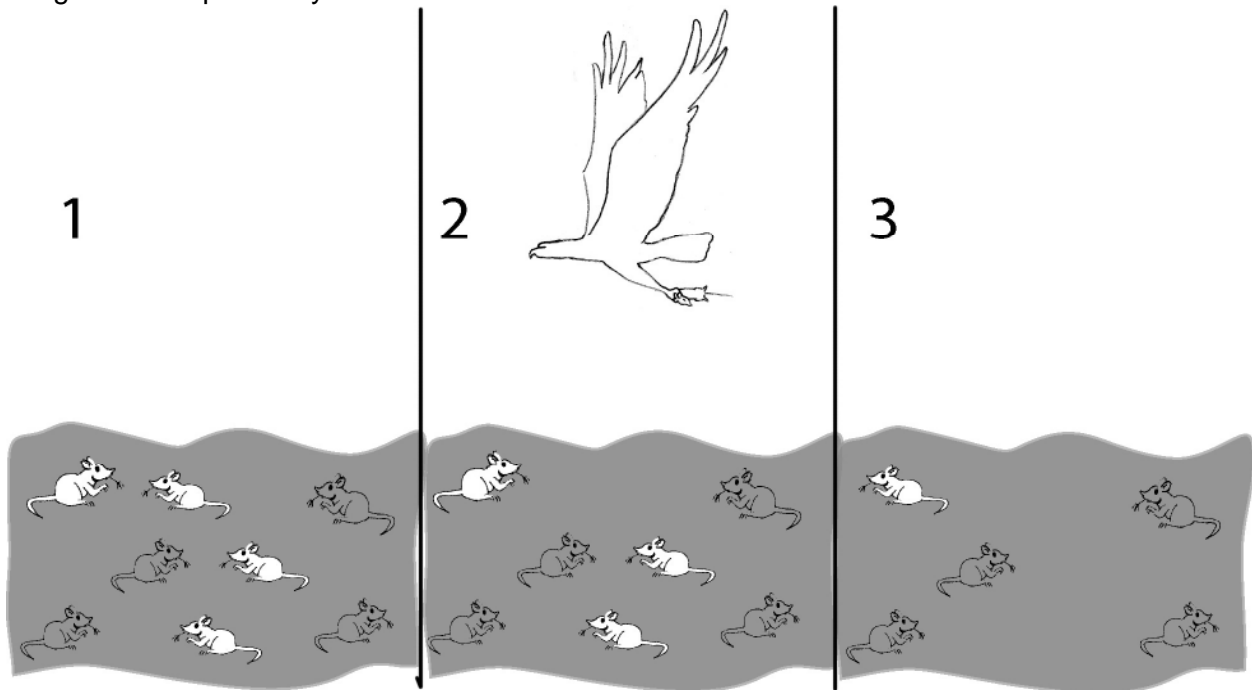


Evolution by Natural Selection

Adapted from the University of California, Los Angeles Life Sciences 1 Demonstration Manual
 Copyright 2012 by Drs. Jennifer Doherty and Ingrid Waldron, Department of Biology, University of Pennsylvania¹

★ Describe what is happening in figures 1-3. Is the population of mice different in figure 3 than in figure 1? Explain why.



Living things that are well adapted to their environment survive and reproduce. Those that are not well adapted don't survive and reproduce. An **adaptation** is any characteristic that increases **fitness**, which is defined as the ability to survive and reproduce.

★ What characteristic of the mice in figure 1 was an adaptation that increased fitness?

The table describes four female mice that live in a beach area which is mostly tan sand with scattered plants.

Characteristics of each female mouse	Color of Fur			
	Black	Tan	Tan and Black	Cream
Running speed	8 cm/sec.	6 cm/sec.	7 cm/sec.	5 cm/sec.
# pups produced by each female	0	11	3	0
Age at death	2 months	8 months	4 months	2 months

★ According to the definition given for fitness, which mouse would biologists consider the fittest? Explain why this mouse would be the fittest.

★ If a mouse's fur color is generally similar to its mother's color, what color fur would be the most common among the pups?

¹ Teachers are encouraged to copy this student handout for classroom use. A Word file (which can be used to prepare a modified version if desired), Teacher Preparation Notes, comments, and the complete list of our hands-on activities are available at http://serendip.brynmawr.edu/sci_edu/waldron/.

A **heritable** characteristic is influenced by genes and passed from parents to offspring. In the mice on the tan sand, tan fur was a heritable adaptive characteristic, and you saw how this characteristic became more common in the pups than in the mothers. In nature, heritable adaptive characteristics become more common in a population over many generations. This process is called **evolution by natural selection**.

Evolution by natural selection leads to adaptation within a population. The term evolution by natural selection does not refer to individuals changing, only to changes in the frequency of adaptive characteristics in the population as a whole. For example, for the mice that lived on tan sand, none of the mice had a change in the color of their fur; rather, due to natural selection, tan fur was more common for the pups than for the mother mice.

In summary, a heritable characteristic that helps an animal or plant to have more offspring which survive to reproduce will tend to become more common in a population as a result of evolution by natural selection.

Questions

1. Explain why a heritable characteristic which helps an animal to live longer will generally tend to become more common in the population as a result of evolution by natural selection.

2. Suppose a different heritable characteristic helped animals to live longer but made them sterile so they could not have any offspring. Explain why this heritable characteristic would not become more common as a result of evolution by natural selection.

Simulation of Natural Selection

We will now play a simulation game to demonstrate how natural selection works. A **simulation** is a good way to mimic and simplify the process so we can observe how evolution by natural selection may work in a real population. This simulation involves pompoms that can reproduce. These pompoms live out their lives on a Black Forest or Red Grassland habitat in the classroom. The only concern our pompom creatures have is the presence of ravenous hunters (that's you!).

The simulation will have the three necessary conditions for evolution by natural selection.

1. **Variation in characteristics:** For natural selection to occur, different individuals in a population must have different characteristics. In our simulation, pompoms vary in color; they are black and red. The hunters vary as well; hunters have two distinct types of feeding structures: forks and spoons.
2. **Differences in fitness:** For natural selection to occur, the different characteristics of different individuals must contribute to differences in fitness (i.e. differences in ability to survive and reproduce). For example, variation in pompom color may influence the probability that a pompom is snatched up by a hungry hunter. Also, different feeding

structures may vary in their success in capturing pompoms. These differences contribute to survival and therefore success in reproducing.

3. **Heritability of characteristics:** For natural selection to occur, the characteristics that affect fitness must be heritable (i.e. passed by genes from one generation to the next). In our simulation, a pompom that is born into the pompom population is the same color as its parent and a hunter that is born into the hunter population has the same feeding structure as its parent.

Here is what you will do:

1. Your class will be split into two groups which will carry out the simulation using two different habitats: Black Forest (represented by a rough black material such as faux fur) and RedGrassland (represented by a red fleece material).
2. Pompoms come in two colors: black and red. Your teacher will scatter an equal number of each color on the Black Forest and on the RedGrassland. Which color pompom do you think will be more likely to survive in each habitat?

Black Forest:

RedGrassland:

Why do you think that?

3. There are two different types of feeding structures: forks and spoons. To arm the hunters, your teacher will distribute the feeding structures so that there are equal numbers of each. You will also be given a cup. This cup will serve as your "stomach". To capture a pompom, you must use only your fork or spoon to lift the pompom from the habitat and put it into your cup. Which feeding structure do you think will do better in each habitat?

Black Forest:

RedGrassland:

Why do you think that?

4. At your teacher's signal, start feeding. Don't be shy about competing with your fellow hunters. However, once a pompom is on a fork or spoon it is off limits. When your teacher calls time, **STOP** feeding.
5. Now count how many pompoms you have eaten and line up with your classmates who were feeding on the same habitat, from fewest pompoms eaten to most pompoms eaten. Only the top half of the hunters will survive and reproduce. Your teacher will tell you who lives and who dies. Those who die will be reborn as the children of the survivors and will now have the same type of feeding structure as their parents had.

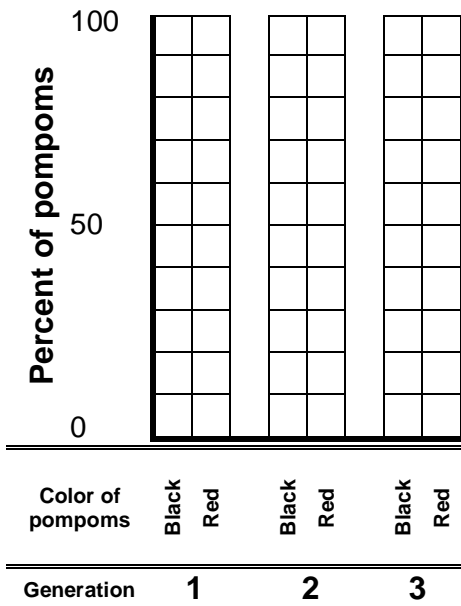
6. Your teacher will count how many pompoms of each color were eaten, calculate how many pompoms survived, and help the surviving pompoms reproduce. Only the pompoms that were not eaten will reproduce.
7. While your teacher is busy preparing for the next round of feeding, discuss the following questions with your group:
- Which feeding structure contributed to greater fitness (ability to survive and reproduce)?
 - What characteristics of forks and spoons increased or decreased fitness?
8. You will run through the simulation one more time. Your teacher will post on the board the numbers of pompoms of each color and hunters of each type at the beginning of the simulation (generation 1) and at the end of each cycle (generations 2 and 3). Copy down the numbers on the board in the table below. Then, for each generation of pompoms in each habitat, calculate the percent that are black or red. Similarly, for each generation of hunters in each habitat, calculate the percent that have spoons or forks as their feeding implement.

	Red Grassland			Black Forest		
	Pompoms			Pompoms		
	Black	Red	Total	Black	Red	Total
<u>Generation 1</u> Number						
Percent			100%			100%
<u>Generation 2</u> Number						
Percent			100%			100%
<u>Generation 3</u> Number						
Percent			100%			100%

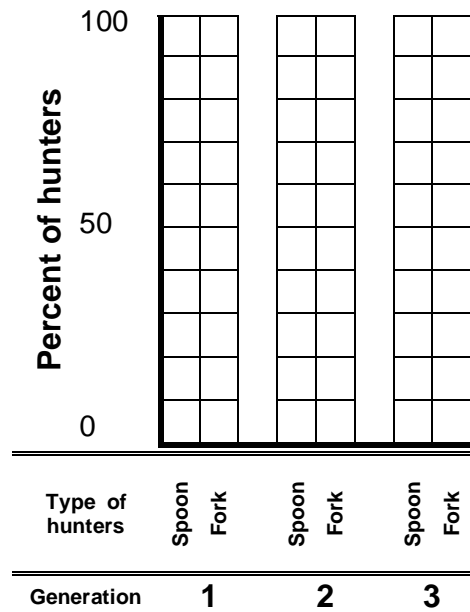
	Red Grassland			Black Forest		
	Hunters			Hunters		
	Spoon	Fork	Total	Spoon	Fork	Total
<u>Generation 1</u> Number						
Percent			100%			100%
<u>Generation 2</u> Number						
Percent			100%			100%
<u>Generation 3</u> Number						
Percent			100%			100%

9. Use the data to complete the following bar graphs. This will allow you to observe the changes in the percent of pompoms of each color and hunters with each type of feeding implement over the three generations in each habitat.

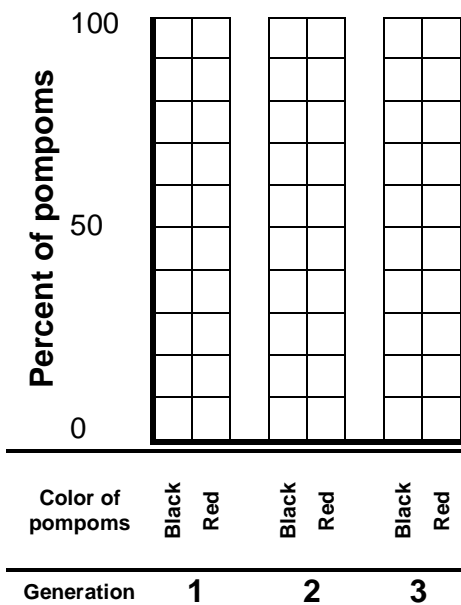
Pompoms in the Black Forest



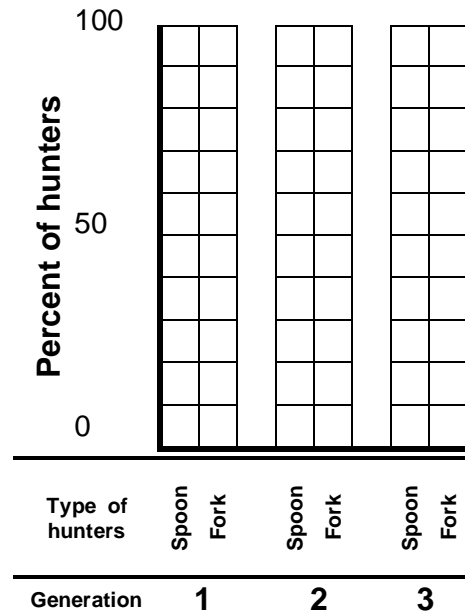
Hunters in the Black Forest



Pompoms in the Red Grassland



Hunters in the Red Grassland



Questions

1. Did evolution by natural selection occur in each pompom population? In other words, did one pompom color become more common over time while the other color became less common? What traits contributed to the survival of pompoms that survived to reproduce?

Black Forest:

RedGrassland:

Remember that the pompom populations were the same on the Black Forest and RedGrassland at the beginning. Explain why the trends differ in these two different habitats and the two populations of pompoms end up so different.

2. For each population of hunters, did one feeding type become more common while the other feeding type became less common? What traits contributed to the survival of hunters that survived to reproduce?

Black Forest:

RedGrassland:

Explain the differences in the trends in the feeding type of the hunters in the two habitats.

3. Did any individual pompoms change color or adapt? If not, then why did the colors of the pompoms in the final population differ from the colors of the pompoms in the original populations?

4. If we ran the simulation for 50 more generations, what would you predict about the colors of the pompoms and the hunter types in each habitat?

Black Forest:

RedGrassland:

5. What do you think would happen to the pompom population if the black forest experienced a prolonged drought so all the trees died and the habitat became redgrassland? First, make your prediction of what would happen if the population of pompoms in the black forest at the beginning included red and black pompoms.

Next, suppose that natural selection over many generations had resulted in only black pompoms surviving in the black forest, and then a prolonged drought resulted in this habitat turning into a red grassland. Would natural selection for pompom color occur?

Based on this example, explain why evolution by natural selection can not occur if there is no variation in a characteristic.

6. Suppose that all the hunters in the simulation were blind-folded and could only find pompoms by touch. Would you expect evolution by natural selection in the color of the pompoms?

Explain why evolution by natural selection can not occur if the variation in a characteristic does not contribute to differences in fitness.

7. The following example will illustrate that evolution by natural selection can not occur if the variation in a characteristic is not heritable. This example also illustrates a more complete definition of fitness, which is the ability to survive and produce offspring who can also survive and reproduce. According to this definition of fitness, which of the four male lions described below would biologists consider the "fittest"?

Name	George	Dwayne	Spot	Tyrone
Age at death	13 years	16 years	12 years	10 years
# cubs fathered	19	25	20	20
# cubs surviving to adulthood	15	14	14	19
Size	10 feet	8.5 feet	9 feet	9 feet

(Adapted from Michigan State University, Occasional Paper No. 91, Evolution by Natural Selection: A Teaching Module by Beth Bishop and Charles Anderson, 1986)

Explain why Dwayne was not the fittest even though he lived the longest and fathered the most cubs.

Which of the following scenarios would result in natural selection?

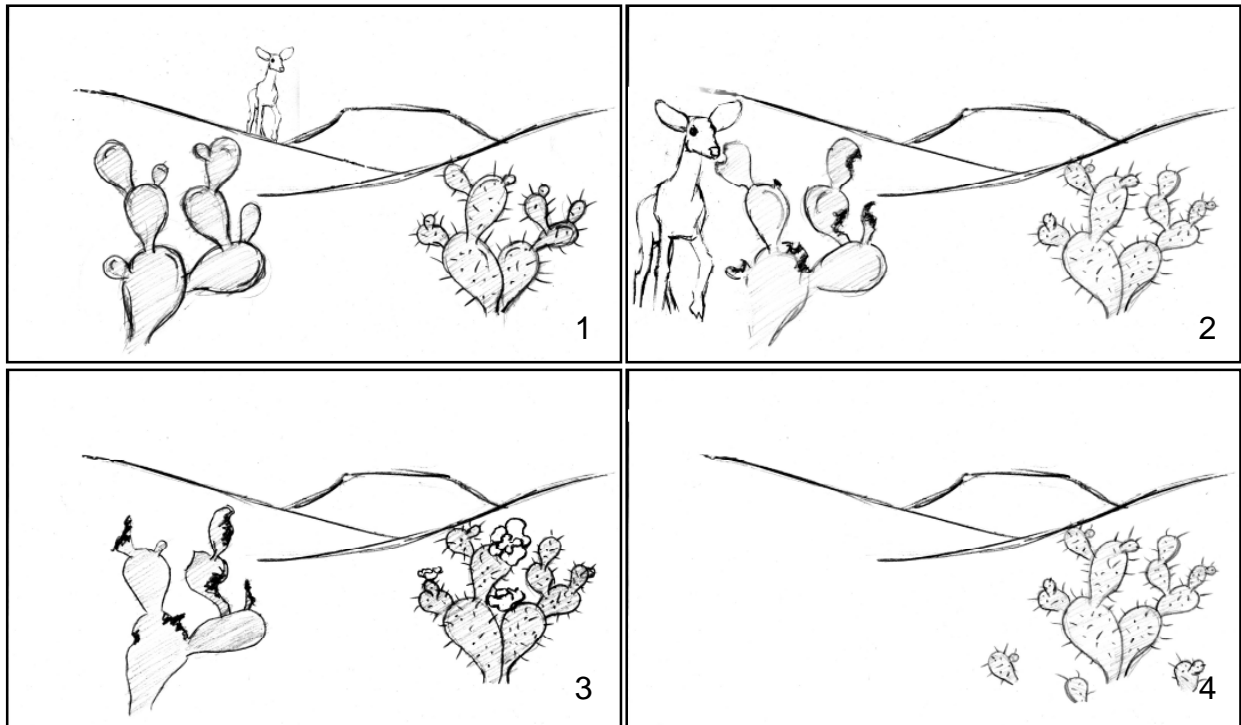
- Tyrone had heritable characteristics that increased resistance to infections, and the cubs that inherited these characteristics were more likely to survive to adulthood.
- Tyrone happened to live near a farmer who put antibiotics in meat which he left out for Tyrone's lion cubs.

Use this example to explain why natural selection does not operate on a characteristic which affects fitness but is not heritable.

8. "Survival of the fittest" is a common expression. What do you think most people mean by this expression?

How would you explain this expression to help someone understand how natural selection actually functions?

9. Below is a series of pictures representing changes in a population of cacti. Pictures 1 and 2 show what happened when a deer came to eat, picture 3 shows the cacti a few weeks later (notice the flowers on the right-hand cactus), and picture 4 shows the situation a few months later.



Recall that the three conditions listed below are necessary for natural selection to take place.

1. **Variation in characteristics within the population:** In picture 1, what is the main difference between the cactus on the left and the cactus on the right?
2. **Differences in fitness (survival and reproduction):** Why would a deer be more likely to eat the cactus on the left than the cactus on the right?

What effect does the deer's behavior have on the survival and reproduction of these two types of cactus?

3. **Heritability of characteristics from parent to offspring:** The difference between the cacti is a heritable characteristic (see picture 4).

Do you think that evolution by natural selection is occurring in this cactus population? Explain why or why not.