Polymorphism: What Makes Some Mammals Molt?

Lesson Question

Where should conservation efforts be focused in order to help the snowshoe hare survive?

Lesson Task

Students analyze data to determine where polymorphic species live, find out why snowshoe hares show resilience to climate change, and look for pockets of genetic variability in the US. They then write a memo to the U.S. Fish and Wildlife Service suggesting places where additional conservation measures should be put in place to protect snowshoe hares from the impacts of climate change.

Standards

- HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics
- HS-LS3-1 and 2: Heredity: Inheritance and Variation of Traits
- HS-LS4-4 Biological Evolution: Unity and Diversity

NGSS Science and Engineering Practices

- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

NGSS Disciplinary Core Ideas

- LS2.C: Ecosystem Dynamics, Functioning and Resilience
- LS2.D: Social Interactions and Group Behavior
- LS4.C: Adaptation
- LS4.D: Biodiversity and Human
- ETS1.B: Developing Possible Solutions

Crosscutting Concepts

- Stability and Change
- Cause and Effect

.

TABLE OF CONTENTS

OVERVIEW

Content Objectives

Students will understand

→ **The evolutionary adaptation of color polymorphism** helps animals match their surroundings and hide from predators. Because changes in day length trigger molting, we mostly see white morphs in winter and brown morphs in summer. But as climate change causes winter snow cover to decline, white morphs do not match their surroundings for significant periods of time and are at greater risk from predators.

→ **There are evolutionary processes** that allow species to respond rapidly to environmental challenges such as current global warming. Specifically, **when populations are in decline and in danger of extinction**, the process of natural selection favors animals in places of **high genetic variability** that can rapidly adapt to the new environmental conditions.

→ It is important to take these evolutionary mechanisms into account when planning conservation efforts; doing so can help us preserve species and protect the Earth's biodiversity.

Skill Objectives

Analytical Thinking

- Assessing evidence in relation to claims
- Generating claims based on data
- Integrating information across sources
- Reasoning with data

Data Communication

- Communicating ideas from data

Data Visualization/Interpretation

- Reading measurements from graphs or tables
- Identifying and describing data patterns

Math/Statistics

- Calculating statistics from a sample
- Evaluating and interpreting relationships between two variables

Instructional Sequence

Share this plan of action with students so they know what to expect from the lesson.

→ **HOOK** We will start by asking how having different coat color affects animal survival and why.

→ **BACKGROUND** We will go over essential information that you need in order to understand the concepts in the lesson. We will learn about color polymorphism and how animals respond to periodic and long-term changes in their habitats. We will define and think about the problem we are studying—The Survival of the Snowshoe Hare in a Warming World—and how nature responds to such problems. We will learn the genetics behind color polymorphism, and why genetic variability is important in isolated and adjacent populations.

→ **DATA ORIENTATION** We'll familiarize ourselves with some tools for analyzing the data we'll use.

→ **INVESTIGATION** Then, on your own or in pairs, as I will direct, you'll analyze data to examine three questions important to understanding snowshoe hare survival. First, in what geographic areas do polymorphic species live? Second, how does snow cover correlate with winter polymorphic populations, and what's special about snowshoe hares? Third, what are two areas where you find snowshoe hare populations with high genetic variability, and are those areas already protected by conservation efforts?

→ **WRITING** As a final product, you'll write a memo to the U.S. Fish and Wildlife Service suggesting two places where conservation efforts should be focused to protect snowshoe hares. You'll explain the challenge snowshoe hares face, present evidence of the snowshoe hare's resilience to climate change, and identify two locations where you think conservation effort should be focused. Finally, you will explain the wider implications of your study.

Lesson Background for Teachers

This lesson introduces—or revisits, depending on students' prior knowledge—several fundamental ideas about evolution and biology: adaptation to changes in the environment, natural selection, genetic variability as an underlying requirement for evolution, the relationship between genotype and phenotype, how nature "rescues" populations of endangered species, and the relationship between biotic and abiotic (for example, climate, geography) aspects of nature. Understanding how rapid climate change affects evolutionary adaptations is important. An important and relatively new scientific idea underlying the lesson—and the writing task in particular—is that conservation efforts should take into account, and amplify, nature's own mechanisms for ensuring species survival. The concepts in this lesson can be extended to other situations and species where climate change poses a threat.

The word polymorphism has several different meanings in biology. In this lesson, color polymorphism refers to species that have two different phenotypes (color) that match their environment. While polymorphic populations contain many genetic variants, those of interest to us control molting from one color to another. Since natural selection "sees" and favors phenotypes, how they look is important.

While the environment is constantly in flux, and species are always adapting to new conditions in order to survive, these evolutionary adaptations take time. The rapid rate at which the planet is currently warming, and the consequent rapid changes in the environment, put unprecedented pressure on organisms. If organisms are to survive, rapid adaptations are needed in order to respond to rapid environmental shifts. The concept of "evolutionary rescue"—a theoretical situation in which a population recovers from environmental pressure through advantageous genetic change, rather than by migration or other demographic change—makes a focus on geographic pockets of high genetic variability useful. The research on which this lesson is based shows the importance of working with nature in order that conservation efforts can be targeted where they will be most effective.

Lesson Logistics for Teachers

Zoom In lessons work best if students have plenty of opportunities to discuss and compare what they are finding in moments of "turn-and-talk," small table-group discussions, and so on. Encourage students to use scientific vocabulary from the lesson and ask them to explain their reasoning during these discussions. Frequent checks for understanding are important. This will help you surface misconceptions and address them through brief whole-class discussions.

The Hook, Background, and Data Orientation sections are designed to be tackled as a class, essentially as a teacher-led mini-lesson, in which you project the screen to the front of the room and students follow along on their own computers. Ask students to read the screen information aloud, have them speculate about what they see, and encourage cross-talk and divergent ideas and questions. Offer clarifications in response to student ideas and misconceptions.

In the Investigation part of the lesson, students should work in pairs or small groups. Social interactions between and among students are central to building knowledge. Students are asked to describe, define, and interpret data by answering questions and prompts. Putting ideas into their own words is an essential part of learning because it centers attention and clarifies thinking. Some questions or prompts may feel repetitive, but viewed as iterative encounters with concepts and data, these may help students gain a deeper and more flexible grasp of the content.

Opportunities for students to engage in scientific practices are woven throughout the lesson: making hypotheses, analyzing and interpreting data, constructing graphs and making calculations, reproducing findings, creating an evidence-based story with the results.

The lesson culminates in a Writing Task that you should preview with students; a writing template serves as an outline. The task calls on them to address the key lesson question using data that they have analyzed and reasoning to explain how the data support their ideas. It is often in the form of a letter to a public official. Students begin by explaining the context or background of their investigation and the problem it addresses; they then summarize their claim or finding, and cite and explain the data that support it. Finally, they discuss conclusions, implications, or additional questions they have.

Student Background Knowledge

At the outset, students should know the following

- Natural selection is one of the most important mechanisms of evolution. It works best when nature has many phenotypes to "select" from. This, in turn, depends on the amount of underlying genetic variability in a population. The more alleles in a population, the more types of organisms available for selection.
- Natural selection acts in a fluid manner on organisms because of the ever-changing environment. For example, a drought or a flood can alter the availability of food or shelter, the climate can get progressively colder or warmer, and so on. As selective pressures change, populations need to have individuals with the right kinds of phenotypes in order to respond.
- Predation is one of the most powerful selective pressures. Animals strive to survive and reproduce, thus adaptations, such as camouflage, that help them avoid predators are very important. Camouflage is one evolutionary adaptation designed to avoid predators.

The Hook

(Estimated time: 10 minutes)

Polymorphism helps animals survive.

Purpose

- To engage students' interest in how climate change is threatening populations whose survival depends on their ability to blend in with their surroundings
- To introduce the idea that camouflage is a way of avoiding predation

Big Ideas

- Predation is a powerful evolutionary force and animals evolve adaptations to avoid being eaten.
- Camouflage adaptations are only effective if they help animals blend with their surroundings.
- As animals' surroundings change, their appearance or phenotype must also change in order for them to blend in.

Facilitation Suggestions

- **Invite students to carefully observe each of the four situations in the panel.** Read the first question, and allow time to think about it. Before they write down the answer to the question, ask students to share their ideas. Review new vocabulary and point out the rollover feature for glossary terms.
- **Introduce the idea** of camouflage, mismatch, and why some of these animals would not match their surroundings as winter gets shorter. Ask students to think about how climate change and the warming of the planet may cause population decrease in these animals. Make sure students understand that climate change means that winter starts later and finishes earlier in terms of how the environment looks (white/brown/green).
- **Elicit responses from students by asking them** to consider how climate change would make the color mismatch better or worse. Attend to how students apply the definition of camouflage and predation in their explanations.
- **Ask students what they think might happen** to the weasel population if climate change continues. Will it die out? Everywhere, or only in certain places? How might the weasel survive? Should it be conserved? Tell them that in this lesson they'll be exploring data to determine how the snowshoe hare—another polymorphic species—might survive climate change.

TRANSITION TO BACKGROUND

Tell students that that all the ideas discussed during the Hook will be developed throughout the lesson. First, they have to learn some relevant background information to understand the lesson concepts. We will start by defining color polymorphism.

Background

[Estimated time: 35 minutes]

Project the background slides to the class, and have students actively read and discuss the content and questions so that they develop background knowledge needed in the investigation. Make sure they understand the concepts before continuing to the "data orientation" and "investigations" sections.

Background 1: Natural Selection & Selective Pressures

Purpose

- To define color polymorphism and how it helps animals avoid predation.

Big Ideas

- Color polymorphism refers to changing seasonal color cover to blend with the environment's appearance.
- Camouflage is an important trait because it helps organisms to avoid predators.

Facilitation Suggestions

Ptarmigan, in Winter and Summer

- **Invite students to look at the pictures on the right-hand panel and describe what they see.** Ask them if they are surprised at how different the same animal looks in winter versus summer. (Notice that we are talking about the phenotype of the animals, which is a translation of the underlying genetic variability.)
- **Ask students to read the first two paragraphs on the left-hand panel aloud.** Check to see that they understand the purpose of this adaptation—predator avoidance and warmth.
- **Optional: Clarify that a change of coat in polymorphic animals involves not only the color but the type of coat.** Birds change feathers to soft, fluffy down feathers that help protect them from the cold. In mammals, the type of fur also changes to one that better protects them from cold

TRANSITION POINT

Tell students that in order for color polymorphism to provide an animal with effective camouflage, it must synchronize with the surroundings. Let's look at how this works.

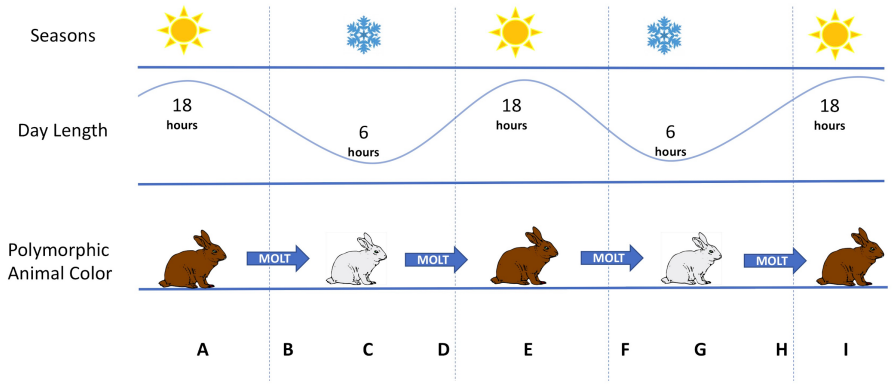
Background 2: How Warming Causes Polymorphic Animals to Become Out of Sync with Their Surroundings

Purpose

- To explain that color polymorphism is triggered by changes in day length
- To emphasize the close relationship between environment, climate, and changes in plumage or fur phenotype

Big Ideas

- Traits adapted to seasonality respond to photoperiod and are regulated by an internal biological clock: the circadian rhythm.
- Molting, as an adaptation to seasons, is being challenged by rapid climate change.



Facilitation Suggestions

- **Have students note the title of this section:** How Warming Causes Polymorphic Animals to Become Out of Sync with Their Surroundings
- **Ask students to identify what is going on in each row** of the diagram:
- Seasons changing from summer to winter
- Day length changing (for example, how long is the day in June versus late December?)
- Polymorphic animals molting from brown to white with the change of seasons
- **Clarify what the vertical lines mean:**
    - **Molting is triggered by changes in day length,** or photoperiod.
    - You may wish to remind students that all organisms, from bacteria to humans to plants, have an internal clock that responds to external cues. This physiological system is the circadian rhythm.
- **Ask students why it is important** that animals are brown in summer and white in winter.
- **In step two, ask students, "What will happen to this system if the amount and duration of winter snow decreases as the Earth gets warmer?"** See if they can identify that, for at least part of the winter, white animals will not have a snowy background to blend into and will be more vulnerable to predators.

TRANSITION POINT

Tell students that this phenomenon is being studied by scientists, and that we are going to hear directly from some of them.

Background 3: The Survival of the Snowshoe Hare in a Warming World

Purpose

- To familiarize students with the research questions underlying this lesson
- To put the lesson into context by listening to the scientists involved in the study.

Big Ideas

- Snowshoe hares, like other polymorphic species, have evolved the ability to change from white coat in winter to brown in summer.
- Climate change presents a problem because, with less snow in winter, these animals will mismatch their environment and be subject to predation.
- Rapid adaptation to changing environmental conditions can help populations of polymorphic species survive

Facilitation Suggestions

- **Tell students** that in order to study this problem more closely, the scientists have focused on one animal, the snowshoe hare.
- **Ask students to watch the video** and, as they do so, to notice what problems snowshoe hares face, and why.
- **After the video, have students answer the questions,** "In your own words, what problems do snowshoe hares face because of climate change? Why?"

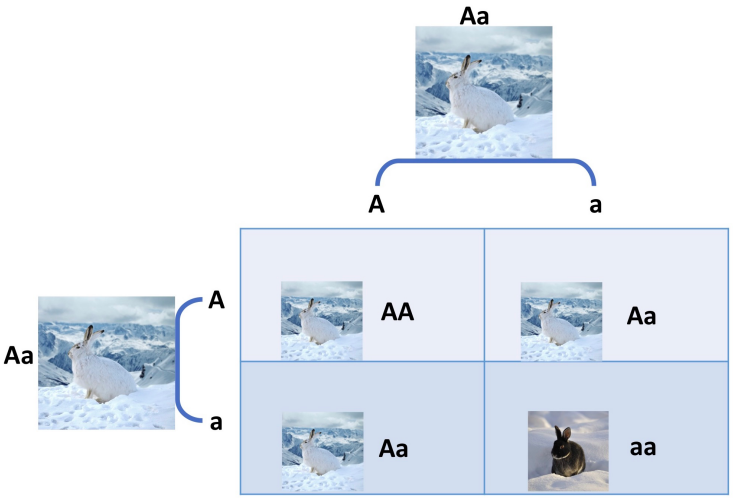
TRANSITION POINT

Explain that in order to understand the problem facing the snowshoe hare, we have to delve a bit deeper into the biology of color polymorphism

Background 4: The Genetics Behind Color Polymorphism in the Snowshoe Hare

Purpose

- To define what a polymorphic population is
- To emphasize that in order to protect polymorphic species, both phenotypes (winter-white and winter-brown) are required
- To show how genetics controls the ratio of winter- white and winter-brown snowshoe hares



Hares having the A allele are white in winter

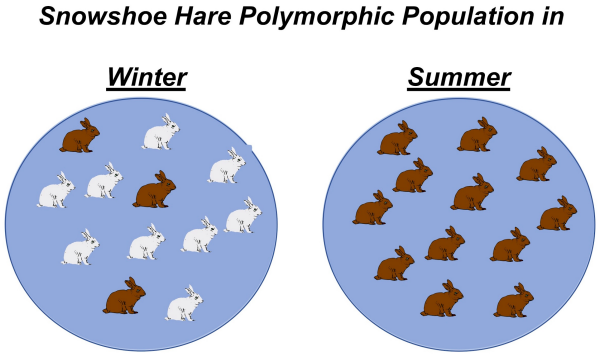
Big Ideas

- Polymorphic species, by definition, are composed of more than one form or morph.
- Genetically, the brown hares are homozygous recessive for the agouti gene (aa) and therefore are few in a population. These hares need to be protected because they are the ones best adapted to mild winters

Facilitation Suggestions

- **Read the left-hand panel** with students; it defines polymorphic populations and describes how they change from summer to winter. Pause for questions and comments, and check for understanding.
- **Examine the Punnett Square carefully.** Ask students: What season is shown in this diagram (summer or winter)? How do you know?
- The diagram shows a cross between two heterozygous (Aa) hares, the most likely cross in a population where 75% have the Aa genotype. **Make sure students know** that if a hare possesses the dominant A allele, this animal will molt from brown to white in the fall and back to brown in spring. Ask students what color the AA, Aa, and aa hares would be in summer, and what color they would be in winter.

- **Ask students to consider** why these polymorphic animals, snowshoe hares, look different in summer and winter? In winter, some animals are brown because they do not have the A dominant Agouti allele that is required to change colors. In summer, they are all camouflaged because they are all brown against a brown/green background.



- **Encourage students to think about animals' mismatch with their surroundings. For example, ask**, "In winter, if a population of hares live in a snow-covered location, which hares will mismatch?" (The aa brown hares.) "What if the hares live in a place where the winters are short and mild?" (The white hares will mismatch.)

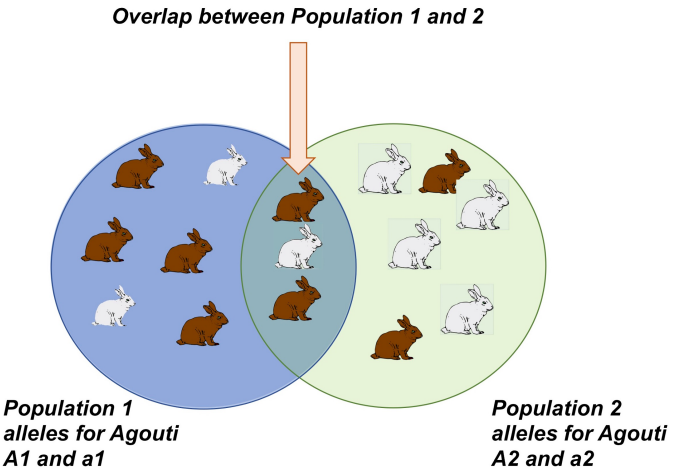
TRANSITION POINT

Tell students that, for species survival, both morphs—brown and white—are required. This means that populations need multiple agouti genes or alleles. That is, they need genetic variability.

Background 5: Genetic Variability is High Where Polymorphic Populations Overlap

Purpose

- To apply the concepts of genetic variability to polymorphic species
- To explain that genetic variability increases when different populations of the same species come together
- To connect genetic variability, increased chances of survival, and the need for conservation efforts



Big Ideas

- Populations are adapted to their local environments.
- Certain alleles will help some individuals in a population thrive and reproduce in their local habitat.
- When populations of the same species come together, the genetic variability and chances of survival increase.

Facilitation Suggestions

- In this section, students are considering the concepts of genetic variability and phenotype in connection with animals' surroundings. **Start by orienting students to the diagram**. Remind them that these animals belong to the same species, but that each population is slightly different.
- **Ask students to explain how populations 1 and 2 are different.** Prompt them to think about the differences in phenotypes and the underlying genetic differences. Check for understanding that populations have different alleles for the same trait, which translates into different phenotypes.
- **Point out that the phenotype or appearance of the two populations are different with more white animals in population 2**. This suggests that perhaps population 2 lives at higher altitude where there is more snow, where white animals can blend with their surroundings, and are not easily seen by predators. **Encourage students to consider where population 2 might live, based on their phenotypes.**
- **Draw students' attention to the area of overlap between population 1 and 2**. Have students read Step 2 and solicit a few of their ideas before they record their answers. Look for the use of the term "genetic variability" in their responses.
- **Read aloud the text on Step 3, pausing for comments and questions.** Ask students what makes the "secret sauce" in the overlapping areas (many alleles, or having lots of choices for natural selection to act on, is good). Then, direct students to record their answers.

- As a possible extension to this section, **invite students to suggest** the type of geography where these overlapping areas may be (for example, mountain peaks, valley, coast, and so on). This prepares student to start thinking about why it's important to focus conservation efforts in places with high genetic variability. By protecting these overlapping areas, we give natural selection a wider variety of alleles to select from and therefore promote survival.

TRANSITION POINT

As we just learned, natural selection works better if there is high genetic variability. In the next section, we're going to find out why.

Background 6: The Advantages of Genetic Variability in a Population

Purpose

- To explain the importance of genetic variability and phenotypic diversity for species survival

Lady beetle population A

This population of lady beetles has many phenotypes because it has high genetic variability _ different types of genes or alleles

Lady beetle population B

This population of lady beetles has only two phenotypes, it has low genetic variability.

Big Ideas

- Higher number of alleles in the population results in a higher variability of phenotypes.
- Only some individuals—those that are fit for their environment—will survive.
- Evolution uses natural selection as the mechanism by which individuals that rapidly adapt to changing environmental conditions are more likely to survive.
- This process is feasible only when and where there is high genetic variability.

Facilitation Suggestions

- **Draw students' attention to the figure showing two different lady beetle populations,** and ask them to compare what might happen to these two populations during different environmental challenges (predation and drought). This exercise may work better if students work in pairs.
- **Check in with students as they analyze each scenario to make sure they're on the right track.** For example, ask students what color the surroundings might be during a drought. Which lady beetles would be obvious to predators on this background?
- In Step Two, before writing down their answers, invite students to explain how genetic variability in a population is key for natural selection and survival, using lady beetles or another animal as examples.

- Step Three iterates these concepts, which are crucial to the lesson's investigation. Some students may need this to clarify or consolidate what they just learned. **Point out that genetic variability and natural selection are especially crucial when populations are rapidly decreasing and in danger of extinction**. Natural selection and genetic variability are essential to evolutionary rescue from extinction.
- If students need additional support to understand the process of natural selection, ask them to imagine that they are engineers and need to purchase a tool with very specific characteristics for their project. Would they go to a store that has a selection of just ten tools, or to one that has 100 different tools? Likewise, if there are many types of genes (alleles) in a population, there will be many phenotypes from which natural selection can choose. The higher the genetic variability, the better are the chances of having individuals with the right characteristic to respond to environmental challenges and survive. These individuals are key to helping the species bounce back and persist.
- As students discuss with their partners or as a class, **look for understanding of the main idea:** If there is enough genetic variability, evolutionary processes can rescue populations that are in decline.

TRANSITION POINT

Let's meet the investigators who are studying polymorphic populations and learn about their research interests.

Background 7: Meet the Investigators

Purpose

- To connect with the investigators involved in the research and learn about their scientific interests
- To learn broader concepts underlying their study
- To identify the source of the data in this lesson.

Dr. Scott Mills

Dr. Jeffrey Good

Big Ideas

- Science is a collaborative endeavor among many people and institutions.
- The problem studied by these scientists have great implications for the survival of many species in the face of climate change.

Facilitation Suggestions

- **Invite** students to learn more about the researchers, where they work, and their interests.
- **Emphasize that** research is a collaborative effort involving many people and institutions, and that it always builds on past research. Point out that students can find more information about the researchers by going to the link provided under "show data source."

TRANSITION POINT

Next, we will look at an overview of the investigations in this lesson.

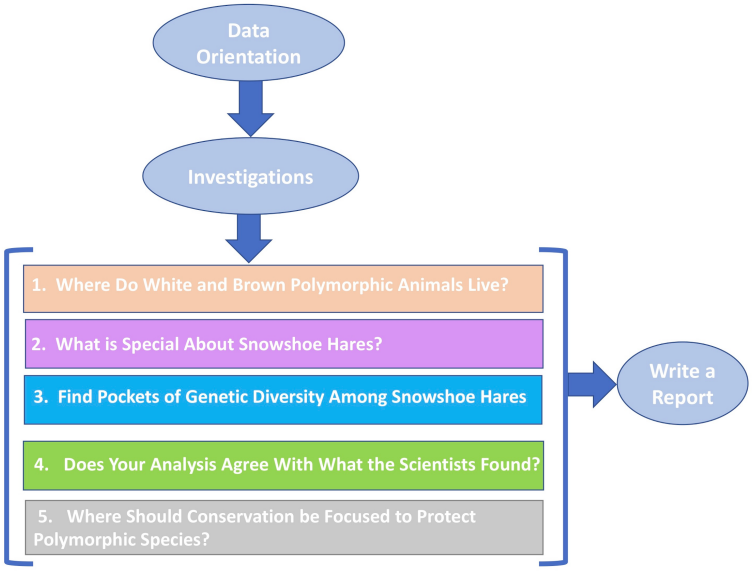
Background 8: Road Map to the Investigations

Purpose

- To outline the rest of the lesson, including the data orientation, data investigations, and writing task.

Big Ideas

- There should be more than one way to study a phenomenon.
- If the results point to the same conclusion, then the interpretation must be correct.



Facilitation Suggestions

- **Walk students through the rest of the lesson, explaining** that they will start by learning how to use the data and analysis tools (for example, making graphs and maps) in the Data Orientation.
- Once students are comfortable with these tools, they will use them to conduct five different investigations. Briefly describe each one.
- In the first investigation, you will explore the type of snow-covered places where polymorphic animals live.
- In the second investigation, you will investigate snow-cover as an environmental element and how the snowshoe hare differs from other species.
- In investigation three, you will identify two geographic locations of high genetic variability that correlate with animal coat color.
- In investigation four, you will find out whether the areas you selected agree with those the researchers identified as pockets of high genetic diversity.
- Finally, you will determine whether these areas are protected by existing conservation efforts.
- **Inform students t**hat the final product of the lesson will be a memo to the U.S. Fish and Wildlife Service where you suggest places where conservation should be focused.

TRANSITION TO DATA ORIENTATION

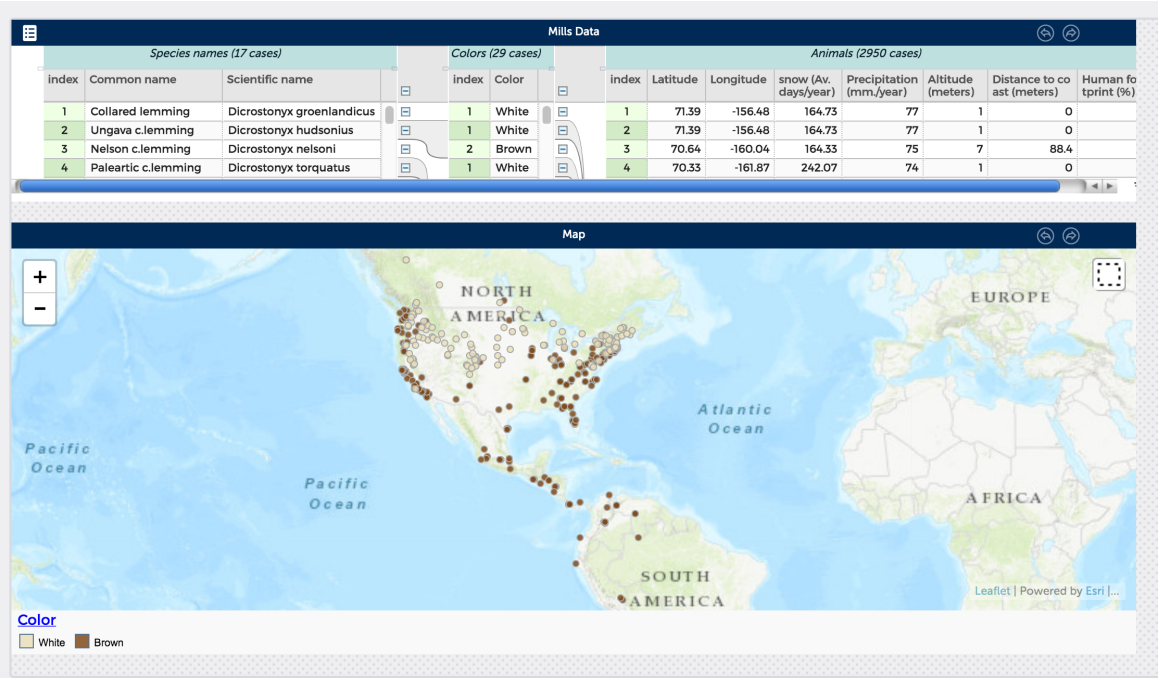
Remind students of the lesson task—*to write a memo suggesting places where additional conservation measures should be put in place to protect snowshoe hares from climate change*—and inform students that in the next section, the Data Orientation, they will be learning how to use the necessary tools to analyze the data collected by the investigators.

DATA ORIENTATION

Estimated Time: 15 minutes

We recommend that the teacher continue to project the lesson to the class, guiding students as they practice working with the data. As students move through the orientation, allow them to explore each data visualization, show them how to construct a graph, and select different areas of the table to highlight data on the map.

Data Orientation 1: The Table and the Map



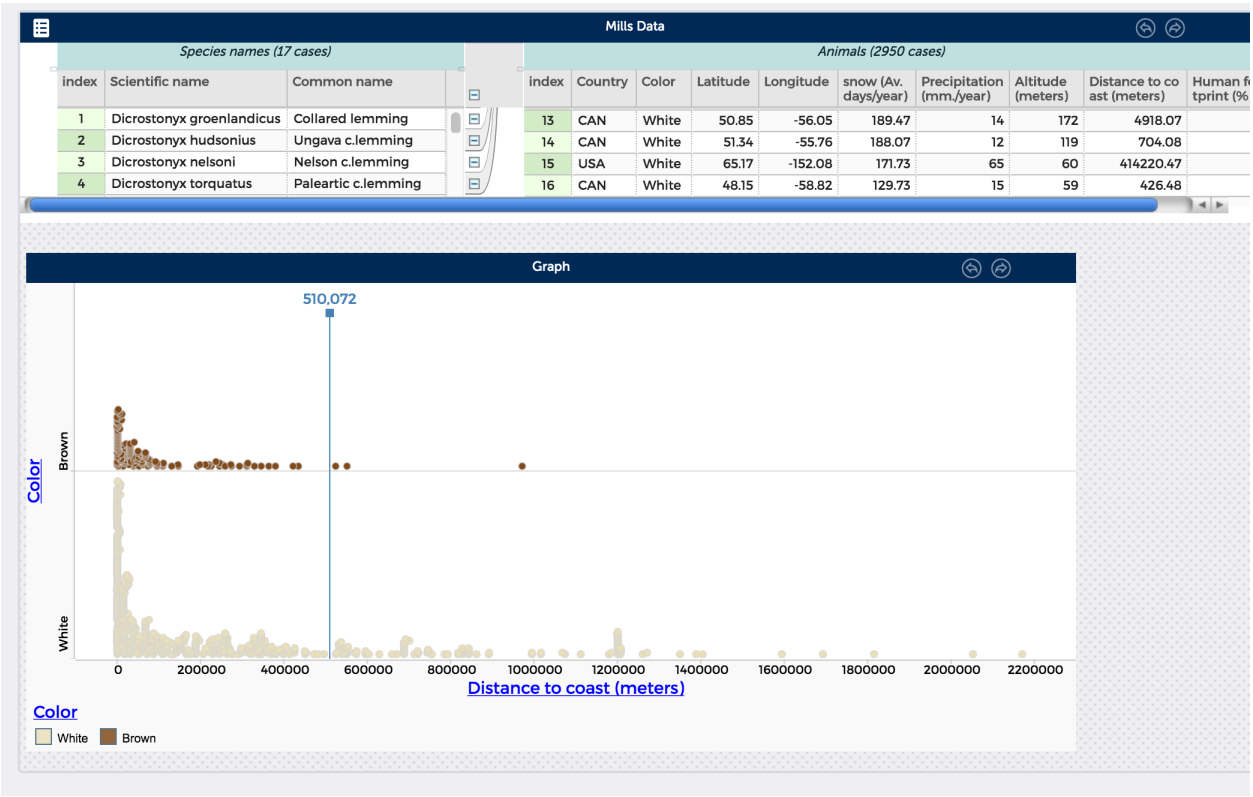
Purpose

- To familiarize the students with the data and how the table and map are related
- To have students manipulate the data in simple ways that prepare them for the investigations
- To learn how to use the analysis features and tools

Facilitation Suggestions

- **Start by reading the text in the left-hand panel.** Make sure students know they are looking at data from animals in winter.
- **Inform students that in step two they will learn to do several things:** color code the data points by coat color, highlight a specific species on the map, and use the case card to find information about selected data points. We recommend that you go through the actions with students. In addition, tell students that if they need help, these moves are demonstrated in the yellow "Hint" box.
- **Next, students will learn how to draw circles on the map.** Take time to demonstrate this action by following the directions in the left-hand panel. This is important, since students should be able to perform the operations by themselves in the investigation.
- **Offer students a lot of support and encourage them** to explore the connections between table entries and map locations by clicking on different rows and points.
- .

Data Orientation 2 : The Graph



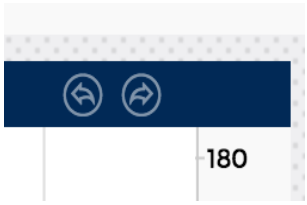
Purpose

- To learn how to make graphs and how to modify them using the data table
- To learn how to use tools to analyze the graph

Facilitation Suggestions

- The left-hand panel provides detailed directions for students to follow.
- **Project this part of the lesson and perform the moves** slowly so students can work alongside and compare it to their graphs, making sure they performed the tasks correctly.

- **Show students how** to drag variables to the y- and x-axes, color code data points, select one species, and add/delete a movable line to the graph. Encourage them to use the "Show How" videos in the Hint boxes if they need help constructing their graphs.
- **Encourage students to explore the connection between the data points represented in the graph and rows in the table.** Click on the data points on the graph to see corresponding data in the table; click on rows in the table to see corresponding data points on the graph. To check for understanding, ask students what each point on the graph means.
- **Inform students that they can go back** to any of the previous sections (Background, Orientation) by using the navigation panel along the top of the screen. Show students that they can always undo or rest their work using these buttons.
-
  - **Start Over**
  -
  -
  -
  -
  -
  -
  - **Undo**



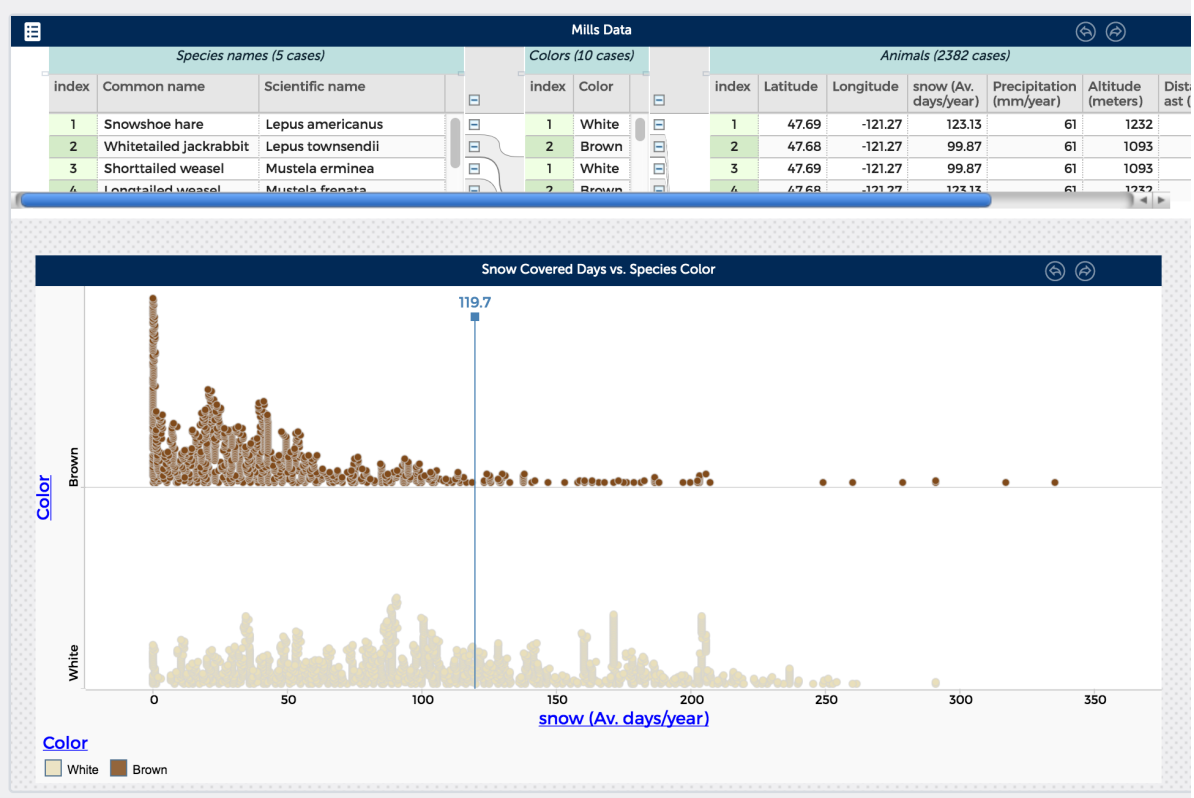
  -
  -

TRANSITION TO INVESTIGATION

Now that students know how to use the data visualization and analysis tools, they will continue to use them to work with the data on their own as they investigate the question, "*Where should conservation efforts be focused in order to help the snowshoe hare survive*?.

INVESTIGATION 1: Where do White and Brown Polymorphic Species Live?

Estimated Time: 20 minutes



Purpose

- To determine whether there is correlation between snow duration and places where polymorphic animals live

Big Ideas

- In general, populations that contain more white morphs than brown morphs are often found in places where snow duration is long, and populations containing more brown morphs than white morphs live in places where snow duration is short.
- There are differences among polymorphic species in the correlation between snow duration and color polymorphism..

Facilitation Suggestions

- **Start by informing students they are narrowing their focus to five species in this investigation.** Students can hover over this text in the left panel to learn more about why this is a common practice among scientists.
- Provide support as needed as students construct their graphs. Remind them that the “Show How” movie will demonstrate how to make the graph and add a moveable line.

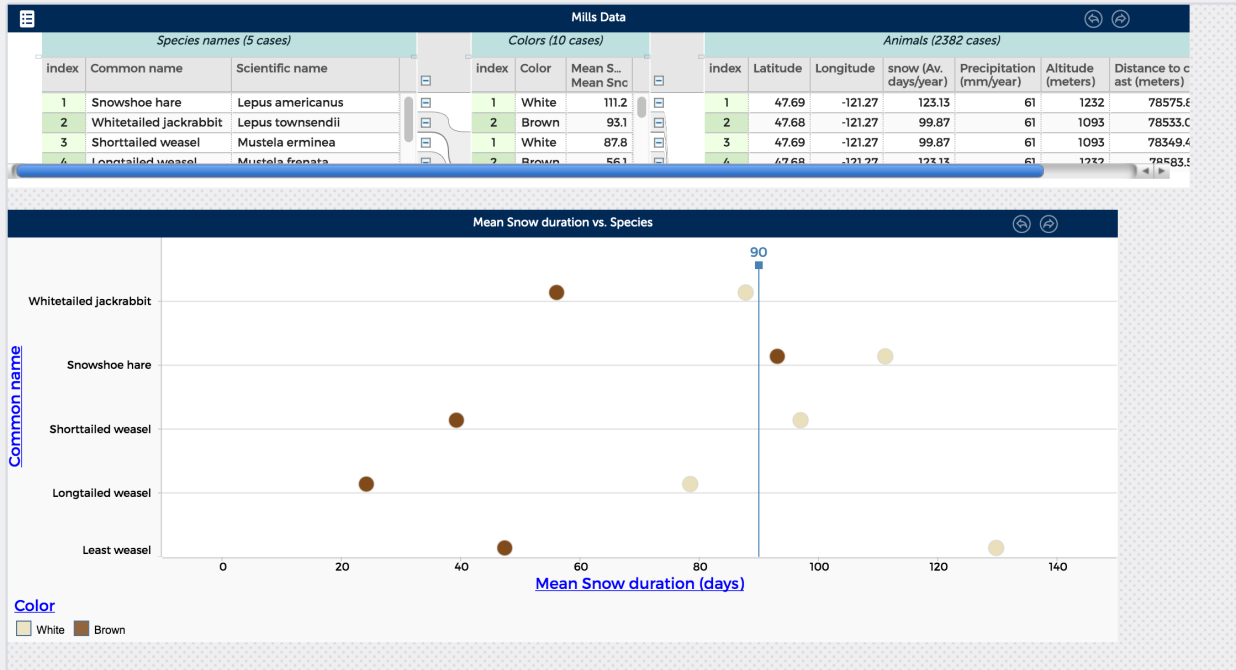
- **Invite students to compare the upper and lower parts of the graph**, to consult with a peer, and to write down their observations. It is a good idea to check that students understand the exercise by asking some students to share their description of the graphs.
- **Ask students to imagine the type of environments** that would have little, medium, and lots of snow in winter, and which hares (white, brown, or both) would be found there.
- **Optional Extension.** Invite students to explore where each species lives, by selecting one species at a time. Give students an example by describing the first species, the snowshoe hare. The brown snowshoe hares are found in places where the average number of snow days is 93.1. Ask students to hypothesize what kind of places would have this amount of snow days in winter. As they continue with the other three species, stop and ask them to compare the graphs and voice their ideas. In the interest of time, these values have been calculated and entered in the Investigation 2 table under "Means Snow Duration (days)."

TRANSITION POINT

For the rest of the lesson, we are going to focus on the snowshoe hare. Next, we will find out what is so special about this animal.

INVESTIGATION 2: What is Special About Snowshoe Hares?

Estimated Time: 30 minutes



Purpose

- To hypothesize about the differences among five polymorphic species and their correlation to snow duration, using the concepts of genetic variability and natural selection.

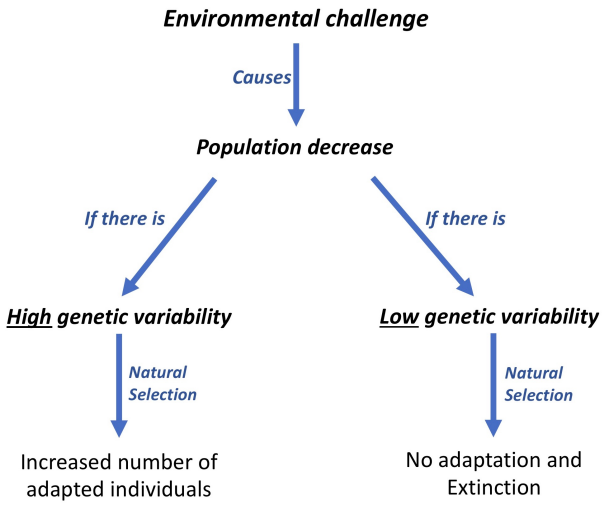
Big Idea

- The mean snow duration for the brown snowshoe hares is very close to the mean snow duration for the white morphs. Thus, in spite of the amount of snow and chances of mismatch, the brown morphs are surviving.
- Natural selection favors brown morphs in mild winter environments.
- The snowshoe hare has more genetic variability than other species.

Facilitation Suggestions

- **Direct students to make a graph of Common Names versus Mean Snow Duration, coloring the points by coat color**. Remind them that the "Show How" movie is available if they need help. Give them time to examine the graph, consult with a peer, and invite a few students to describe what they see.
- **Make sure students save their graph** in their notebook by taking a snapshot.
- **Ask students** if they find anything surprising when comparing the mean snow durations for the five species. Do all species' coat color correlate with snow duration as expected?

- In Step Two, students will propose a hypothesis to explain why the mean snow duration for the brown and white hares is so similar. Note that this proximity in mean snow duration is different from the other four species. Read the question and the possible answers aloud.
- **Before students go on to construct their hypothesis, point out the "**How Nature Works" hint (shown below). If they need further assistance, suggest revisiting the Background 6 exercise on lady beetles.



- As a class, discuss each of the following ideas that may inform students' hypotheses about the mean snow duration for brown and white snowshoe hares.
    - Mild winters. In this investigation, 90 days of snow is considered a mild winter, and brown snowshoe hares are found in places with an average of 93 days of snow per year. As the climate changes and the Earth warms, winters get shorter, especially at lower elevations like places near the coast. In these areas, we would expect to see both white and brown morphs during the winter. Brown hares will survive in higher numbers near the coast, in lower elevations, and perhaps in lower parts of the mountains.
    - The number of brown morphs is increasing. Compared to the other species, the data show that the number of brown snowshoe hare morphs is increasing. We see them in spite of mismatching the surroundings and being obvious to predators in places where there are about three months of snow per year.
    - Natural selection. The data show that both morphs are present in places that have very similar numbers of snow days. This suggests that natural selection is favoring the brown snowshoe hare in these places. This is consistent with evolutionary processes where natural selection works to increase the number of certain genes or phenotypes in the face of environmental challenges.

  - Genetic variability. Natural selection acts when there is genetic variability in a population. While the data do not provide information on genetic variability, students may suggest that the reason the snowshoe hare is favored is because there are pockets where genetic variability is high, which is correct.

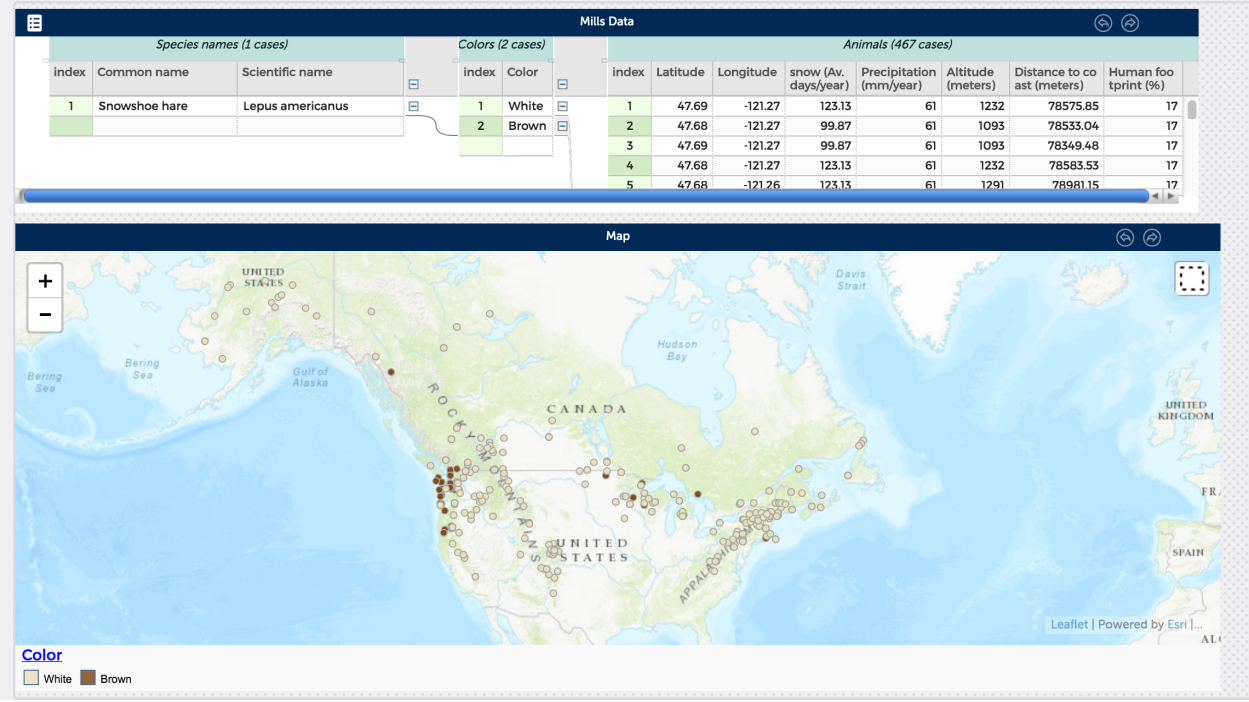
- **Direct students to go back to the question,** "Why do we see brown snowshoe hares in snow covered places?" and to answer on their own the question by posing their hypothesis. Tell students that they can use one or more of the ideas discussed (mild winters, increasing numbers, natural selection, genetic variability) to answer the question and to explain their reasoning.
- Possible answer: Natural selection has favored brown hares; they have adapted to shorter snow duration. The graph suggests that there are areas where both white and brown hares live together; in these places, the average snow duration is between 90 and 111 days. As we learned in the Background, places where populations of polymorphic animals come together have high genetic variability and many types of hare phenotypes, and thus evolution can help restore the species in decline.

TRANSITION POINT

Now that you know that natural selection has favored brown snowshoe hares for survival in mild winter places, and that when you see both morphs it suggests high genetic variability, let's identify areas of high genetic variability in the United States.

INVESTIGATION 3: Find Pockets of Genetic Variability Among Snowshoe Hares

Estimated Time: 20 minutes



Purpose

- To identify specific regions where both white and brown snowshoe hares cohabitate
- To describe locations with potential high genetic diversity

Big Idea

- Places where both morphs coexist suggest high genetic variability.
- These places may have special local environmental characteristics that favor certain individuals.

Facilitation Suggestions

- **Before beginning, make sure students understood the previous investigation (2) by asking**, "If natural selection is favoring some individuals in places with high genetic variability, what would you look for in order to identify these places? Remember that we need both morphs to save the species, and that in snowshoe hares we see brown hares and white hares in places with similar amount of snowy days per year."
- **Direct students** to find out where in the U.S. both snowshoe hare morphs live, draw a circle around them, and make sure they save the snapshots to their notebooks. Show students how to magnify areas on the map and target specific regions using the hand icon. This activity may work best in pairs.
- Remind students that the "Show How" movie is available if they need a refresher on how to draw circles on the map.

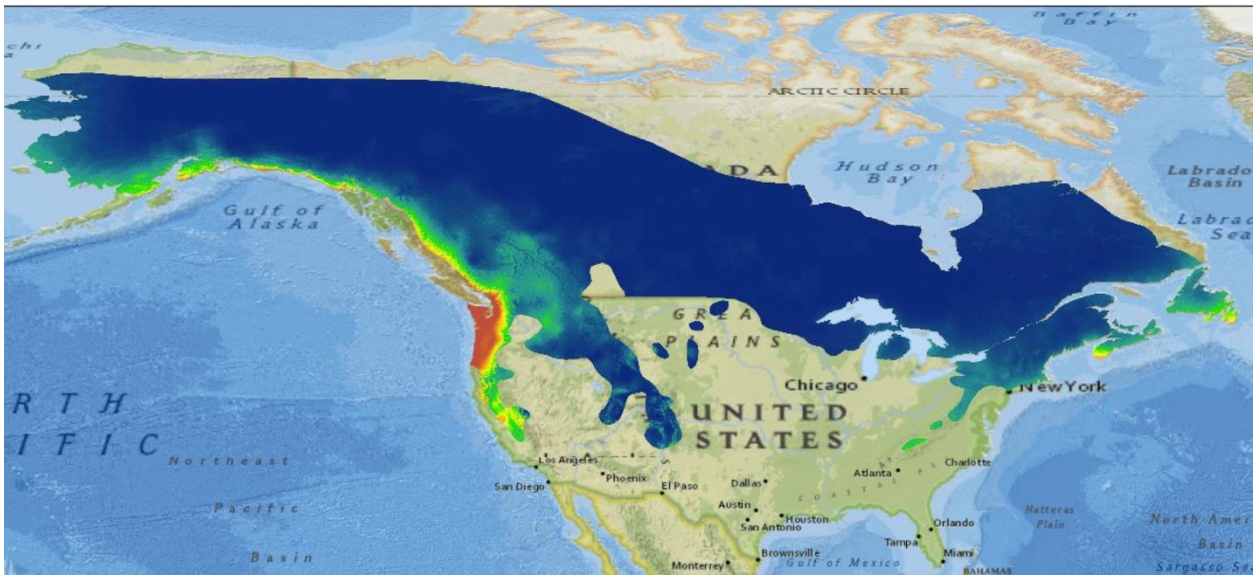
- **Once students identify a location,** encourage them to describe their chosen locations. Make sure they know how to go to high magnification, and see if they can name some features on the map, like mountains and rivers. You may want to have a brief conversation in class about how these environments look in winter. This may help you check if the students are on the right track.
- **Then, encourage students to look closer at where single individuals live**. Within the selected area, students should select one individual and go to the case card for information. They may try another individual found in this location and confirm that they share some environmental attributes, such as altitude and so on.
- **Students should use the same process** to find a second location, making sure they save snapshots of their locations to their notebooks.

TRANSITION POINT

Let's see if students' selected areas fall within the areas that the investigators selected as pockets of high diversity for the snowshoe hare.

INVESTIGATION 4: Does Your Analysis Agree with What the Scientists Found

Estimated Time: 10 minutes



Purpose

- To find out what geographical zones were designated as important for polymorphic species by the investigators
- To find out whether students' results agree with those of the investigators.

Big Idea

- In winter, polymorphic animals live in discrete pockets across the U.S. In the investigator-identified areas, white and brown individuals are found together.
- In the investigator-identified areas, polymorphic species have an equal chance to be winter white or winter brown. They have high genetic/phenotypic variability.

Facilitation Suggestions

- **In this investigation, students will analyze a U.S. map showing the zones where researchers found snowshoe hares.** The investigators created zones—blue, orange/red, and greenish/yellow—that have a high probability to have white, brown, or both morphs, respectively.
- **Allow time for students** to familiarize themselves with the map, the legend, and what the different colored areas signify. Tell students that they can use the "ZOOM IN" button at the bottom of the map to magnify the picture.
- **Remind the class** that in places with high genetic variability, there is a better chance of natural selection for those individuals that are better adapted to the new environmental conditions (for example, mild winters). Ask students what areas they would expect to have higher genetic variability: blue, orange/red, or greenish/yellow? **Ask students to keep this in mind as they answer the first question.**

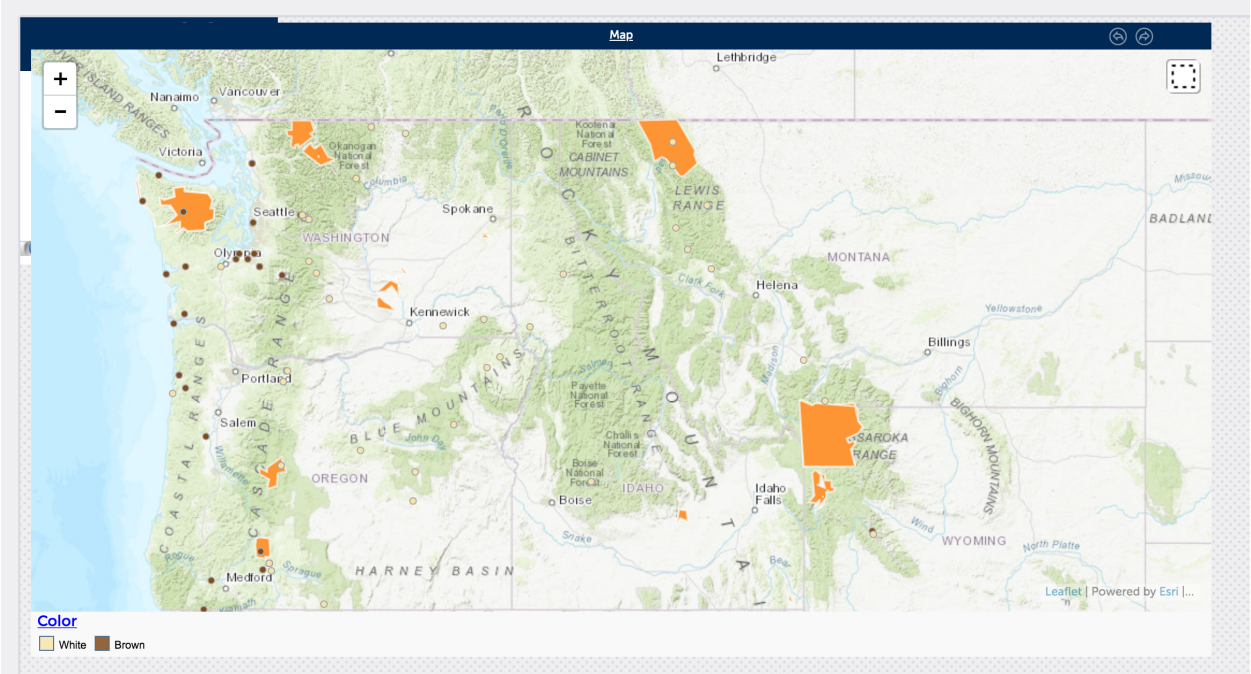
- **Tell students to recall the areas they identified in investigation 3** and judge whether they are within the zones that the investigators found. If so, are they in polymorphic (greenish/yellow) zones? If so, this would corroborate their results and be a sign that they're on the right track. Some students will need to go back and forth from the maps in investigations 3 and 4 in order to give a detailed answer.

TRANSITION POINT

Next, students will determine whether snowshoe hares live in areas where conservation is already in place and, more specifically, whether the two locations they identified are protected.

INVESTIGATION 5: Where Should Conservation be Focused to Protect Polymorphic Species?

Estimated Time: 20 minutes



Purpose

- To investigate whether protected areas in the U.S. overlap with habitats of polymorphic populations of snowshoe hares

Big Idea

- Polymorphic animals need protection because, as the planet warms, their population will decrease due to predation.
- Conservation efforts should take into account places where there is rich genetic diversity so that evolutionary processes have more chance to succeed in saving the species.

Facilitation Suggestions

- **Point out** that the map shows the locations of white and brown snowshoe hares, and that the areas in orange represent areas of protection.
- **Prompt students to look at the map and identify** where, if anywhere, there are overlaps between the protected areas and where polymorphic populations of snowshoe hares live.
- **Make sure students know how to zoom in and out on the map,** and allow time for students to explore it before asking them to share their ideas or discuss with a peer.
- **Keep in mind that the data show only a sample of animals,** not total numbers. If we find two to four brown and white hares together, the assumption is that there may be many more—a polymorphic population.

- In step two, students will examine whether the areas they identified in Investigation 3 are within areas of protection. **Encourage students to find their locations in this map (they may need to zoom in) and direct them to** take a snapshot for their notes.
- **Before students get ready to write their memo, discuss as a class:** "Why is it important to protect areas where polymorphic populations coexist?" Encourage students to use some of the terms they learned in the lesson, for example, genetic variability and natural selection.
- **Tell students to make sure to save the graph** with the mean and standard deviation in their notebook by taking a snapshot.
- **Encourage students to describe the graph, and ask them** to explain what the outliers represent. Then ask students to find the mean and use this data to answer the questions in the Step 4 panel.
- **Direct students to query divergence** by finding the standard deviation and judging which lizard populations have more variability of color—and why. Ask the students to keep in mind when answering the questions that there are no predators on the island.
- **The second part** of the exercise asks students to determine whether the lizards are more homogeneous in color on the mainland or island, and why.
- **Direct students to modify the graph** to show habitat versus correlation to population. **Make sure to save the graph** to their notebook by taking a snapshot.
- In interpreting the results, **encourage students to think of the process of natural selection**. The predator would eat the lizards that do not match their habitat, so only a narrow range of colors is allowed, and thus most of the lizards look like each other. If there are no predators, there is no need to look similar.
- **Color measurements.** Investigators measured reflectance of 200 lizards' dorsal body surfaces using a spectrometer. A matrix correlation was constructed in which two identical populations would have a matrix correlation of one, whereas two populations with no overlapping color would have a correlation of zero. The same type of matrix correlation was used for the phenotype-environment matching.

TRANSITION TO WRITING

Remind students that they will be writing a memo to the U.S. Fish and Wildlife Service recommending two areas in which conservation efforts should be focused to protect the snowshoe hare. Ask them to keep in mind that their statements should be supported by evidence from their notes.

WRITING TASK: Where should conservation measures be put in place to help the snowshoe hare survive the impacts of climate change?

Estimated Time: 35 minutes

Purpose

- To synthesize what students have learned from the lesson in order to address the lesson question
- To use the learned concepts and results in order to write a memo which makes an argument supported by evidence?

Big Idea

- Effectively communicating findings is an important part of the scientific process.
- Presenting data, explaining what they mean, and discussing the implications in writing is often the concluding step in an investigation.

Facilitation Suggestions

- **Tell students they will write a memo to the U.S. Fish and Wildlife Service recommending two areas in which, based on their investigation, conservation efforts should be focused to protect the snowshoe hare.**
- **Encourage students to review their notes and to revisit the Background section** if they need to refresh their memory of certain parts of the lesson and investigation. Remind students that they should select the appropriate evidence and snapshots from their notes to support their ideas.
- **Project the Writing Task and walk students through the outline that they will follow.**

    1. *Intro Paragraph*—Students will describe the challenge by explaining how climate change is negatively impacting polymorphic species. They may find it helpful to use their notes on molting, color mismatch, and effects of climate change from the Background section.
    2. *Evidence and Reasoning Paragraph 1*—In their first evidence paragraph, students should describe evidence that snowshoe hare populations already are showing resilience in a changing climate.
    3. *Evidence and Reasoning Paragraphs 2 and 3*—In these paragraphs, students will propose two locations where polymorphic snowshoe hares live and should be protected. Each paragraph should explain how the evidence supports students' statements, and should include
        - a summary sentence stating the location of the proposed areas to implement conservation efforts;
        - sentences citing data and including maps as evidence for their statements;
        - sentences explaining why the areas should be protected.
    4. *Conclusion Paragraph*— In this paragraph, students should discuss how the results of this investigation may influence the way the U.S. Fish and Wildlife service protects other species.

Sample Writing Product

Dear U.S. Fish and Wildlife Managers,

In this memo, I recommend two areas, based on my investigations, in which conservation efforts should be focused to protect the snowshoe hare.

Snowshoe hares and other polymorphic animals change their coat color to match their surroundings in the winter (white) and summer (brown). Color molting is triggered by day length, so in order for color polymorphism to be effective as a camouflage strategy, day length, snow cover, and molting have to be in sync. Climate change is affecting snow cover amount and duration, and increasing the likelihood of camouflage mismatc— for example, where a hare's coat has turned white, but winter snow has not yet begun. This makes those individuals more vulnerable to predators and imposes strong selective pressure against camouflage mismatch, leading to population decrease by predation and spelling the species' extinction.

In our investigation, we found evidence that natural selection may be helping this species survive. As shown in the graph, the winter-brown hares are found in regions characterized by many more snow days than are other species (for example, white-tailed jackrabbits, long-tailed weasels, and Japanese hares). The fact that the distribution of winter-brown snowshoe hares so closely mirrors that of winter-white individuals (in contrast to the other three species, where the distributions of winter-white and winter-brown individuals are dramatically different) suggests that winter-brown individuals are more broadly represented in the population. This is what we would predict in a scenario where environmental challenges (climate change) are causing population decreases and triggering natural selection to act on genetic variability in order to save the species.

However, even with this evolutionary process in play, nature needs help because the current rate at which the climate is changing is unprecedented and species have little time to adapt. We have identified two locations where polymorphic populations of snowshoe hares are found and are examples of places where we recommend conservation efforts be located.

The first area that should be protected is shown in the map, near Lake Superior in the Superior National Forest. This location has many little lakes and rivers, an average of 133 snow days per year, and it rains 47 millimeters per year. There are not many people around (4%), suggesting that wildlife may be relatively undisturbed. We find both brown and white snowshoe hares in this area, suggesting a pocket of high genetic variability. If this area were protected, it would encourage natural selection to start or continue the evolutionary processes of selecting adapted individuals and increasing the numbers of snowshoe hares. This location lies within a zone identified by the investigators as having a high probability for white morphs. However, the researchers identified a polymorphic zone (where both morphs are found) close by, around Lake Superior and covering areas near the coast. The hares were found at an altitude of 555 meters and at a distance of only 547 kilometers from the coast, suggesting that our results are corroborated by the researchers'. We analyzed the U.S. map showing areas of conservation (in orange) and found that Location 1 is not protected. [Map 1 in Investigation 5] This would be a new area of protection. The closest protected area is an island in Lake Superior, the Isle Royale National Park, at the border with Canada.

The second area we propose to protect is the Wind River Range in the Rocky Mountains of Wyoming. This location has many ravines and rivers running down to form lakes. We found both brown and white snowshoe hare morphs high in the mountain range, at 3885 meters of altitude, suggesting the presence of polymorphic populations in this area and thus high genetic variability. This area has an average of 317 snow days per year, and precipitation of 12 millimeters per year. The location is far from the coast (1,094.37 kilometers) and a human presence of 4% suggesting an area undisturbed by humans. The animals were found within polymorphic areas determined by the researchers (map color green), which corroborate our findings. This would be a good location to focus conservation efforts, since there is high genetic diversity. However, this area is not protected [Map 2 in Investigation 5 notebook]; the closest protected areas are Teton National Park and Yellowstone National Park.

Although conservation areas are widespread across North America, the overlap between conservation areas and zones where polymorphic snowshoe hare populations occur is relatively small. Conservation efforts should be focused on places where there is high genetic variability and therefore foster polymorphic species' resilience to environmental challenges. Our results underlined the importance of studying how polymorphic species respond to rapid climate change. This phenomenon happens very often— for example, in plant flowering, butterfly migration, coral bleaching, and so on. This lesson's ideas of working with nature can be applied to other situations.

ASSESSMENT

Writing Product Assessment

Look for the following when evaluating students' writing tasks.

INTRO PARAGRAPH: THE CHALLENGE

- ❑ Begins by describing the challenge snowshoe hares, as a polymorphic species, face against climate change.
- ❑ Includes the concepts of molting, environmental mismatch, day length, and predation

EVIDENCE OF SNOWSHOE HARE RESILIENCE

- ❑ Compares snowshoe hares to other polymorphic species.
- ❑ Includes natural selection and genetic diversity in the explanation of resilience.

EVIDENCE AND REASONING PARAGRAPHS

- ❑ Includes two paragraphs, each proposing a location in the U.S. as places where conservation efforts should be placed.
- ❑ Each paragraph should present supporting evidence *and* explain why these locations should be considered by including, for example
    - identification of the location, including geographical and environmental features;
    - evidence that both morphs were found in the location, and why this indicates genetic diversity;
    - a determination of whether the location lies within the polymorphic zone described by the investigators;
    - a judgment as to whether the location lies within existing protected wildlife areas

CONCLUSION PARAGRAPH

- ❑ Recommends including evolutionary processes in the U.S. Fish and Wildlife Service conservation planning and includes reasons for this.
- ❑ Includes questions, doubts/uncertainty, comments on the study, and/or proposes further experiments to answer the questions

Key Question Notes

We suggest that teachers use these Key Notes to find out whether students understand the concepts and whether they are keeping pace with the rest of the class.

Key Question 1. Why is genetic variability important for natural selection?

Where. Background 6: The Advantages of Genetic Variability in a Population

Key Understanding. Students should demonstrate understanding of how natural selection works and why genetic variability is important.

Sample Answer. Genetic variability is important because the more choices (variants) there are, the better the chances of finding one that fits the environmental requirements for survival.

Key Question 2

Why do you see brown morphs in places where there are 93 days of snow per year?

Where: Investigation 2: What is Special About Snowshoe Hares?

Understanding: Students should verbalize their understanding of the graph and interpret their results using the concepts presented.

Answer: Natural selection has favored brown hares; they have adapted to the shorter snow duration of mild winters. The graph suggests that there are areas where both winter white and winter brown hares live together. In these places, the average snow duration is between 90 and 111 days.

Key Question 3

Why is it important to protect areas where polymorphic populations coexist?

Where Investigation 5: Should Conservation be Focused to Protect Polymorphic Species?

Understanding: Students are at the end of their investigation and this question shows whether they have reached a conclusion before going to the writing section of the lesson.

Answer: Because in these areas there is high genetic variability. Thus, the polymorphic populations that coexist there have a greater chance of survival, since both nature and humans could help rescue them from extinction.