Developing an Explanation for Mouse Fur Color

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Activity
Educator Materials

OVERVIEW

In this activity, students will investigate a classic study of the evolution of fur color in rock pocket mouse populations, using the short film *The Making of the Fittest: Natural Selection and Adaptation* and additional sources of evidence. Their goal is to understand how to collect and analyze evidence that supports each of the major conditions for evolution by natural selection in order to develop a full explanation for how populations change over time. Ultimately, students should be able to use the Evolution by Natural Selection Explanation Table they use in this activity to summarize the evidence for any claims about a trait changing in response to natural selection in any species. This activity helps students develop useful skills aligned with the science practices of constructing explanations and engaging in argument from evidence.

At the end of the activity, students are asked a couple of questions about the evolution of skin color in humans. Those questions are tied to another HHMI short film, *The Biology of Skin Color*.

KEY CONCEPTS

- Natural selection is a mechanism for evolution.
- Natural selection is a nonrandom process that is the result of
  - existing variation among individuals in a population;
  - the increased survival and reproduction of individuals with certain variations; and
  - inheritance of favorable variations by the offspring.
- Mutations that give rise to variation in a population occur at random.
- Natural selection leads to adaptations, as the frequencies of traits and the genes that code for those traits change within a population over time.
- Many different sources of scientific evidence support claims that evolution by natural selection has occurred and is still occurring.
- Constructing an explanation in science involves supporting claims with evidence and linking claims and evidence with scientific concepts.

STUDENT LEARNING TARGETS

- Summarize, analyze, and describe the evidence needed to make claims about natural selection.
- Develop an explanation for a case of evolution by natural selection that includes logic and evidence, linking claims to evidence through scientific reasoning.

CURRICULUM CONNECTIONS

Standards	Curriculum Connection
NGSS (2013)	MS-LS2-2, MS-LS4-4, MS-LS4-6, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-LS4-2, HS-LS4-4
AP Bio (2015)	1.A.1, 1.A.2, 1.A.4, 1.C.3, 4.C.3, SP5, SP6
IB Bio (2016)	5.1, 5.2
AP Env Sci (2013)	II.C
IB Env Systems and Societies (2017)	2.1
Common Core (2010)	ELA.WHST.6-12.1, WHST.6-12.5, WHST.6-12.9, Math.S-IC.3, MP2
Vision and Change (2009)	CC1, CC3, DP2

KEY TERMS

adaptation, argument, explanation, inheritance, natural selection, variation

TIME REQUIREMENTS

- One 50-minute class period. Class discussion may extend the activity, and procedure steps can be assigned for homework to reduce the amount of class time needed.

SUGGESTED AUDIENCE

- Middle school life science
- High school biology, including general, honors, AP and IB

PRIOR KNOWLEDGE

Students should

- know that variations in some traits are inherited as well as the terms DNA, gene, and allele; and,
- have previous practice developing arguments based on evidence and using scientific concepts to link claims and evidence to produce a scientific explanation.

MATERIALS

- *The Making of the Fittest: Natural Selection and Adaptation* short film
- Student handout for this activity (PDF)
- Evolution by Natural Selection Explanation Table (PDF)
- *The Making of the Fittest: Natural Selection and Adaptation* transcript (PDF)
- Additional Evidence for an Explanation(PDF)

TEACHING TIPS

- Understanding your students is important when introducing natural selection and evolution, as some students may find these concepts difficult to reconcile with their worldviews. Successful science teachers keep a major focus on the nature of scientific knowledge and also create an environment in which students know and feel that their worldviews are respected. If you want help learning how to create such an environment, consider reading the Cultural and Religious Sensitivity (CRS) Teaching Strategies Resources that are a part of the Teaching Evolution through Human Examples project from the Smithsonian Institution (available at http://humanorigins.si.edu/education/teaching-evolution-through-human-examples). The CRS Teaching Strategies Resources have specific activities designed to help students deepen their understanding of the nature of science and to reflect on how studying evolution fits into the nature of science.
- For Step 1, download or prepare to stream the short video *The Making of the Fittest: Natural Selection and Adaptation* (http://www.hhmi.org/biointeractive/making-fittest-natural-selection-and-adaptation).
- The goal of procedure Step 2 is to let students and you explore their prior ideas about natural selection. Consider asking students to share their initial ideas with a partner. As the students discuss their answers, circulate among them and note the frequency of correct ideas and common misconceptions such as that the mice changed because they needed to change. Use your observations to help you plan how long you will need to spend on the rest of the lesson.
- After students discuss their ideas in Step 2, hold a brief class discussion. When discussing 2b, address the common misconception that new traits arise “as needed.” The mutation for dark-colored fur did not occur simply because the mice needed it. Instead, the new trait arose due to random mutation. Clarify that explanations for change based on the needs or wants of an individual are common explanations but are not scientifically accurate.

- When photocopying the Evolution by Natural Selection Explanation Table, try to leave the second side blank, as students may need more room to write in all the evidence from both the video and the additional data they analyze.
- If the process of natural selection is new to your students, you may need to spend extra time in Step 3 to describe each of the major conditions for evolution by natural selection.
- Consider having students complete Steps 6 and 7 with a partner, or sharing their answers with a partner after they have recorded their own ideas.
- Asking students to revisit their prior ideas, as is done in Step 7, helps them develop important metacognitive habits. It may be useful to have them use different ink colors to indicate revisions.
- Perhaps the most challenging aspect of developing an explanation for students is linking evidence to claims using scientific principles. In this activity, the scientific principles are given to the students in the Evolution by Natural Selection Explanation Table, which should make the task more approachable. Still, you may want to go through an ideal student response to one of the questions that ask students to show how evidence and claims are linked by scientific principles, such as procedure Step 6c.
- In the last part of the handout, students answer questions about the evolution of human skin color. Both human skin color and mouse fur color are determined in part by variations in the *MC1R* gene. At the end of this activity, you may watch the film *The Biology of Skin Color* (http://www.hhmi.org/biointeractive/biology-skin-color) with students. As an extension activity, students could fill out another Evolution by Natural Selection Explanation Table using information from that film.

ANSWER KEY: PROCEDURE

2. On your own, write your best answers to the following questions.
   a. How would biologists explain how the mice on the lava flow evolved black fur? Include all the elements you think are needed for a full explanation.

The following answer reflects an ideal student answer. Keep in mind that in the first part of this activity, students are not expected to have a fully developed answer. However, they will revisit their answers to these questions later in the activity. A complete explanation would incorporate the major conditions that are associated with evolution by natural selection.

- *Variation: Within a population of mice on the lava flow, some individuals had the dark fur trait, whereas others did not.*
- *Inheritance: The differences in mouse fur color are inherited (passed from parents to offspring). The origin of the variation stems from mutations.*
- *Differences in survival/reproduction: More offspring are born than can survive, leading to competition within a species. In certain environments, individual mice that have dark fur will survive and have more offspring than mice with tan fur.*
- *Adaptation: The frequency of the mice with dark fur and the alleles that cause dark fur will increase in the population over generations. In this case, the population will change from one in which most of the individuals had tan fur to one in which most of the individuals have dark fur.*

   b. Would biologists say that the mice changed because they wanted or needed to change? Why or why not?

Be open to a range of student ideas at the beginning of the lesson. Listen for students expressing the common misconception that changes to organisms are directly caused by an individual wanting or needing to change.

5. A summary of evidence that students may record after watching the video and reviewing the transcript is in Table 1.

Table 1. Possible evidence for each major condition for evolution by natural selection in rock pocket mice after students see the video and review the transcript.

Condition	Description	Evidence
Variation	Individuals in a population or group differ in some trait of interest.	• There are black rock pocket mice and tan rock pocket mice, and they belong to the same species. • Black mice may be found in a population of tan mice with a frequency of about 1 for every 100,000 births.
Inheritance	The variation in the trait of interest is at least partially inherited (passed from parents to offspring). The variation stems from random mutations and the recombination that accompanies sexual reproduction. The genetic variation may have arisen many generations in the past.	• New mutations cause black color (time mark 3:24). • Fur color is controlled by many genes (4:29). • Most genes are identical, but dark and light rock pocket mice differ in one gene (*Mc1r*; 4:55).
Differential survival and reproduction	More offspring are born than can survive, resulting in competition among individuals within a population. Some individuals with a particular trait are more likely to survive and/or have relatively more offspring compared to individuals that do not have that trait. Selection depends on the specific context of a species. Traits that are beneficial in one environment may cause problems in another environment.	• Mice of different fur colors do not show a preference for background color, but predators weed out mice that do not match their background (2:58). • Tan mice blend into the environment when on desert sands but stand out when on dark lava (1:32).
Adaptation	The frequency of the trait that helps individuals survive or leave more offspring will increase in the population over time, as will the alleles that affect the trait. This process can take many generations and extend over very long periods of time.	• The video suggests that on the dark lava flows, dark-colored rock pocket mice are more numerous than light-colored mice. • A survival advantage of 1% for dark rock pocket mice on a dark background, starting at 1% of the population, would result in 95% of the mice having dark fur in 1000 years (6:18). • A survival advantage of 10% would cause the same change in a population in only 100 years (6:34).

7. Calculate the percentage of tan mice in each population from the data in Table 1.

   a. Enter your calculations in the last row in Table 1. *See the last row in the table below.*

Population →	**Christmas Pass**	**Tule Well**	**Lava (West)**	**Lava (Mid)**	**Lava (East)**	**O'Neill Pass**
Soil color	Light	Light	Dark	Dark	Dark	Light
Number of tan mice	6	80	0	0	3	34
Number of dark mice	0	5	7	5	42	43
Total number of mice	**6**	**85**	**7**	**5**	**45**	**77**
Percentage of tan mice	***100%***	***94%***	***0%***	***0%***	***7%***	***44%***

b. Which populations show evidence for variation in fur color? Add the evidence to your Evolution by Natural Selection Explanation Table as needed.

The Tule Well, Lava (East), and O'Neill Pass populations show evidence of variation. Students may note that the samples sizes in populations that do not show variation are relatively small. A larger sample is likely to show variation.

c. Describe how the evidence you collected illustrates one of the conditions for evolution by natural selection.

One of the requirements for evolution by natural selection is that a population show variation for a trait that can affect survival or reproduction. Fur color is likely to affect survival. The data show that in populations in which a relatively large number of individuals were collected, there are mice with different fur colors. This means that the population has the opportunity to undergo selection for fur color.

8. What pattern or patterns do you see on the graph in Figure 3?

The color of a mouse's fur is affected by the alleles they inherit for the MC1R gene. Mice that have two copies of allele 1 have the lightest fur, those with two copies of allele 2 have the darkest fur, and heterozygotes have intermediate fur color (though it is closer to the dark fur color).

a. Make a claim about whether differences in fur color are inherited. Support your claim with evidence from Figure 3. Add the evidence to your Evolution by Natural Selection Explanation Table as needed. Also, describe how the evidence relates to the major conditions for evolution by natural selection.

The data show that a mouse's alleles for MC1R gene, which they inherit from their parents, affect their fur color. These data support the claim that differences in fur color can be passed from parents to offspring. In order for natural selection to affect the frequency of a trait in future generations in a predictable way, the differences in traits must be partially inherited.

9. Make a claim about whether the frequencies of alleles that affect fur color are different in populations on light or dark backgrounds. Support your claim with evidence from Figure 4. Add the evidence to your Evolution by Natural Selection Explanation Table as needed. Again, describe how the evidence relates to the major conditions for evolution by natural selection.

In areas with dark soil color, the frequency of the MC1R allele that causes dark fur (allele 2) is high in the mouse population. For example, the frequency of MC1R allele 2 in the Lava (West) population is approximately 0.90. The opposite pattern is true in areas with light soil color. For example, the frequency of the MC1R allele 2 in the Tule Well population is approximately 0.05. These data fit the expected pattern if mice with dark fur survive better and leave relatively more offspring on dark soils and vice versa for mice on light soils. The evidence suggests that dark fur color is an adaptation for mice in dark-colored backgrounds, as both the frequency of the trait and the allele that causes the trait have changed. These data also support the idea that selection depends on environmental context, as dark mice were favored in some environments but not in others.

Table 2. Possible evidence for each major condition for evolution by natural selection in rock pocket mice after students see the video, review the transcript, and add evidence from the Additional Evidence for an Explanation handout.

Condition	Evidence
Variation	• There are black rock pocket mice and tan rock pocket mice, and they belong to the same species. • Black mice may be found in a population of tan mice with a frequency of about 1 for every 100,000 births. • **Data from Data Set 1 show that the Tule Well, Lava (East), and O'Neill Pass populations show evidence of variation.**
Inheritance	• New mutations cause black color (time mark 3:24).

	• Fur color is controlled by many genes (4:29). • Most genes are identical, but dark and light rock pocket mice differ in one gene (*Mc1r*; 4:55). • **Data from Data Set 2 show that a mouse's genotype for the *MC1R* gene affects their fur color. Mice with two copies of allele 2 have the darkest fur.**
Differential survival and reproduction	• Mice of different fur colors do not show a preference for background color, but predators weed out mice that do not match their background (2:58). • Tan mice blend into the environment when on desert sands but stand out when on dark lava (1:32). • **Data from Data Set 3 show that selection depends on environmental context, as dark mice were favored in some environments but not in others.**
Adaptation	• The video suggests that more dark-colored rock pocket mice live on the dark lava flows than light-colored mice. • A survival advantage of 1% for dark rock pocket mice on a dark background, starting at 1% of the population, would result in 95% of the mice being dark in 1000 years (6:18). • A survival advantage of 10% would cause the same change in a population in only 100 years (6:34). • **Data from Data Set 3 show that the frequency of mice with dark fur and the frequency of the alleles that cause dark fur are only high in populations found on dark-colored backgrounds.**

10. Review your answer to Step 2a after watching the video and analyzing additional evidence. Describe how many of the conditions of evolution by natural selection you used in your initial answer. Also describe the changes you would make to your answer based on what you've learned.

Students should revise their answers to reflect the ideal student answer provided in Step 2a.

ANSWER KEY: APPLY WHAT YOU LEARNED

1. Oldfield mice (Peromyscus polionotus, also called beach mice) in the southeastern United States belong to a different genus than rock pocket mice (Chaetodipus intermedius). Oldfield mice from the mainland live in areas with dark soils. These mice mostly have dark fur. Populations of the same species that live on the white beaches of Florida and Alabama have light fur. Describe the evidence you would need to collect to support the claim that the differences in color in these populations are due to evolution by natural selection.

Students should recognize that they would need to collect evidence to support each of the major conditions for evolution by natural selection.

- *Variation: Within a population of mice, students would need to be able to collect mice and show that some individuals had the dark fur trait, whereas others had light fur.*
- *Inheritance: Students could suggest a range of studies to show that fur color is inherited. For example, they could measure the fur color of parents and their offspring while keeping the environment constant. They could also explore genes that code for proteins in the pathway to make the molecules responsible for fur color. Convincing evidence would show that certain alleles for some or one of the genes are associated with changes in fur color.*
- *Differential survival and reproduction: Useful evidence would include data showing that dark-colored mice on light-colored soil have lower rates of survival than light-colored mice. On dark-colored backgrounds, mice with dark-colored fur would show higher rates of survival.*
- *Adaptation: Students could suggest collecting evidence that shows that the frequency of the mice with light fur and the alleles that cause light fur have increased in the populations near the white beaches over generations.*

2. Describe the types of evidence you would need to collect to support the claim that differences in skin color among humans are the result of natural selection.

Again, evidence would need to be collected to support each of the major conditions for evolution by natural selection.

- *Variation: Students already recognize that humans show variation in skin color. It would be useful to be able to quantify skin color and measure it across a range of different people. Biologists quantify skin color using an instrument called a reflectometer.*
- *Inheritance: Students could suggest a range of studies to show that skin color is inherited, using the same types of evidence described in the answer to Question 1.*
- *Differential survival and reproduction: Useful evidence would include data showing that people with dark-colored skin have or had survival or reproductive advantages in certain environments, whereas people with light-colored skin have or had advantages in other environments. Detailed explanations would be able to describe the physical basis for how light or dark skin specifically affects survival or reproduction for people in different environments.*
- *Adaptation: Useful evidence would show that the frequency of people with dark skin and the alleles that cause dark skin have increased in certain populations that live in areas associated with some environmental variable. Conversely, evidence could show that the frequency of people with light skin and the alleles that cause light skin have increased in other populations that live in areas associated with another environmental variable.*

3. Humans also have an MC1R gene, and scientists have discovered that it's one of the genes that determines the type and amount of melanin in a person's skin. If you wanted to study whether skin color has, like mouse fur color, evolved by natural selection, what additional challenges do you imagine in collecting data or designing experiments to explore skin color evolution in humans? Make a list of at least three additional challenges.
   - *In the mouse studies, the factor that has a big impact on mouse fitness is predation, which is still ongoing. Cultural adaptations in humans, such as the development of clothing, shelter, vitamin supplements, sunscreen, and modern medicine, may have changed the factors that influence fitness as it relates to skin color.*
   - *Humans have moved to different parts of the world at a rapid rate in recent times. Patterns we see in the world today for the prevalence of people with certain skin colors may not reflect historical patterns.*
   - *In the mouse studies, selection against mice with a fur color that was mismatched to the color of their background was strong due to the activity of visual predators. The impact of skin color on human fitness is not likely to be as large. Small impacts of fitness are important, especially over long periods of time, but they can be difficult to measure, especially when contemporary pressures are diminished compared to the past.*
   - *Working on similar issues in humans raises important ethical considerations.*
   - *Humans have a much longer generation time than the mice, which makes studying humans more difficult.*

Much of the evidence described for the evolution of human skin color has been discovered. See the HHMI video The Biology of Skin Color at http://www.hhmi.org/biointeractive/biology-skin-color to explore this evidence in more detail.

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This activity is adapted from an activity in the *Evolution of Human Skin Color* curriculum unit for AP Biology that is a part of the Smithsonian Institution's National Science Foundation-funded Teaching Evolution through Human Examples project (Grant No. 1119468). See http://www.hhmi.org/biointeractive/making-fittest-natural-selection-and-adaptation to explore the full curriculum supplement.