

Teacher Preparation Notes for Evolution by Natural Selection

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This activity includes:

- introductory questions and explanations to help students understand how natural selection works (pages 1-2 of the Student Handout)
- a simulation of natural selection (pages 2-4)
- analyzing and graphing the data (pages 4-5)
- answering additional questions to interpret the results and understand how the results demonstrate the principles of natural selection (pages 6-8).

In our experience, completing all these component tasks approximately 90 minutes with an average class of high school students. (For students with poor graphing skills, you may need more time.)

To complete this activity in a shorter amount of time, you can simplify the activity by focusing solely on natural selection in the pom-pom population and removing variation from the hunter population (use only forks or only spoons). This will allow you to omit having the students line up after each round, omit the data charts for the hunters on page 4 of the Student Handout and the graphs for the hunters on page 5, and omit question 2 on page 6.

Teaching Points:

- Different individuals in a population have different characteristics; this is variation.
- Some of this variation in characteristics can be inherited by a parent's offspring; these are heritable characteristics.
- Some characteristics make some individuals better at surviving and reproducing than others. Fitness refers to the ability to survive and produce offspring which are capable of reproducing. The specific characteristics which contribute to fitness will differ in different environments.
- A characteristic that increases an individual's fitness is an adaptation. Notice that biologists use the terms adaptation and fitness to have different meanings than the common meanings of these words in every day language.
- Heritable adaptive characteristics become more common in a population over many generations. This process is called evolution by natural selection.
- Evolution by natural selection occurs *if* there is variation in heritable characteristics which contribute to differences in fitness.
- Evolution by natural selection results in changes in the frequency of characteristics and alleles or genes in a population, *not* changes in an individual.
- Which characteristics are adaptive and how a population evolves depends on what kind of environment the population is in. The same population will evolve differently if placed in a different environment. Organisms are not evolving to some pre-ordained "perfection" but are evolving to maximum fitness in a given environment.
- Evolution by natural selection is a gradual process that takes place over many, many generations. (Remind them that the simulation and the examples in the Student Handout are simplified versions of reality.)

The information and questions in the Student Handout present most of these Teaching Points very clearly, but you will probably want to explicitly introduce the last two Teaching Points.

¹These teacher preparation notes and the related student handout are available at http://serendip.brynmawr.edu/sci_edu/waldron.

Depending on your students, it may be useful to discuss the original sources of variation in heritable characteristics, including random mutation and, in sexually reproducing organisms, recombination and independent assortment.

Equipment and Supplies:

- 2-3 yards of black cloth for habitat (should be faux bear fur or some other rough cloth)The size of the habitat should accommodate foraging by half the students in your class.
- 2-3 yards of red cloth for habitat (should be furry fleece with a different texture than the black habitat)
- 5 or 7 mm black and red pompoms(300 of each color per class)Pompoms can be purchased at your local craft store (for example: Michael's, JOANN's, or Wal-Mart) or on the internet.

The specific colors of the pompoms and habitats need not be black and red, so long as there is a very good color match between each habitat and one color of the pompoms. Both color cloths should be textured, since even pom-poms of a matching color tend to be readily visible on plain flat cloth. If possible, the textures should be as deep or deeper than the diameter of the pompoms. The textures should be different to demonstrate that different hunter adaptations may be more successful in different habitats.²

- Plastic forks and spoons for hunter implements (1 of each for each student)³
- Cups for hunter stomachs (1 per student) (To make the hunting task a little more challenging, you can use small plastic test tubes or the small plastic tubes that florists put on the ends of cut roses. Alternatively, plastic bottles with narrow necks can be used for hunter stomachs if you have trouble preventing your students from cheating, i.e. laying their cups on the habitat and shoveling multiple pompoms in with their implement.)
- calculator for calculating percents (page 4 of Student Handout) and watch or timer for timing 15-30 second feeding times

² This simulation can also be done with two different color poster board habitats and squares or circles of the same colors as the two habitats to serve as the prey; the student predators can use their fingers or tweezers. This is more economical than using cloth and pom-poms, at least in the short term. We prefer cloth that meets the above specifications, but poster board habitats and matching circles or squares will probably give better results than using cloth which is not highly textured and/or is a poor color match for the pom-poms.

Some versions of this type of natural selection activity suggest using beans, but beans of different colors often vary in size and weight and it is difficult to find a good color match for the background, and these problems tend to distort the results of simulations using beans.

³On some types of fabric, fork and spoon feeding implements have similar fitness. If you want to ensure that there will be a difference in fitness between the two types of feeding implements, you can substitute plastic knives for either the forks or spoons. In our experience, the fitness of forks and spoons usually differs on at least one of the textured materials and the outcome for forks versus spoons is less obvious to students in advance of the simulation (no one wants to have a knife as a feeding implement).

Teacher Preparations:

1. Before class, count out 2 batches of pompoms with 45 pompoms of each color in each batch. (If you have a particularly large class, you may want to have 60 pompoms of each color in each batch.) For each class you teach, you will need two copies of the data sheet in step 9 on page 4. You will probably also want to draw on the board copies of the charts on page 4 and the graphs on page 5 of the Student Handout or prepare to project these for student viewing.
2. You may want to choose one or two students to be your helpers during the simulation.
3. When you are ready to begin the simulation, split the class in half (with each half becoming the hunters on one habitat type) and give each student a fork or spoon (one half each). Scatter one batch of 90 pom-poms in each habitat. (You may want to do this at the last minute since the simulation works better if students do not have time to overcome the camouflage by searching for pom-poms ahead of time.) Record the number of pom-poms of each color and hunters with each type of feeding structure in the generation 1 rows in the table in step 9 on page 4.
4. Remind the students of the rules of the game.
 - a. They will have 15-30 seconds in which to feed. (You should adjust the number of seconds, depending on the number of students you have, cloth size, etc.)
 - b. During this time they must try and pick up as many pompoms as possible and transfer them to their cups. They must pick up the pompom with their implement and put it in the cup.
 - c. They must keep their cups upright at all times and are not permitted to tilt the cups and shovel pompoms into them.
 - d. Competition for resources is fair (and acceptable) but once a pompom is on a feeding implement, it is off limits.
5. Start the students feeding and call stop after 15-30 seconds.
6. After feeding the students will count how many pompoms they have in their cups. Students from each habitat type will then line up separately in order of how many pompoms they have in their stomachs (least to greatest).
7. Once they are in line, you or your helpers should go down the line of students and record how many pompoms of each color were eaten and then enter the total number of each color eaten in each habitat in the chart on the next page. You may need to remind students **not** to put the pompoms they have “eaten” back onto the habitats since those pompoms are dead.
8. Determine which hunters will get to survive and reproduce, i.e., which ones caught enough pompoms. For each habitat, have the students stay in line. The half of the students in each habitat who “ate” the most pompoms will survive and reproduce. The half of the students who “ate” the fewest pompoms will die and be “reborn” as the children of the half of the students who survived. Start with the person with the lowest number of pompoms, apologize that they did not eat enough to survive, and tell them that they are now the offspring of a hunter that survived. Give the student the same implement as the person with the highest number of pompoms. Work your way up the line of students, matching each low person with the next person from the high end of the line. If you have an odd number of students in a group, the student in the middle survives but does not get to reproduce. In the chart on the next page, record how many hunters of each type there are in the next generation **after** all the implements have been changed.

9. Calculate how many pompoms of each color survived, using the chart below. Since each surviving pompom is joined by two offspring, the number of pompoms to add to each cloth/habitat type will be twice the number of surviving pompoms for each color. Scatter the appropriate number of offspring pompoms of each color on the habitat. Depending on your students, you may be able to speed the process by having student helpers carry out the calculations and post information for the charts from page 4 of the Student Handout on the board and having other student helpers collect and sort the pompoms that were eaten into groups of 10 of the same color, ready to count out and scatter the appropriate number of offspring pompoms on each habitat.

Habitat Type:		
Pompom Color	Black	Red
# in generation 1		
# eaten		
# remaining (<i># generation 1 - # eaten</i>)		
# new (<i>2 X # remaining</i>)		
# in generation 2 (<i># remaining + # new</i>)		
# eaten		
# remaining (<i># generation 2 - # eaten</i>)		
# new (<i>2 X # remaining</i>)		
# in generation 3 (<i># remaining + # new</i>)		
Hunter Type	Spoon	Fork
# in generation 1		
# in generation 2		
# in generation 3		

10. Once the new pompoms have been scattered on the habitats and everyone has their implements for the second generation, start the second round.
11. After the second round is finished, repeat steps 6-9 and complete the above table (make sure to get hunter numbers for generation 3). The students return to their seats.
12. Finish putting the data in the charts on the board and have the students record the data and calculate the percentages in the tables on page 4 of the Student Handout and complete the graphs on page 5 of the Student Handout.
13. Use the questions on pages 6-8 of the Student Handout to guide your students in interpreting the results of the simulation and understanding how natural selection works.

Suggestions for Discussion:

To help students understand that the word "fitness" has a different meaning in common usage vs. discussions of natural selection, you can compare the first two rows in the table on page 1 of the Student Handout (running speed, which is an indicator of fitness in the common usage sense vs. #pups produced by each female, which is a measure of fitness as the term is used in discussing natural selection). You will probably also want to point out that in discussing natural selection we use the word "adaptation" to refer to a heritable characteristic that increases survival and reproduction, and this differs from the common usage meaning of adaptation as a change in an organism's characteristics in response to the environment. The last question on page 1 is an important first opportunity for students to understand how natural selection works.

Questions 5-7 on pages 6-7 of the Student Handout are designed to help students understand the requirements for natural selection by considering what would happen if any of these conditions is not met. In the second part of question 5, students are asked whether natural selection could occur if the black forest habitat became red grassland due to a prolonged drought, but only black pompoms had survived in the population. The simple answer is "no", but more sophisticated students may point out that natural selection could occur if a mutation for red color occurred in the population or if red pompoms migrated in from another population. For question 7, you may want to explicitly tell your students to assume that all four male lions are in the same population. Some students may notice that the criterion for fitness has been expanded to include whether the offspring survived to adulthood (and thus would be able to reproduce). This illustrates the general point that the criterion for fitness varies in different circumstances. In this context, a useful definition for fitness is "the extent to which an individual contributes genes to future generations, or an individual's score on a measure of performance expected to correlate with genetic contribution to future generations (such as lifetime reproductive success)" (from Evolutionary Analysis by Freeman and Herron).

Additional Resources:

Two good web sites with information and activities for teaching evolution:

<http://evolution.berkeley.edu/> and <http://www.pbs.org/wgbh/evolution>

For example, the "All in the Family" activity at

<http://www.pbs.org/wgbh/evolution/change/family/> is a very useful activity to help students understand the importance of homology and similarities in development for establishing phylogenetic relationships.