

IN-DEPTH FILM GUIDE

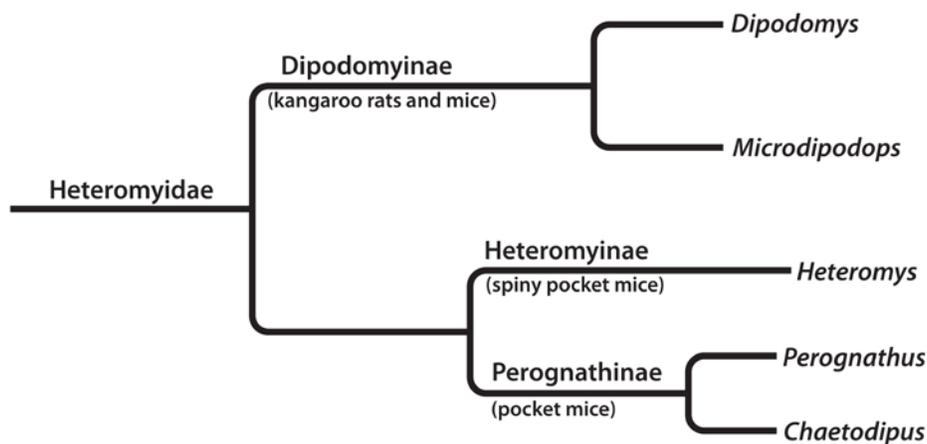
KEY CONCEPTS

- A. A mutation is a random change to an organism's DNA sequence.
- B. The environment contributes to determining whether a mutation is advantageous, deleterious, or neutral.
- C. Mutations that increase fitness of an organism increase in frequency in a population.
- D. Evolution can happen quickly (hundreds of years, or even less); advantageous genetic mutations can increase in frequency in a population quite rapidly, even if the fitness advantage to the organism is small.
- E. Different mutations in the same gene, or even mutations in different genes, can result in the same phenotype.
- F. While mutations can be random, natural selection is not random.
- G. Selective pressure depends on the environment in which an organism lives. This means that other organisms in the environment (in this case, the predators) can be a selective force.

BACKGROUND

The rock pocket mouse (*Chaetodipus intermedius*) is a small rodent in the Heteromyidae family. Even though it looks very much like a mouse, pocket mice are more closely related to pocket gophers than to true mice. Classification and Heteromyidae phylogeny are shown below.

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Rodentia
Family: Heteromyidae
Subfamily: Perognathinae
Genus and species: *Chaetodipus intermedius*



The rock pocket mouse, found throughout the southwestern United States, is well adapted to its dry, rocky desert environment. Their kidneys highly concentrate waste, resulting in very viscous urine. They stay in cool underground burrows during the day. They have been observed plugging the entrance to their burrows, which may serve to retain moisture. When the temperature is extremely high, rock pocket mice may estivate, a form of dormancy characterized by lowered activity and metabolic rate.



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Rock pocket mice are solitary and claim small territories. Females usually give birth to multiple litters of one to seven pups each year during the spring and summer months. Young have been seen emerging from their burrows from April through August.

The rock pocket mouse is an excellent model organism to study geographic variation in phenotype within a single species. Rock pocket mice that live in areas with a light-colored granite substrate are usually sandy in color. Most rock pocket mice that live in areas covered by dark-colored lava rocks, however, are dark in color. Dark-colored rock pocket mice have uniformly pigmented hairs. Light-colored rock pocket mice have fur composed of banded hairs that have a dark-colored base and tip. Biologists have investigated and found the genetic mutations responsible for the dark-color mutation. Interestingly, different populations have different mutations that result in the same general dark-colored phenotype. Similar mutations are also responsible for dark-colored phenotypes in other species such as jaguars.

DISCUSSION POINTS

- In the film, we learn that the dark-colored rock pocket mice have light-colored underbellies. Help students understand that the underside color of the rock pocket mouse would not be under strong selection pressure since it is not involved in camouflage. It is likely that there has been a mutation for dark-colored underbellies, but without selection for the trait, it has not become common.
- Your students may wonder why camouflage is important for a nocturnal species such as the rock pocket mouse. Nocturnal predators such as owls are able to discern color differences at night. In the 1940s, Dr. Lee Dice conducted experiments showing this. See the paper in the references section below by Dr. Dice for more information.
- It seems that dark coloration lends some selective advantage even on a light-colored substrate. Ask your students if they can come up with a good explanation. Researchers think it is because rocks and shrubs cast shadows, and the dark-colored mice are pretty well hidden unless they run across the open, light-colored, sandy areas. The same cannot be said of light-colored mice on dark-colored substrates; they stand out whether or not they are in shadow.
- Be sure to reemphasize with your class that mutation is random. The dark coloration in the rock pocket mouse did not arise *because* there was a lava flow. Rather, a random mutation proved adaptive to the mice living in areas of dark-colored volcanic rock. Because dark coloration was helpful in this environment, more mice with the dark-color mutation survived to reproduce, thus passing on their genes (including the mutation for dark-colored fur) to the next generation with greater frequency than those without the mutation. In a population of mice living in areas of light-colored rock, the mutation would not be adaptive and would therefore not persist.
- The rock pocket mouse story is very similar to another that your students may have heard about, that of the peppered moths. The peppered moth can be light-colored or dark-colored. Dark-colored peppered moths became more common in Britain following the industrial revolution in part because they were able to avoid predation by blending in with soot-covered trees when resting. You or your students may have heard that this story is “fake,” and indeed, there were some problems with the original research. The essential elements are, however, correct and a good example of natural selection “in action.” For more on the peppered moths and the problems cited by some, see www.millerandlevine.com/km/evol/Moths/moths.html

CLASSROOM RESOURCES FOR THE FILM

(all available at www.biointeractive.org/activities/pocketmouse.html)

Color variation over time in rock pocket mouse populations

Data collection and analysis activity that examines selection for coat color in rock pocket mouse populations on different colored substrates over time. Students collect data, prepare graphs, and answer questions that apply concepts introduced in the film.

Appropriate for: middle school life science, high school biology (all levels)



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Allele and phenotype frequencies in rock pocket mouse populations

This activity uses real rock pocket mouse data collected by Dr. Michael Nachman and his colleagues to illustrate the Hardy-Weinberg principle. Students use the data to calculate allele and phenotype frequencies and then manipulate selection values using an Excel spreadsheet.

Appropriate for: high school biology (all levels), introductory college biology

Molecular genetics of color mutations in rock pocket mice

This activity requires students to transcribe and translate portions of the wild-type and mutant rock pocket mouse *Mc1r* genes and compare sequences to identify the locations and types of mutations responsible for the coat color variation described in the film.

Appropriate for: high school biology (all levels), introductory college biology

Biochemistry and cell signaling pathway of the *Mc1r* gene

This advanced activity requires students to analyze partial DNA sequences of the *Mc1r* gene and identify the effects of altered amino acid chemistry on the functionality of the mutated MC1R protein pathway.

Appropriate for: high school biology (AP, IB), introductory college biology

Natural selection and evolution of rock pocket mouse populations

In this activity, students analyze amino acid data and draw conclusions about the evolution of coat color phenotypes in different rock pocket mouse populations. The activity reviews key concepts and causes of evolution including mutation, gene flow, genetic drift, and natural selection.

Appropriate for: high school biology (all levels), introductory college biology

OTHER BIOINTERACTIVE RESOURCES

Natural and Artificial Selection (www.biointeractive.org/evolution/Selection/01.html)

A Click and Learn activity in which students learn about natural and artificial selection. Features multiple clips from the lectures on evolution (see below).

Endless Forms Most Beautiful, by Sean 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 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/evolution/stickleback_environment.html)

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 sticklebacks. The presence of different predators in different lakes dictated the subsequent evolution of each isolated lake stickleback 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/evolution/stickleback_fossil_record_anim.html)

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—the fish population can be seen to dramatically reduce the size of their pelvic spines. This particular fossil record is remarkably complete with nearly year-by-year detail, which includes documentation of intermediate forms.



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QUIZ QUESTIONS AND ANSWERS

The student version of this quiz is available as a separate file. Key concepts covered by each question are noted here. You may wish to use some or all questions below to test your students' knowledge depending on 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 or not 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 frequency of mutations that encode beneficial traits for that environment (or, conversely, a decrease in mutations that influence deleterious traits in that particular environment). Students may provide an example to support their answer (such as the rock pocket mice from the video), but this is not necessary for a complete answer.
6. (Key Concepts C, D, and F) As you saw in the video, 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)*, *evolution (or evolve)*.
A complete answer should resemble the following, with partial credit given to students who do not include all key terms/concepts (key terms 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.

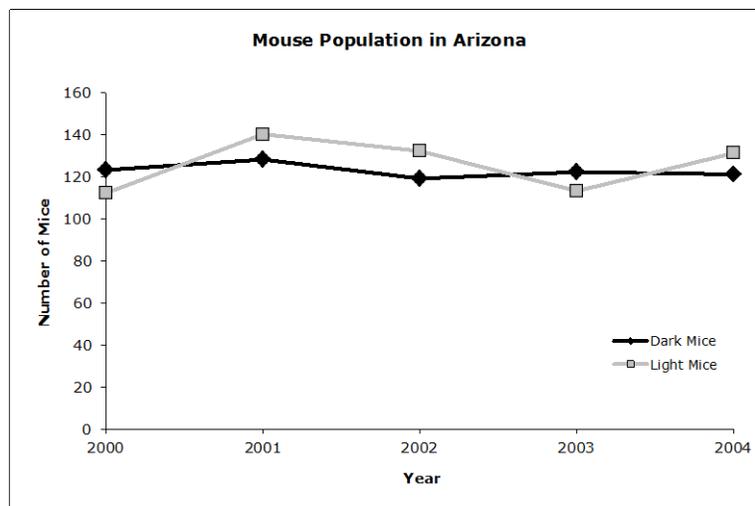
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7. (Key Concept F) Near the end of the video, Dr. Sean Carroll states that, "While mutation is random, natural selection is not." In your own words, explain how this is possible.
A complete answer for this question should include the idea that natural 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) 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 live on a different patch of volcanic rock. Which of the following could explain this observation? (Answer in **bold**.)
- The mice in the two populations evolved from the same ancestral population.
 - The volcanic rock caused the same mutation in each rock pocket mouse population, resulting in dark coloration.
 - The same mutation spontaneously arose in the two different populations.
 - Both a) and c) are possible.**
 - All of the above are possible.
9. (Key Concept G) For the rock pocket mouse, 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) 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:



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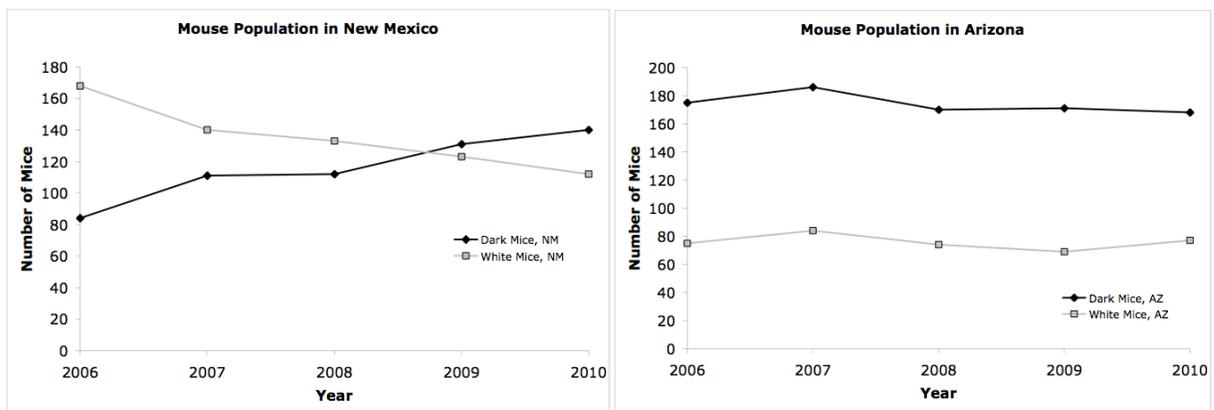
- a. In one or two sentences, summarize the data presented in the graph.

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), survival (or survive).

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), survival (or survive).

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.



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Prior to 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 are possible. Important points to be included in any answer for full credit would be:

- **A clearly stated hypothesis.**
- **An experimental design that tests the students' stated hypothesis.**
- **A description of data that the students would collect in their experiment, which must be able to test the students' stated hypothesis.**

This is an example of a 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 they will be kept separate to prevent interbreeding. Every year for 5 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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