

Evolution by Natural Selection

Adapted from the University of California, Los Angeles Life Sciences 1 Demonstration Manual
Copyright 2006 by Jennifer Doherty and Dr. Ingrid Waldron, Department of Biology, University of Pennsylvania

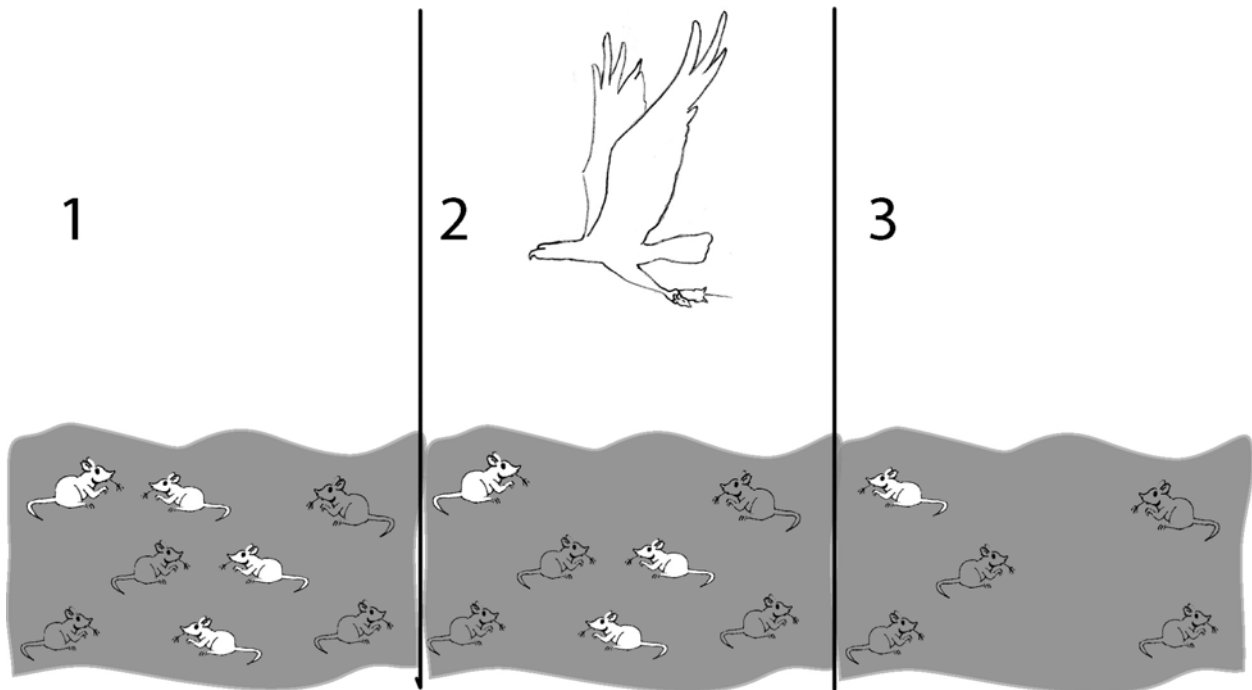
What are some differences you have noticed in the size and shape of dogs in your neighborhood?

Do their differences make them better at some things, but not well-suited for others?

What would happen if the world suddenly changed, so the only thing that dogs could eat was deer and there was absolutely no way for a dog to eat if it wasn't big or strong enough to catch and kill a deer?

Most likely, smaller dogs would die off, and the bigger ones would survive and reproduce. After a while, instead of a population of dogs of all sizes, most of the dogs in the population would be big dogs.

Next, think about the mice shown below. Describe what is happening in figures 1-3.



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 are some characteristics of animals or plants that affect their fitness?

Below are descriptions of four female mice that live in a beach area which is mostly tan sand with scattered plants. According to the definition given for fitness, which mouse would biologists consider the fittest? Explain why this mouse would be the fittest.

Color of fur	Brown	Tan	Tan and Brown	Cream
Age at death	2 months	8 months	4 months	2 months
# pups produced by each female	0	11	3	0
Running speed	8 m/min.	6 m/min.	7 m/min.	5 m/min.

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

A more complete definition of fitness is the ability to survive and produce offspring who can also survive and reproduce. Below are descriptions of four male lions. According to this definition of fitness, which lion would biologists consider the "fittest"? Explain why.

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)

Suppose that Tyrone had genes that he passed on to his cubs that helped his cubs to resist infections, so they were more likely to survive to adulthood. These genes would be more common in the next generation, since more of the cubs with these genes would survive to reproduce. A characteristic which is influenced by genes and passed from parents to offspring is called **heritable**.

Over many generations heritable adaptive characteristics become more common in a population. This process is called **evolution by natural selection**. Evolution by natural selection takes place over **many, many** generations.

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 in the beach area with tan sand, none of the mice had a change in

the color of their fur; however, 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 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. Not all characteristics which contribute to longer life become more common in the population. Some characteristics contribute to long life, but not more offspring. For example, a female cat which is sterile and cannot have any offspring may live longer because she will not experience the biological stresses of repeated pregnancies. Explain why a characteristic like this which contributes to a long life, but with few or no offspring, 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 simplify the problem in such a way that we can observe how evolution by natural selection may work in a real population. This simulation involves pom poms that can reproduce. These pom poms live out their lives on a Black Forest or Red Grassland habitat in the middle of the classroom. The only concern our pom pom creatures have is the presence of ravenous hunters (that's you!). All we need is a system that has 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, pom poms vary in color; they are black, red, and white. The hunters vary as well; hunters have three distinct types of feeding structures: forks, knives, 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). It seems possible that variation in pom pom color will influence the probability that a pom pom is snatched up by a hungry hunter. It also seems possible that different feeding types may vary in their success in capturing pom poms. 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 pom pom that is born into the pom pom 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 exactly what we 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 Red Grassland (represented by a red fleece material).
2. Pom poms come in three colors: black, red, and white. Your teacher will “plant” an equal number of each color on the Black Forest and on the Red Grassland at the beginning of the simulation. Which color pom pom do you think will be more likely to survive in each habitat?

Black Forest:

Red Grassland:

Why do you think that?

3. Now it is time to arm the hunters. There are three different feeding types: forks, knives, and spoons. 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;” a pom pom capture is only successful if you can manage to get the pom pom into your cup using just your feeding apparatus. Which feeding structure do you think will do better in each habitat?

Black Forest:

Red Grassland:

Why do you think that?

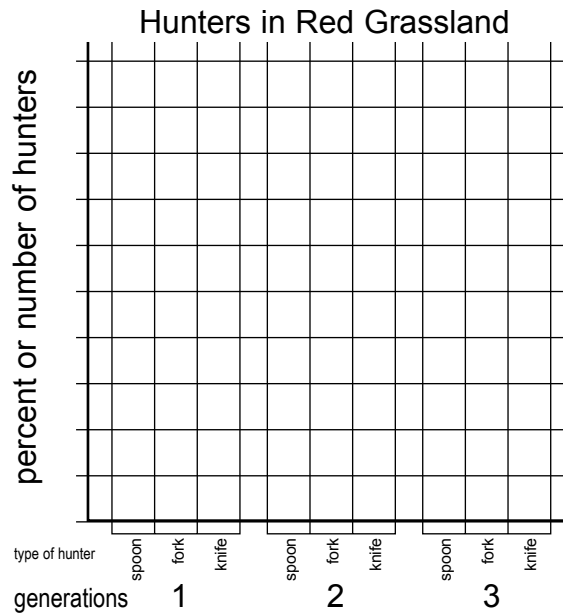
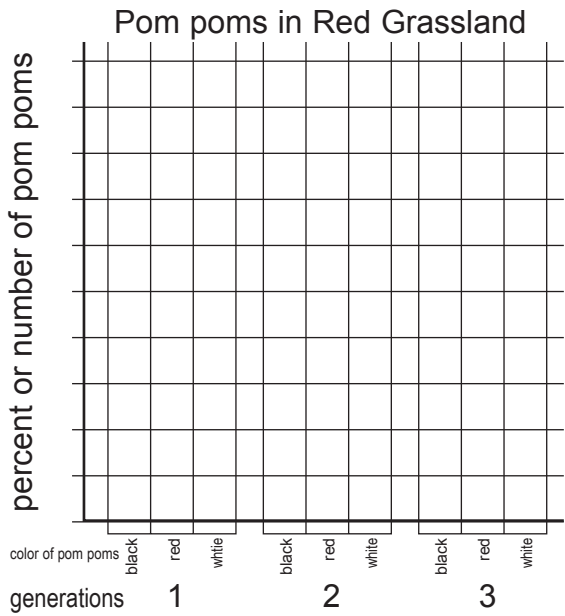
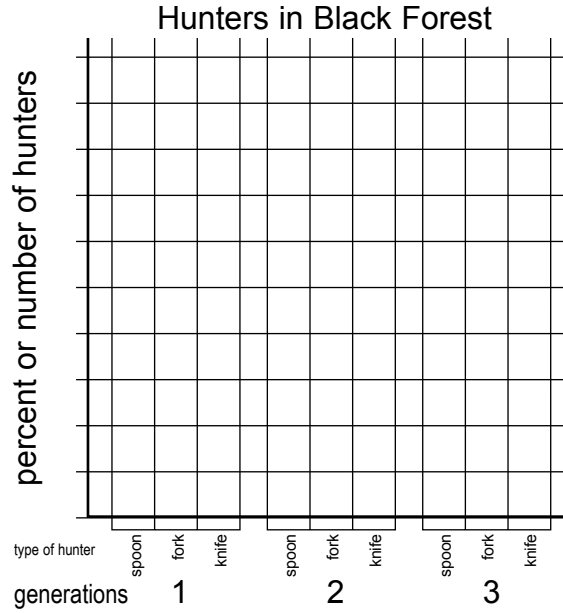
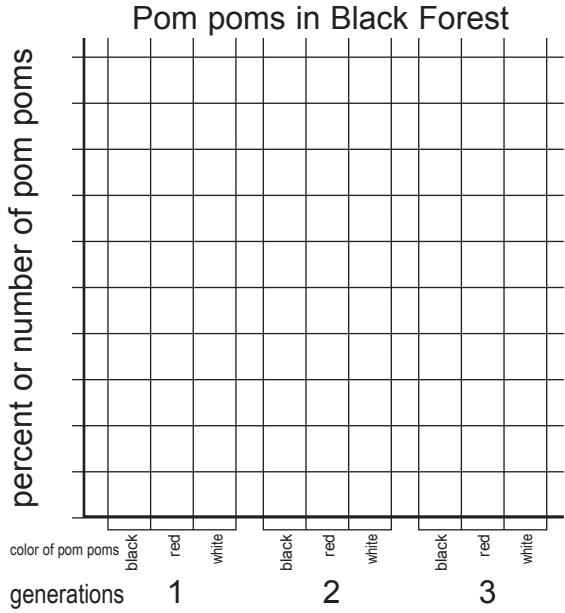
4. Your teacher will record the initial numbers of each type of pom pom and each type of hunter in each habitat on the board.
5. At your teacher’s signal, start feeding. Don’t be shy about competing with your fellow hunters. However, once a pom pom is in a cup it is off limits. When your teacher calls time, **STOP** feeding.
6. Now count how many pom poms you have eaten and line up with your classmates, least to greatest. 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 their parents had.
7. Your teacher will count how many pom poms of each color were eaten, calculate how many pom poms survived, and help the surviving pom poms reproduce. Only the pom poms that were not eaten will reproduce.

8. You will run through the simulation two times. Your teacher will post on the board the numbers of pom poms 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 pom poms in each habitat, calculate the percent that are black, red, or white. Similarly, for each generation of hunters in each habitat, calculate the percent that have spoons, forks, or knives as their feeding implement.

	Red Grassland				Black Forest			
	Pom poms				Pom poms			
	Black	Red	White	Total	Black	Red	White	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	Knife	Total	Spoon	Fork	Knife	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 4 bar graphs. Show the changes in the percent or number of pom poms of each color and hunters of each type over the three generations in each habitat.



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

Black Forest:

Red Grassland:

Remember that the pom pom populations were the same on the Black Forest and Red Grassland at the beginning. Explain why the trends differ in these two different habitats and the two populations of pom poms end up so differently.

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

Black Forest:

Red Grassland:

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

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

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

Black Forest:

Red Grassland:

14. What do you think would happen to the hunter and pom pom populations if the black forest experienced a decade long drought and became red grassland? First, make your prediction of what would happen if the population of pom poms in the black forest at the beginning included red, white and black pom poms.

Pom pom population:

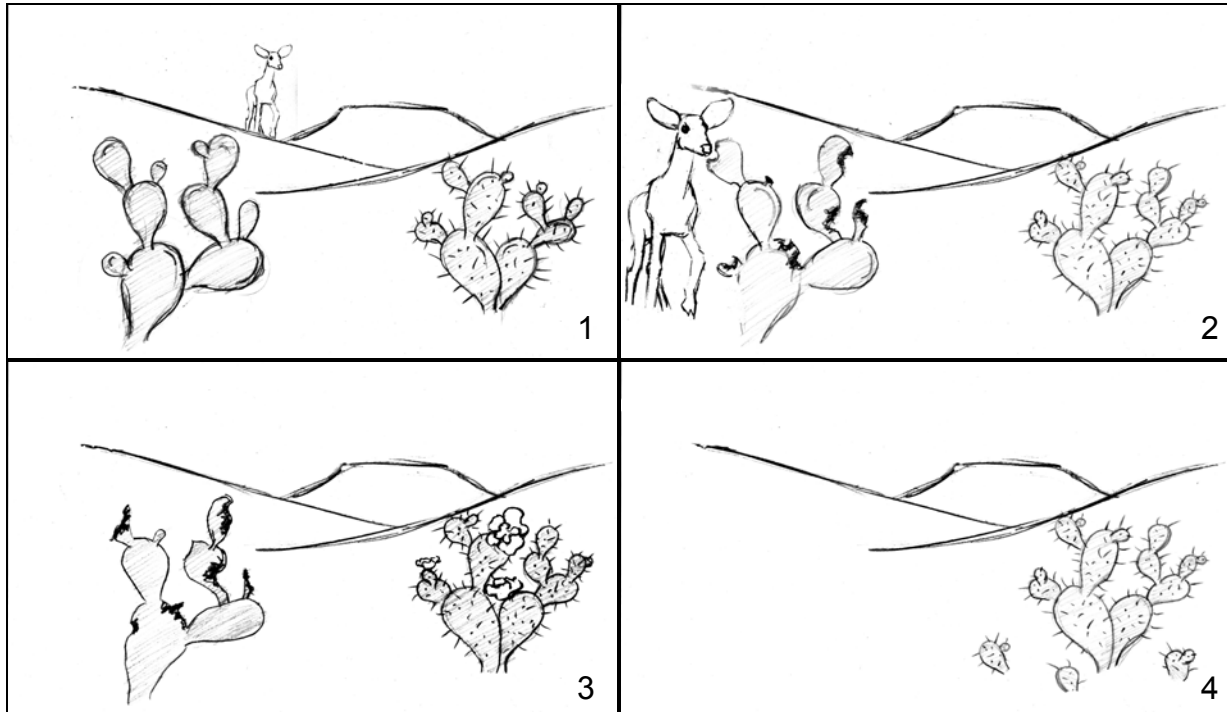
Hunter population:

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

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

15. Explain why evolution by natural selection can not occur if the variation in a characteristic does not contribute to differences in fitness. Suppose, for example, that all the hunters in the simulation were blind-folded and could only find pom poms by touch. Would you expect evolution by natural selection in the color of the pom poms?
16. Explain why evolution by natural selection can not occur if the variation in a characteristic is not heritable. Suppose, for example, a tree limb fell on a young lion and broke his leg, and the leg never healed normally. Obviously, this would affect the lion's ability to survive and reproduce. However, if this lion did manage to have cubs, the offspring would each have four normal legs. Explain why natural selection does not operate on characteristics like this which affect fitness but are not heritable.

17. Below is a series of pictures representing changes in a population of cacti over many generations.



Why would a deer be more likely to eat the left cactus than the right cactus?

In figure 3, the right cactus has flowers, but the cactus that has been eaten by the deer is too damaged to make flowers. Figure 4 shows the situation several months later. What has happened? Do you think that evolution by natural selection is occurring in this cactus population? Explain why or why not.

What adaptation seems to increase the fitness of the cacti? How do you think this adaptation increases the ability of cacti to **both** survive and reproduce?

18. "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?

19. What characteristics of humans do you think helped them survive and reproduce during the hundreds of thousands of years when they were hunter-gatherers?