Endless Forms Most Beautiful, by Dr. Sean B. Carroll (media.hhmi.org/hl/05Lect1.html)

In this lecture, Dr. Carroll, a leader in the field of evolutionary developmental biology (or evo devo), explores how key developmental genes, natural selection, and time fuel the evolutionary process.

Evolution: Fossils, Genes, and Mousetraps, by Dr. Ken Miller (media.hhmi.org/hl/06Miller.html)

In this lecture, leading evolution educator Dr. Ken Miller discusses the controversy surrounding the teaching of evolution and presents compelling evidence for evolution and reasons why intelligent design is not scientific. The presentation features Dr. Miller's responses to questions from a live audience of high school students.

Stickleback Environment (www.biointeractive.org/stickleback-environment)

This video shows how, at the end of the Ice Age, the retreating ice sheet created many new lakes, some of which were colonized by stickleback fish. The presence of different predators in different lakes dictated the subsequent evolution of each isolated lake's stickleback population over the course of about 10,000 years. Some groups kept their spines to use against predatory fish, such as trout. Others lost their spines, perhaps to evade aquatic insect predators.

Fossil Record of Stickleback Evolution (www.biointeractive.org/fossil-record-stickleback-evolution)

This animation illustrates how a quarry site in Nevada carries the evolutionary history of a population of stickleback fish that resided there when it was a freshwater lake. In a short time span in evolutionary terms—about 10,000 years—we can see the size of the pelvic spines dramatically reduce in the fish population. This particular fossil record is remarkably complete with nearly year-by-year detail, which includes documentation of intermediate forms.

QUIZ QUESTIONS AND ANSWERS

The student version of this quiz is available as a separate file. We note the key concepts covered by each question here. You may wish to use some or all of the questions below to test your students' knowledge, depending on the content you wish to emphasize.

1. (Key Concept A) *Define "mutation."*
   A mutation is a change in an organism's DNA sequence. Students may also mention that the change is random, but this is not necessary for a complete answer.

2. (Key Concepts A, B, and F) *Is the following statement true or false? Justify your answer in one or two sentences: "Mutations are caused by selective pressure in the environment."*
   False; the mutations discussed in this film occurred at random. (Mutations can be nonrandom, but they are not caused by selective pressure.) Students may also mention that environmental selective pressure acts on the phenotype that results from the mutations but does not cause the mutations or the phenotype to appear.

3. (Key Concepts B and G) *Is the following statement true or false? Justify your answer in one or two sentences: "The same mutation could be advantageous in some environments but deleterious in others."*
   True; the environment or selective pressure determines whether a mutation is beneficial.

4. (Key Concepts A, B, and F) *Is the following statement true or false? Justify your answer in one or two sentences: "The appearance of dark-colored volcanic rock caused the mutation for black fur to appear in the rock pocket mouse population."*
   False; selective pressure does not cause mutations but rather determines whether a mutation is advantageous or deleterious in a particular environment. Students may also mention that the dark-colored volcanic rock played a role in making dark-colored fur (and the corresponding alleles or mutations) favored, but this is not necessary for a complete answer.

5. (Key Concepts B, C, and G) *Explain how the environment plays a role in changing the frequency of a mutant allele in a population.*
Some traits are more advantageous (or deleterious) in certain environments than others. As a result, organisms with traits (and therefore the mutations that result in those traits) that make them better suited to a particular environment are more likely to have offspring and pass on their genes. Over time, this results in an increase in the frequency of mutations that encode beneficial traits for that environment (or, conversely, a decrease in the mutations that influence deleterious traits in that particular environment). Students may provide an example to support their answers (such as the rock pocket mice from the film), but this is not necessary for a complete answer.

6. (Key Concepts C, D, and F) *As you saw in the film, rock pocket mice evolved to have dark-colored fur in certain habitats. In three to five sentences, explain how this trait increased in frequency in the population. Include the following key terms: "fitness" (or "fit"), "survival" (or "survive"), "selection" (or "selective"), and "evolution" (or "evolve").*
A complete answer should resemble the following, with partial credit given to students who do not include all the key terms or concepts (key terms are in *italics*): "Rock pocket mice with dark-colored fur were more *fit* on dark-colored volcanic rock because visual predators could not see them well; that is, natural *selection* favored individuals with dark-colored fur. As a result, more of the dark-colored mice *survived* and reproduced. This caused the population of rock pocket mice to *evolve* to have more individuals with dark-colored fur."

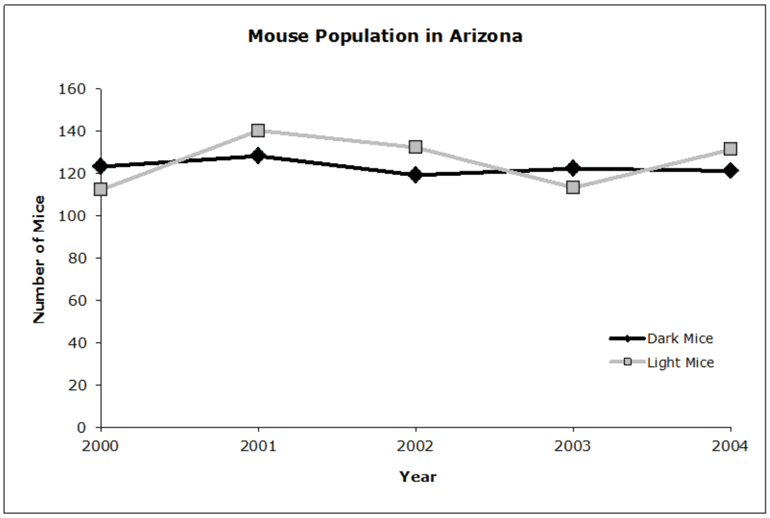
7. (Key Concept F) *Near the end of the film, Dr. Sean B. Carroll states that "while mutation is random, natural selection is not." In your own words, explain how this is possible.*
A complete answer for this question should include the idea that natural selection acts on traits, which results in the mutations for those traits being more likely to be passed on to the next generation. However, it does not actually cause the mutations to appear in the population; many mutations appear randomly. Paraphrasing the above quote is not sufficient for a complete answer.

8. (Key Concepts D and E) *Suppose you are studying a recently discovered population of rock pocket mice with dark-colored fur that lives on volcanic rock. You take a DNA sample from a member of this new population and determine the DNA sequence of a gene known to play a role in fur color. The sequence you get is identical to that of the same gene in another rock pocket mouse population with dark-colored fur that lives on a different patch of volcanic rock. Which of the following could explain this observation?* [Answer is in **bold**.]
   a. The mice in the two populations evolved from the same ancestral population.
   b. The volcanic rock caused the same mutation in each rock pocket mouse population, resulting in dark coloration.
   c. The same mutation spontaneously arose in the two different populations.
   d. Both (a) and (c) are possible.
   e. All of the above are possible.

9. (Key Concept G) *For rock pocket mice, which of the following contributes to selective pressure favoring dark-colored fur? Write "yes" or "no" next to each of the four possible responses.* ***There may be more than one yes response.***

Predators	**Yes**	Genetic mutations	**No**
Rock color	**Yes**	Availability of food for the rock pocket mice	**No**

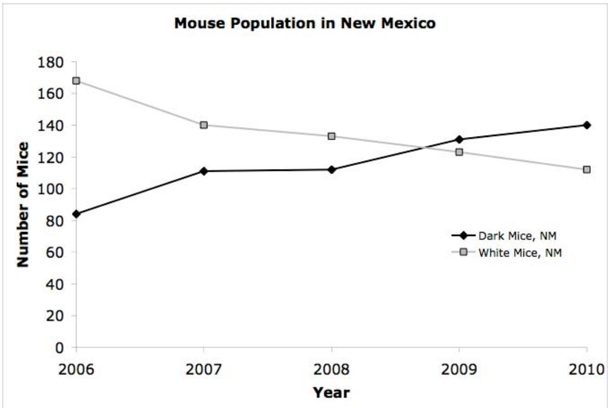
10. (All Key Concepts) *Suppose you are studying a new population of rock pocket mice in Arizona. These mice live on a recently discovered patch of dark-colored volcanic rock. This environment does not have nearly as many visual predators as in previously studied areas in New Mexico. You observed the following numbers of light- and dark-colored mice on this new patch of rock.*

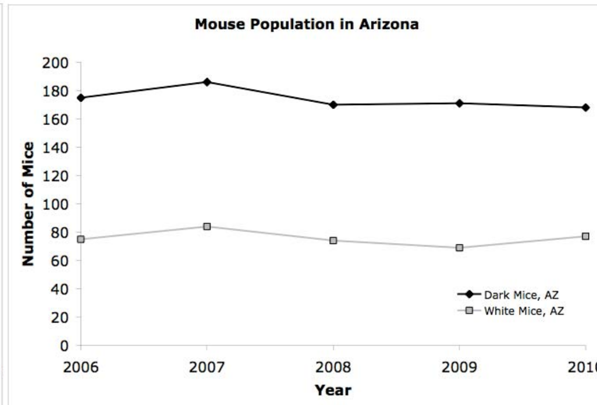


a. *In one or two sentences, summarize the data presented in the graph.*
Students should note that the numbers of both light- and dark-colored mice are relatively stable over the observed time period.

b. *Provide one possible hypothesis that would explain the observed data. Be sure to include the following key words in your answer: "selection" (or "selective"), "fitness" (or "fit"), and "survival" (or "survive").*
Sample answer (key terms are in *italics*): "Due to the absence of predation pressure, having light- or dark-colored fur does not make a difference to an organism's overall *fitness* and therefore likelihood of *survival*. The two coat colors are equally suited to the environment, so natural *selection* does not change the frequency of these traits."

You next decide to move 50 of these newly discovered light-colored rock pocket mice from Arizona to a colony in New Mexico that also lives on dark-colored volcanic rock. You also move 50 dark-colored mice from the New Mexico colony to the Arizona colony. You monitor the populations for five years and observe the following.





c. *In one or two sentences, summarize the data presented in the graphs above.*
The population of dark-colored mice in New Mexico is increasing while the population of light-colored mice is decreasing. In Arizona, there is little to no change in the light- and dark-colored mouse populations.

d. *Provide an explanation for these observations. Be sure to include the following key words in your answer: "selection" (or "selective"), "fitness" (or "fit"), and "survival" (or "survive").*
Sample answer (key terms are in *italics*): "In New Mexico, there is a *selective* advantage to having dark-colored fur. Dark-colored mice are less visible to predators. This makes them more *fit* in this environment and therefore more likely to *survive* and reproduce. In Arizona, where there are fewer visual predators, there is no selective advantage to light- or dark-colored fur. Different colored mice are equally fit and therefore equally likely to survive and reproduce."

Before your experiment above, you take a DNA sample from one dark-colored mouse in each population and sequence a gene known to play a role in making mice dark colored. You discover that the dark-colored mice from Arizona have a different allele of this gene than the dark-colored mice from New Mexico.

e. *Design an experiment to test which population of dark-colored mice is more evolutionarily fit in an environment of your choice. You may want to use the above experiments as a guide. Be sure to state your hypothesis, as well as what type of data you will record.*
Because this question is very open ended, a wide range of creative answers is possible. Important points to be included in any answer for full credit are
- **a clearly stated hypothesis;**
- **an experimental design that tests the stated hypothesis; and**
- **a description of data that the students would collect in their experiments, which must be able to test the stated hypothesis.**

Possible complete response: "I hypothesize that the population of dark-colored mice from Arizona is more evolutionarily fit than the population of dark-colored mice from New Mexico in a desert with black sand. To test this hypothesis, I will take 50 dark-colored mice from each population and place them in a black sand desert. Each population will be on a separate patch of black sand that is identical in every way, but I will keep them separate to prevent interbreeding. Every year for five years, I will count the number

of mice in each patch of black sand and see how many mice from each population survive. If more of the mice from Arizona survive than mice from New Mexico, this will support my hypothesis."

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FIELD TESTERS (QUIZ)

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