.e., the numbers from Row 4). These numbers are used in Row 1 of Generation 2.

e. (ODA ASSESSMENT) Instruct students to continue the simulation for three subsequent generations, and then graph their results in Procedure Step 12.

In the previous activity, students were given a Student Sheet for making the graphs. Here they are expected to make their own graphs using graph paper. Students may reference their graphs from the last activity when creating their graphs for this activity. Students may want to use different colored pencils to represent the two worm colors, or they could use different symbols. For a sample Level-4 response, see Sample Student Response to Student Sheet 2.1 at the end of this activity, and Sample Student Response, "Worm Population Graph," below.

SAMPLE LEVEL-4 RESPONSE



BUILD UNDERSTANDING

4. If you have not done so in previous units, introduce the crosscutting concepts of patterns, and cause and effect.

   a. Explain that crosscutting concepts bridge disciplines.

   They can be a lens or touchstone through which students make sense of phenomena and deepen their understanding of disciplinary core ideas. Refer students to Appendix G, "Crosscutting Concepts," and point out the symbols and discuss definitions provided.

   b. Introduce the crosscutting concept of patterns.

   Display the definition and symbol used for Patterns in Appendix G, "Crosscutting Concepts." The pattern can be structural, as shown in the diagram, or a pattern in events, such as the pattern of results in which worm color is more likely to survive. Point out to students that seeing patterns in nature can lead scientists to organize and classify their observations. It can also lead them to ask questions about relationships and the causes of patterns. Students will look for patterns when they analyze and interpret data, ask questions about the patterns they observe, and suggest cause-and-effect relationships to explain patterns.

c. Introduce the crosscutting concept of cause and effect: mechanism and explanation.

Scientists investigate and try to explain how things work, and try to figure out what causes various events, including patterns, in their data. Introduce the symbol for Cause and Effect in Appendix G, "Crosscutting Concepts," which shows a simple diagram of cause and effect, where A (the cause) might or might not cause B (the effect) to happen. For example, in this activity, beige worms in a green environmental cause the worms to be more visible to predators. The beige color is the cause, and the increased visibility to predators is the effect.

5. The class discusses the results.

a. Select two or three student groups to briefly summarize their results to the class.

In most cases, groups will have similar results. If the activity was conducted on green grass, for example, most groups are likely to see an increase in the green worm population and a decrease in the beige worm population.

b. Review the fact that worm color is a genetic characteristic by asking students, "What if a beige worm were dyed green and released again into the environment—would its chances of survival improve? What about its offspring: would their chances of survival improve?"

c. Project Visual Aid 2.1, "Worm Color Model," and have students explain the model.

This model shows that against a beige surface, beige worms survive because they are not eaten by a predator. They reproduce, and their offspring are beige. Those beige offspring survive. If a green worm is dyed or painted beige, this worm would survive because it likewise escapes predation. However, its offspring are green. Their offspring have little chance of survival because they are visible to predators, and the green trait would die out eventually.

d. (AID ASSESSMENT) Direct students to answer Analysis item 1.

Analysis item 1 is the first use of the ANALYZING AND INTERPRETING DATA (AID) Scoring Guide. Optionally project or distribute the Scoring Guide. Point out how it has the same levels like the previous guide but different descriptions for each level. Review the levels as needed. For more information, see Teacher Resources III, "Assessment."

e. Have students complete the remaining Analysis items.

Note that Analysis item 3 assumes that the activity was conducted on a green surface, resulting in increased survival of green worms. If this was not the case in your classroom, consider rewriting the question to reflect this. Use this question to emphasize the fact that natural selection depends on the particular conditions in the environment.

SAMPLE RESPONSES TO ANALYSIS

1. (AID ASSESSMENT) Look at your results.

SAMPLE LEVEL-4 RESPONSES

a. Compare the number of green worms to the number of beige worms using a ratio. For example, the ratio of green to beige worms in Generation 1 is 25:25, or 1:1.

Sample ratios based on the sample data tables are shown here:

Generation 1: 25:25, or 1:1

Generation 2: 35:15, or about 2.3:1

Generation 3: 45:5, or 9:1

b. Calculate the percentage of green worms and beige worms in each generation.

Generation 1: Green worms 50%, beige worms 50%

Generation 2: Green worms 70%, beige worms 30%

Generation 3: Green worms 90%, beige worms 10%

c. Describe how the percentage of green and beige worms changed over the three generations.

The percentages are likely to have either increased or decreased, depending on the surface on which the activity was conducted. In the case of the sample data:

The percentage of green worms in the population increased significantly from the first generation to the last. Beige worms, which were equal in percentage at the start, declined to a very small percentage by the end.

d. Did any individual worm change color? Explain.

No, none of them changed color. Either the worm was eaten or the worm stayed the same color and produced offspring of that color. No worm could change its own color to blend into the environment.

e. Why do you think you observed this pattern?

Hint: A pattern is something that happens in a repeated and predictable way. Provide a cause-and-effect explanation for this pattern.

The green toothpicks were harder to see in the grass. This allowed more green worms to survive and reproduce, increasing their population while the overall population of worms stayed constant. The opposite was true for the beige worms: they were easier to see, which left fewer beige worms alive. Since fewer beige worms were left, they could not have as many offspring, so their population went down.

2. Imagine that you performed this simulation for another generation. What do you predict the percentage would be of green and beige in the population of worms? Explain your prediction.

   If their results show a trend, students may predict that the trend would continue. For this example:

   I predict that the beige worms will completely disappear from the population eventually. This would cause the proportion of green worms to be 1.00 from then on.

3. Due to a drought, grass begins to dry out and die, leaving only dead grass stalks. What is likely to happen to the ratio of green to beige worms? Explain.

   Dead grass stalks are beige. The beige worms would be harder to see than the green worms. The beige worms would be more likely to survive and reproduce, while the green worms would more likely be eaten. This means that not as many green worms would survive to reproduce. This would make the ratio of green to beige worms decrease, with the number of green worms going down and the number of beige worms going up. (This can happen only if there are beige worms in the population when the environmental change occurs.)

4. Compare and contrast your findings with those from the previous activity, "The Full Course." How are they similar? How are they different?

   Both of the activities showed that when the environment changes, the populations of organisms living in the environment change. The difference is that in "The Full Course," the environment was inside another organism, and an added chemical substance changed the environment. In this activity, the change in the environment was caused by a predator that hunted by seeing the worms.

REVISIT THE GUIDING QUESTION

How does the environment affect an individual's probability of survival and successful reproduction?

As the environment changes, the trait that increases the chance of survival may change. For example, in this activity, if the worms live in an environment that is leafy and green, then a green individual has a trait that allows it to escape predation, so it is more likely to survive and reproduce. That trait will then become relatively more common in the next generation. But if the environment changes to dirt or dry grass, the green trait may no longer increase the chance of survival, and over time it is likely to become less common.

ACTIVITY RESOURCES

KEY VOCABULARY

pattern

trait

variation

BACKGROUND INFORMATION

ADAPTIVE COLORATION

Cryptic appearance is an adaptive characteristic found in countless animal species. Color, texture, pattern, shape, or a combination of these characteristics can allow an organism to blend in with its surroundings. The phenomenon is not limited to prey species—for example, the stripes and spots of many of the big cats also provide camouflage.

A classic example is that of the peppered moths in the Manchester area of England. The first record of a black individual of this species was made in 1848; by 1895, 98% of the population in that region was dark. In 1937, this dramatic population shift was attributed to the effects of rapid industrialization, which caused the tree trunks upon which the moths rested to darken with soot. In the 1950s, H. B. D. Kettlewell tested this hypothesis through the controlled release and recapture of tagged moths, both dark and light, and both in areas with soot-blackened trees and those untouched by the effects of factories. Recapture statistics, along with videotaped footage of birds predating upon individual moths, confirmed the hypothesis. The dark-colored trait, however, was not a direct effect of the environmental change; it existed in the population before industrialization's effects as the result of random genetic mutations.

Name____ Date__________

STUDENT SHEET 2.1

WORM POPULATIONS

Generation 1

		Green worms	Beige worms
1	Initial population	25	25
2	Surviving adults		
3	Offspring produced by surviving adults (multiply Row 2 by four [4] because each adult has four offspring)		
4	Total number of survivors and offspring (add Row 2 and Row 3)		

Generation 2

		Green worms	Beige worms
1	Initial population (from Row 4 in Generation 1)		
2	Surviving adults		
3	Offspring produced by survivors adults (multiply Row 2 by four [4] because each adult has four offspring)		
4	Total number of surviving and offspring (add Row 2 and Row 3)		

Generation 3

		Green worms	Beige worms
1	Initial population (from Row 4 in Generation 2)		
2	Surviving adults		
3	Offspring produced by surviving adults (multiply Row 2 by four [4] because each adult has four offspring)		
4	Total number of survivors and offspring (add Row 2 and Row 3)		

Name *Sample student response* Date

STUDENT SHEET 2.1

WORM POPULATIONS

Generation 1

		Green worms	Beige worms
1	Initial population	**25**	**25**
2	Surviving adults	*7*	*3*
3	Offspring produced by surviving adults (multiply Row 2 by four [4] because each adult has four offspring)	*28*	*12*
4	Total number of survivors and offspring (add Row 2 and Row 3)	*35*	*15*

Generation 2

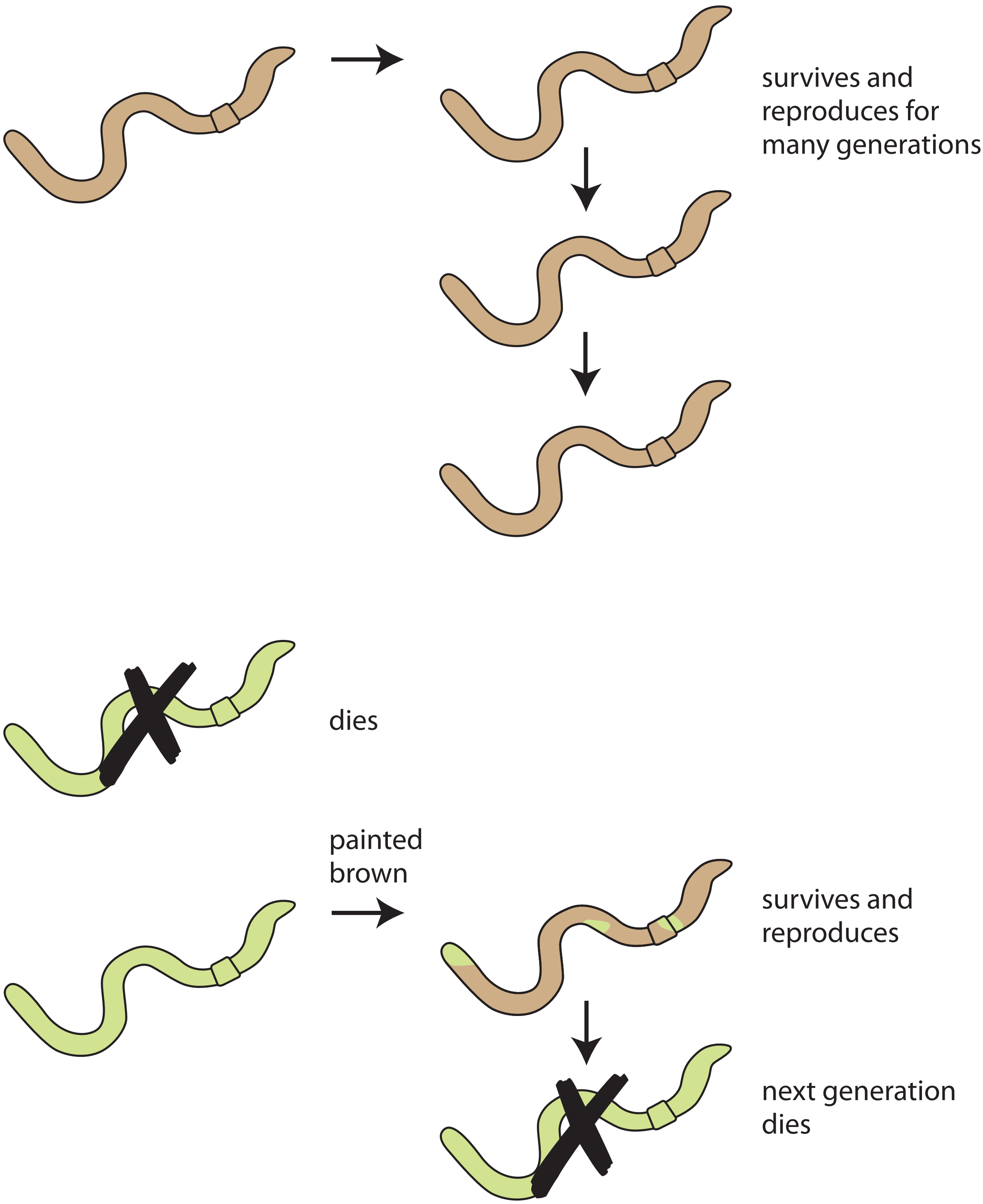
		Green worms	Beige worms
1	Initial population (from Row 4 in Generation 1)	*35*	*15*
2	Surviving adults	*8*	*2*
3	Offspring produced by survivors adults (multiply Row 2 by four [4] because each adult has four offspring)	*32*	*8*
4	Total number of surviving and offspring (add Row 2 and Row 3)	*40*	*10*

Generation 3

		Green worms	Beige worms
1	Initial population (from Row 4 in Generation 2)	*40*	*10*
2	Surviving adults	*9*	*1*
3	Offspring produced by surviving adults (multiply Row 2 by four [4] because each adult has four offspring)	*36*	*4*
4	Total number of survivors and offspring (add Row 2 and Row 3)	*45*	*5*

VISUAL AID 2.1

WORM COLOR MODEL



3 *A Meeting of Minds*

ROLE PLAY

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

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.

NGSS CORRELATIONS

Performance Expectations

Working towards 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 towards 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.

Working towards 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.

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.

MS-LS3.B Variation of Traits: In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

Science and Engineering Practices

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

Engaging in Argument from Evidence: Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.

Crosscutting Concepts

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

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

Common Core State Standards—ELA/Literacy

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

WHST.6-8.9: Draw evidence from literary or informational texts to support analysis, reflection, and research.

WHAT STUDENTS DO

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 engage in scientific argument as they 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.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Scoring Guide: CONSTRUCTING EXPLANATIONS (EXP)
- *For each student*
  - 1 Student Sheet 3.1, "A Meeting of Minds"
  - 1 Literacy Student Sheet 4a, "Writing Frame—Constructing Explanations" (optional)
  - 1 Scoring Guide: CONSTRUCTING EXPLANATION (EXP) (optional)

Decide if you will have all students perform the role play in groups of four or if you will assign the role play to one group to practice and present to the class; this may be a group of students ahead with their work or students who have trouble with written assignments but excel at performing. Because of the complexity of the ideas contained in the role play, you may wish to have students do the activity both in groups and then in a full-class format.

TEACHING SUMMARY

GET STARTED

1. The class uses the example of dogs to discuss inherited vs. acquired (non-inherited) traits.
    a. Ask students to consider the following scenario about dog breeding:
    b. Encourage students to think about which of the two traits—the unusual coat color or the trimmed ears—is more likely to be inherited by the offspring.
    c. Tell students that they will participate in a role play that discusses how a species can come to look different after many generations.

DO THE ACTIVITY

2. (LITERACY) Students read the role play aloud.
    a. Have groups of four or the pre-identified four students read through the role play.
    b. Consider having a brief discussion after students have had a chance to read through the role play one time.
    c. If appropriate, have your students read the role play again, either in their groups or individually.
    d. Distribute Student Sheet 3.1, "A Meeting of Minds."
    e. Have students complete Student Sheet 3.1 individually first and then discuss it in their groups of four. Finally, have a class discussion to come to a consensus.

BUILD UNDERSTANDING

3. The class reviews the key concepts.
    a. Reinforce the distinction between Lamarckian and Darwinian evolution by revisiting the story of the dogs.

b. Review the definition of an *adaptation* in the context of natural selection, contrasting it with the everyday definition.

c. Direct students to Analysis items 1 and 2.

d. (EXP ASSESSMENT) Direct students to Analysis item 3.

TEACHING STEPS

GET STARTED

1. The class uses the example of dogs to discuss inherited vs. acquired (non-inherited) traits.

   a. Ask students to consider the following scenario about dog breeding:

      "You breed dogs for a living. You own five adult dogs, all similar in appearance. One of the dogs was born with an unusual coat color that is highly desired by dog owners. Many people prefer these dogs to have ears that stand up, and you had one of your dog's ears "trimmed" so they stand up. Your children are interested in breeding the dogs and selling the puppies. Dogs with the unusual coat color and/or the ears that stand up will sell for a higher price. Your daughter would like to breed the dog with the unusual color because she thinks her puppies are more likely to have that color. Your son would like to breed the dog with the trimmed ears because he thinks her puppies are more likely to have ears that stand up. What do you tell your children about breeding the dogs?"

   b. Encourage students to think about which of the two traits—the unusual coat color or the trimmed ears—is more likely to be inherited by the offspring.

      The dog with trimmed ears acquired this trait after it was born, just as some humans acquire pierced ears. There is no reason to expect her puppies to have such ears. The dog with the unusual coat color, however, was born with that coloring. It is likely, though not certain, that this is a genetic trait that may be passed on to her puppies. Use this example to distinguish between inherited and acquired traits.

   c. Tell students that they will participate in a role play that discusses how a species can come to look different after many generations.

      Inform students that in the 1800s, two different theories were proposed about how species change over time; they will learn about these theories in the role play.

DO THE ACTIVITY

2. (LITERACY) Students read the role play aloud.

   a. Have groups of four or the pre-identified four students read through the role play.

      If the pre-identified four students will read the role play aloud, decide whether you want others to follow along in the book or close their books and listen. You might allow each student to choose which they think will work for them.

   b. Consider having a brief discussion after students have had a chance to read through the role play one time.

      Point out the mention in the role play of strong muscles developed through exercise as an example of an acquired characteristic. This example helps to address the misconception that acquired characteristics can be inherited.

   c. If appropriate, have your students read the role play again, either in their groups or individually.

      You may wish to point out that in this role play, Lamarck and Darwin are engaging in a scientific argument. Each of them is arguing that their explanation for how species change over time is the better one. Through argumentation, scientists come to more accurate explanations for observations and phenomena.

      Encourage students to make notes and write down any questions they have in their science notebooks.

   d. Distribute Student Sheet 3.1, "A Meeting of Minds."

      The role play is supported with a Directed Activities Related to Text (DART) strategy, wherein students are provided with activities that are related to the reading to help process the information. The questions allow students to process and manipulate the information that they encounter in the reading. For more information on DARTs, see the Literacy section of Teacher Resources II, "Diverse Learners."

   e. Have students complete Student Sheet 3.1 individually first and then discuss it in their groups of four. Finally, have a class discussion to come to a consensus.

      Ask groups to share any questions where the group members disagreed. Ask students to defend their arguments by using scientific reasoning.

Remind students that arguing in science is an important practice that results in more complete and accurate explanations for phenomena. Just as Darwin and Lamarck politely disagreed with one another, students should respect other students' explanations. The goal is for students to be able to identify which of the statements are consistent and inconsistent with Darwin's theory.

BUILD UNDERSTANDING

3. The class reviews the key concepts.

   a. Reinforce the distinction between Lamarckian and Darwinian evolution by revisiting the story of the dogs.

      Ask students about the dog with the ears that were trimmed to stand-up: "Which scientist—Lamarck or Darwin—would be more likely to argue that this trait could be passed on to the dog's offspring?" Students should be able to answer that Lamarck believed in the inheritance of acquired characteristics, whereas Darwin believed that only variation naturally occurring at birth was inherited by subsequent generations.

      Being able to understand the differences between Lamarckian and Darwinian evolution relies, in part, on an understanding of genetic vs. non-genetic traits. If students have not completed the Reproduction unit, be prepared to review the use of the terms *genes* and *traits*, and to discuss the difference between inherited and non-inherited traits.

   b. Review the definition of an *adaptation* in the context of natural selection, contrasting it with the everyday definition.

      The role play explores what an adaptation really is: a trait typical of a population, due to the favored survival and reproduction of individuals with that trait. In particular, emphasize natural selection acting upon pre-existing variation. To reinforce this point, you may want to remind students that the source of variation in a population is naturally occurring genetic differences. Be alert to students' assertions such as, "The giraffe evolves/adapts its neck to reach higher leaves," which are a sign of Lamarckian thinking.

   c. Direct students to Analysis items 1 and 2.

      Have students discuss their responses in their groups first, followed by a class discussion. A firm understanding of these items will help students be successful on item 3. Remind students about productive ways to engage in scientific discussion by referring them to "Developing Communication Skills," found in Appendix E in the Student Book.

Also, see "Teacher Discussion Starters" in Teacher Resources II, "Diverse Learners," for guidance on how to facilitate whole-class or group discussion.

d. (EXP ASSESSMENT) Direct students to Analysis item 3.

Analysis item 3 is the first use of the CONSTRUCTING EXPLANATIONS (EXP) Scoring Guide in this activity. Optionally project or distribute the Scoring Guide. Point out how it has the same levels as the previous guides but different descriptions for each level. Review the levels as needed. For more information, see Teacher Resources III, "Assessment."

Consider distributing Literacy Student Sheet 4a, "Writing Frame—Constructing Explanations," if students need structured support with writing scientific explanations.

SAMPLE RESPONSES TO ANALYSIS

1. Compare and contrast Lamarck's and Darwin's theories of change over time.

a. What are the similarities? What are the differences?

Both Lamarck and Darwin thought that changes in species happened slowly, over many generations. Lamarck thought that any body part of an individual could change over the individual's lifetime, and these changes could be passed on to offspring. The accumulation of such events could make the entire species look different over time. Darwin noted that individuals in a population differed at birth. He proposed they could pass on only those traits they already had, not the ones they acquired. The reason that populations looked different over time is because some individuals had survived to reproduce more than others had, and their traits were passed on.

b. Why do scientists find Darwin's theory more convincing?

Scientists find Darwin's theory more convincing because of evidence for how characteristics are passed from one generation to the next. Variation within a population can be observed. Today, the study of genetics has demonstrated that many traits are, at least in part, inherited. However, acquired traits are not inherited, since they do not affect the genes. Thus, the evidence has supported Darwin's theory while disproving Lamarck's theory.

2. Explain why earthworms are beige or brown and not green

a. using Darwin's theory of natural selection.

Earthworms are beige because in previous generations, beige earthworms were more likely to avoid being eaten by predators by blending in with the *background. This makes sense because earthworms live in the dirt, which is brownish black. These beige earthworms had offspring that were also beige. Earthworms will continue to be beige until the environment changes.*

b. using Lamarck's theory of change.

Earthworms became beige or brown over time because they were living in dirt. They kept changing their color until they blended in with the dirt.

3. (EXP ASSESSMENT) Explain whether Darwin's theory or Lamarck's theory is a better explanation for your results in the previous activity, "Hiding in the Background."

   Hint: Be sure to cite evidence from the activity.

   SAMPLE LEVEL-4 RESPONSE

   Darwin's theory better explains the results from the worm activity. In the activity, individual worms were always either green or beige throughout their lives. They didn't change by living in either types of environment. The green population increased over time not because of changes in individual worms, but because predators ate the beige worms. There were more green worms at the start of the next generation, and they had green offspring. Green worms became more and more common.

REVISIT THE GUIDING QUESTION

How does natural selection happen?

Individuals possess traits that they inherited from their parent(s). Some of these traits make the individual well suited, or adapted, for the present environment. This individual will be better able to survive and reproduce. This trait then becomes relatively more common in the next generation. As the environment changes, traits may be more or less suitable for the new environment.

ACTIVITY RESOURCES

KEY VOCABULARY

adaptation

evolve

gene

natural selection

trait

BACKGROUND INFORMATION

LAMARCKIAN VS. DARWINIAN EVOLUTION

Until the early years of the 19th century, most people believed that the history of Earth was relatively short (less than 6,000 years) and that all species that existed on Earth had always been present. Jean-Baptiste Lamarck (1744–1829) articulated the first major theory explaining how species changed. Called the *inheritance of acquired characteristics theory*, it was founded on the idea that frequent and vigorous use of a body part led to a slight increase in its size. While this could be observed in the case of muscle tissue, Lamarck applied this idea to all aspects of an organism's anatomy. Lamarck further proposed that these changes were heritable and could lead an entire population to transform gradually over time. Due to advances in genetics, it is now known that acquired traits are not inherited.

(Lamarck argued that his theory could also explain the shrinking of organs no longer used, such as the human appendix. In fact, the application of natural selection to vestigial organs can be subtle, as discussed below.)

An outline of Lamarck's theory of evolution might consist of only two steps:

1. An organism's use of an organ causes it to enlarge.
2. The offspring of that organism are born with larger versions of that organ.

In Lamarck's view, individual organisms adapt to their needs as their bodies become modified, however slightly; evolution occurs because as generations pass, the population accumulates the results of those changes. Lamarck's theory is often misrepresented as *teleological*, or dependent on an animal's will. (In fact, Darwin's theory is also misrepresented this way.) But Lamarck never argued that creatures strove to better themselves or that an animal's effort was what caused it to change. Lamarck merely referred to what he thought was an obvious biological fact, at least for certain aspects of a body: that frequent and rigorous use of a body part caused it to enlarge (the opposite is seen, for example, in the well-known phenomenon of muscle atrophy). He further assumed that such changes are inheritable.

Charles Darwin (1809–1882) and Alfred Russel Wallace (1823–1913), on the other hand, argued that adaptations are acquired over many generations by a population. Darwin, living long before the turn of the 20th century, was not aware of Gregor Mendel's work in genetics, which became understood by other scientists only after chromosomes were discovered. Darwin was therefore unable to link the appearance of new or modified traits with genetic mutations; he did not know that there was a single source of all the variation in a population. His main contribution was the observation that variation does exist within any population and provides the raw material for a selective process.

(Interestingly, Darwin thought that variation might arise in numerous ways, including the use and disuse of body parts—at that time, the scientific knowledge did not exist to refute Lamarck's position. Darwin's goal in proposing natural selection was to introduce a mechanism for change in the composition of a population over generations, one that is powerful regardless of the source of variation. He also extended evolutionary change to the diversification of species, which he called *descent with modification*; this will be addressed in later activities.)

Darwin and Wallace's theory, now more commonly known as *natural selection*, can be summarized with the four steps below. Note that "survival of the fittest," the catch phrase for natural selection, is only one component of a process that, like Lamarck's, depends on the gradual accumulation of change over many generations.

1. Variation within a species occurs naturally. (We now know this is due to genetic mutations occurring during chromosome replication.)
2. Organisms must compete for limited resources to survive.
3. The individuals that are better fit for current environmental conditions (due to their traits, which we now know are encoded, at least in part, in their genes) survive and reproduce more often than the others do ("survival of the fittest").
4. As a result, the genes and traits that are most common in a population can change through time.

Even vestigial organs can be explained by Darwinian selection: If they persist for a long time, the selective pressure for their shrinkage must be very small. However, natural selection does eventually reduce even relatively harmless vestigial organs, since individuals that more efficiently allocate their biochemical energy to useful parts of the body have a selective advantage, however slight.

A challenge often posed to natural selection is the ubiquity of "poorly adapted" traits in nature. These are readily explained by understanding evolution as a process that occurs in context—not only in an environmental context, but also in the context the genetic composition of a species. Only certain mutations occur at any point in time, and natural selection can act only on the variation available in the population.

EVOLUTION-RELATED MISCONCEPTIONS

Development is frequently misused as a synonym for evolution. *Biological development* is the transformation over an individual's lifetime from a zygote into an adult organism. Though evolutionary change can gradually change the patterns of development within a population, development and evolution refer to different processes.

The use of the term *adapt* can also be misleading. The noun *adaptation* refers to a trait that increases an individual's chance of survival and reproduction, and has evolved due to selective pressure. The verb *adapt* is often incorrectly used to describe the response of a single organism to the environment. More precisely, an organism does not adapt physiologically to changing environmental conditions but, rather, adjusts or acclimates. For example, in cold temperatures, your body shivers and raises its metabolic rate. But a single organism does not "adapt"—to describe it so is an inaccurate statement suggestive of a Lamarckian view of inheritance.

Because evolutionary history shows the development of life from simple to more complex, there is often a tendency to assume that complex organisms are more successful. Portrayals of evolution in the media constantly reinforce this idea, especially with regard to humans as the pinnacle, or culminating, species. It is true that increasingly complex life forms have appeared throughout recent geologic history. But many of the simplest life forms (particularly bacteria) have survived and proliferated on Earth for the longest periods of time, in the greatest numbers, and in the most diverse environments. Simplicity is arguably the most successful approach.

EVOLUTION AS HISTORICAL SCIENCE

One reason for public misunderstanding of evolution is that it is a historical rather than an experimental science. Most of the data analyzed in studying evolution is gathered (in forms such as fossil evidence and DNA sequence comparison) and not generated. Nevertheless, as in any area of science, explanatory theories are proposed and tested with data. Natural selection as a general theory has withstood every scientific test to which it has been subjected.

Name____ Date__________

STUDENT SHEET 3.1

A MEETING OF MINDS

Would scientists today agree or disagree with the following statements? Read each statement and put an X on the appropriate line.

Scientists today would

AGREE	DISAGREE	
______	______	**1. If a bird population's food source changes from soft berries to hard seeds, birds with the variation of stronger beaks are more likely to survive than birds with weaker beaks.**
______	______	**2. Because the birds now have to eat hard seeds, their beaks will grow stronger during their lifetime, and they will pass these stronger beaks on to their offspring.**
______	______	**3. Because these birds have to eat hard seeds, the birds with the strongest beaks will survive and reproduce; over time, the entire population will have stronger beaks.**
______	______	**4. If an environmental change occurs, some individuals within a population may have a physical variation that allows them to survive better than others.**
______	______	**5. If an environmental change occurs, the entire population of animals will physically change over one or more generations.**
______	______	**6. A parent who practices their free throw and can sink a basket routinely will very likely pass the ability to sink free throws to their child.**
______	______	**7. A parent who is a good athlete may pass the characteristic of good coordination to their child.**

Name *Sample student response* Date

STUDENT SHEET 3.1

A MEETING OF MINDS

Would scientists today agree or disagree with the following statements? Read each statement and put an X on the appropriate line.

Scientists today would

AGREE	DISAGREE	
X		**1. If a bird population's food source changes from soft berries to hard seeds, birds with the variation of stronger beaks are more likely to survive than birds with weaker beaks.**
	X	**2. Because the birds now have to eat hard seeds, their beaks will grow stronger during their lifetime, and they will pass these stronger beaks on to their offspring.**
X		**3. Because these birds have to eat hard seeds, the birds with the strongest beaks will survive and reproduce; over time, the entire population will have stronger beaks.**
X		**4. If an environmental change occurs, some individuals within a population may have a physical variation that allows them to survive better than others.**
X		**5. If an environmental change occurs, the entire population of animals will physically change over one or more generations.**
	X	**6. A parent who practices their free throw and can sink a basket routinely will very likely pass the ability to sink free throws to their child.**
X		**7. A parent who is a good athlete may pass the characteristic of good coordination to their child.**