Evolution

ARTIFICIAL SELECTION

Can extreme selection change expression of a quantitative trait in a population in one generation?

■ BACKGROUND

Evolution is a process that has existed throughout the history of life on Earth. One of the key driving forces of evolution is natural selection, which is differential reproduction in a population — some organisms in a population may reproduce more than others and leave more viable offspring in the next population or generation. Differential reproduction results in a population with a genetic makeup that is different from that of the previous population. Thus, populations may change over time. This process of change is evolution. With natural selection, environmental factors play a key role in determining which organisms reproduce and how many of their offspring survive. In artificial selection, humans determine which organisms reproduce, allowing some individuals to reproduce more than others. What will happen to a population of these organisms over time when exposed to artificial selection?

For the first part of this investigation, you and your classmates will perform one round of artificial selection on a population of Wisconsin Fast Plants®. First, you will identify and quantify several traits that vary in the population and that you can quantify easily. You will then perform artificial selection by cross-pollinating only selected plants. You'll collect the seeds, plant them, and then sample the second-generation population and see if it is different from the previous one. Your results will generate questions, and you then will have a chance to test your own ideas about how selection works.

■ Learning Objectives

- To investigate natural selection as a major mechanism of evolution

- To convert a data set from a table of numbers that reflects a change in the genetic makeup of a population over time and to apply mathematical methods and conceptual understandings to investigate the cause(s) and effect(s) of this change

- To apply mathematical methods to data from a real population to predict what will happen to the population in the future

- To investigate how natural selection acts on phenotypic variations in populations

- To evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time due to changes in the environment

- To design an investigation based on your observations and questions related to the importance of a single trait in the life history of a plant

■ General Safety Precautions

When growing plants under lights, be careful to avoid any situation where water or fertilizer could come in contact with the electrical wires.

■ THE INVESTIGATIONS

■ Getting Started

In *On the Origin of Species*, Charles Darwin used artificial selection — the kind of selection that is used to develop domestic breeds of animals and plants — as a way to understand and explain natural selection. Like natural selection, artificial selection requires variation in the population under selection. For selection to work, the variations must be inheritable. To conduct artificial selection, humans decide on a specific trait of a plant or animal to enhance or diminish and then select which individuals with that desired trait will breed, producing the next generation and the next population.

Materials

- Lighting: light box systems (grow lights)
- Growing system: recycled plastic soda or water bottles
- Wicking: mason twine
- Fertilizer: Miracle-Gro Nursery Select All Purpose Water-Soluble Plant Food or Peters Professional with micronutrients
- Soil: Jiffy-Mix (soil mix, not potting soil)
- Vermiculite
- Fast Plant seed (C1-122 works well and provides some additional options; it is heterozygous for two Mendelian traits, green/light green leaves and with anthocyanin [purple stems] and without anthocyanin. Other seed stocks, such as standard Fast Plant seeds, work as well.)
- Bee sticks for pollination
- Digital cameras to record the investigation
- Plastic magnifiers
- Laboratory notebook

■ Procedure

How will you know if artificial selection has changed the genetic makeup of your population? That is one of the questions you will be trying to answer. You then will have a chance to test your own ideas about how selection works.

Plant Cultivation: First-Generation Plants

Step 1 Prepare growing containers. Go to the Wisconsin Fast Plants website and find the instructions for converting small soda bottles into planting containers (*http://www.fastplants.org/grow.lighting.bottle.php*). Plan to use one-liter bottles or smaller. You can raise up to 6 plants per container.

Figure 1. Notice that the scissors are cutting along the bottom of the bottle curve. This provides better control.

Figure 2. Feed mason twine through a small hole in the lid.

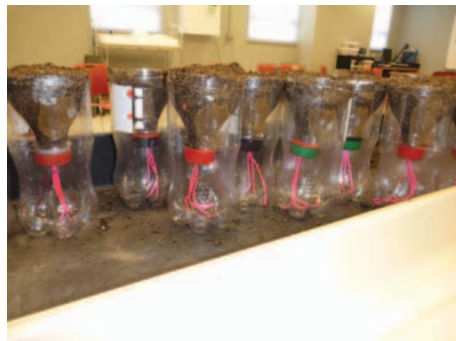**Figure 3. The growing systems are ready for planting.**

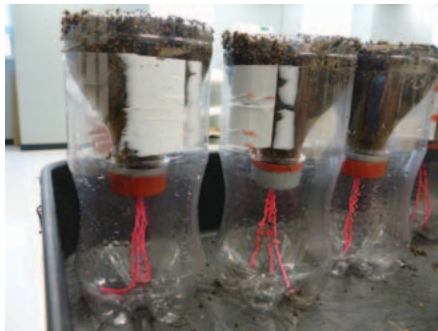**Figure 4. Soil is in place along with the wicking.**

Figure 5. Mix fertilizer — one bottle cap of fertilizer in eight liters of water. Wet the soil gently until water drips from the wicks. Then fill the reservoirs with the dilute fertilizer solution. Plant the seeds carefully — about six to a bottle, uniformly spaced on the surface, not buried in the soil.
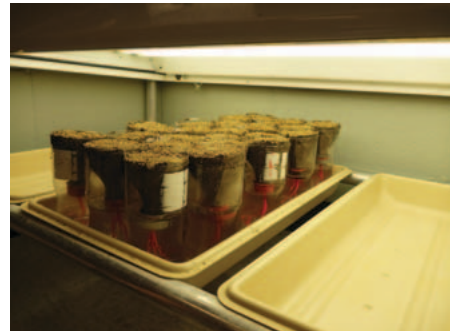

Figure 6. Cover with a light layer of vermiculite. Place the reservoirs — with fertilizer water, seeds on the surface of the soil, and a light layer of vermiculite on the soil — under the lights.

Step 2 Each day, check your plants and make sure that the reservoirs are full, especially on Fridays. These reservoirs have enough volume to last a three-day weekend for small plants.

As your plants grow, record your observations daily. Also try to identify a trait that you could measure or observe reliably. Look for variation in the plants you are growing and describe any you see in your notebook. Observe your classmates' plants as well. Are there also variations in their plants?

Note: Carefully read Steps 3–7 *before* the plants begin to flower.

Step 3 When the plants are about 7 to 12 days old (Figure 7), the class needs to choose 1–2 variable traits for artificial selection. Several variable traits can work for this. Compare your observations with those of other students. You want a trait that varies between plants in a single bottle but also varies between containers. The trait should not be something that is Yes or No, but rather something that varies within a range. That is, look for traits that you can score on a continuum (length, width, number, and so on).

If you and your classmates cannot identify a trait on your own, your teacher will provide additional guidance.

Trichomes

Figure 7. The plants here are 7–12 days old.

Step 4 Score each of your plants for the trait that your class chose to evaluate. You may need a magnifier to do this accurately. Don't be surprised if some plants are not very different from one another.

Step 5 In your lab notebook, compile a list of all the possible traits your class identified. Calculate appropriate descriptive statistics for the class data for the first generation: mean, median, range, standard deviation, etc. Create a histogram that shows the frequency distribution of the trait that you have selected. You can find help for this in Chapter 3.

Step 6 You are now ready to make selection decisions. Directional selection tends to move the variability of a trait in one direction or the other (increase or decrease the trait in the next population). As a class, pick a trait you want to try to affect. Find the top (or bottom) 10% of plants with that trait in the entire class's population (e.g., out of a population of 150 plants, the 15 hairiest plants), and mark any that are in your plant bottle container. Using scissors, cut off the tops of the remaining plants in your container (those not in the top 10%).

Step 7 Just as you did in Step 5, construct a new histogram and calculate descriptive statistics for the selected population of plants. Record the data in your lab notebook. Once you have finished, isolate these selected plants from the rest of the population. Move the bottles of selected plants to another light system so that the plants can finish out their life cycle in isolation. This population will serve as the parents for a new generation.

Step 8 On about day 14–16, when several flowers are present on each of the selected plants, cross-pollinate the selected plants with a single bee stick or pollinating device. Fast Plants® are self-incompatible — each plant must be fertilized by pollen from

another plant. Collect and distribute pollen from every flower on every plant in the selected population. Reserve this bee stick for only the selected population. Avoid contaminating with the pollen from the remaining Fast Plants. Pollinate flowers in the selected population for the next three days with the same bee stick. Be sure to record observations about pollination in your lab notebook. Likewise, with separate bee sticks you can pollinate the plants from the larger population, but be careful to keep them separate from the selected population.

Step 9 Maintain the plants through the rest of their life cycle. As the seedpods form be sure to limit each of the plants to 8 to 10 seedpods. Any more will likely result in poor seed quality. Once the seedpods start to turn yellow (about day 28–36), remove the fertilizer water from the reservoirs and allow the plants to dry for several days. After the plants and seedpods have dried (about a week later), harvest the seedpods from the selected population into a small paper bag for further drying. Be sure to record observations about the plants' life cycle in your lab notebook.

Step 10 Continue to monitor, pollinate, and maintain your control plants throughout the rest of their life cycle. Just be careful to keep the original population and the selected population separate.

Plant Cultivation: Second-Generation Plants

Step 11 You should now have two populations of second-generation seeds: (1) a population that is the offspring of the selected plants from generation one and (2) a population that is the offspring of the remaining plants from generation one. Take seeds from the selected population and plant them to grow the second generation of plants under conditions that are identical to those you used for generation one. Use new bottle containers or, if you choose to use the previous bottle systems, make sure that you thoroughly clean the systems and sterilize with a dilute (10%) bleach solution. Use new wicking cord and new soil. To get your seed, break open the seedpods into a small plastic petri dish lid.

Step 12 When the second-generation plants are about seven to 12 days old, reexamine the plants and score for the trait you selected. Score the plants at the same life history stage using the same method.

Step 13 Unless you plan on growing these plants for another generation (maybe another round of selection), you do not have to save these plants. You can discard them and clean up your growing equipment at this point.

Step 14 Compile, analyze, and graph the class data as you did for the first generation. What is the outcome of your artificial selection? Be sure to record this preliminary analysis in your notebook.

■ Analyzing and Evaluating Results

Up to this point of the investigation, your analysis has largely been descriptive, but your data should raise some questions.

- Are the two populations/generations before and after selection actually different?

- Are the means significantly different?

- Should you use median or mean as a measure of central tendencies at this point in the investigation?

- Compare your two graphs from the two populations. The chapter on quantitative methods in this lab manual (Chapter 3) provides some guidance here. Consider constructing a bar graph to compare the mean number of hairs per generation. Include error bars, but first determine what is appropriate.

- What statistical test could you apply to help you define your confidence about whether these two populations are different?

- Compare the second population to the parent subpopulation of generation one. How do these two populations compare? How does this comparison differ from your other comparison?

As you carry out your analysis, be sure to include your rationale for the quantitative methods you have chosen in your discussion. Did evolution occur in your Fast Plant population? Justify your conclusion in your laboratory notebook.

■ Designing and Conducting Your Investigation

In the previous steps, you quantified a variable trait and then selected about 10% of the plants in the population that strongly expressed that trait. You isolated this subpopulation from the larger population during pollination and the rest of the life cycle. You then planted the resulting second generation of seeds, raised the plants to a similar life stage as the previous population, and scored the variation in the second-generation plants. During this long process, you recorded your observations, reflections, and perhaps some questions in your laboratory notebook.

As you worked, you likely started to think about questions of your own. You might want to know why the trait you tested is even variable to start with. How does it help the plants grow and survive? You might also have identified some other trait that you want to explore instead of the one the class chose.

Does one form or another of the trait offer an advantage in the natural world? How could you test this? Phenotypic variation is the result of the interaction of the genotypic variation with the variables in the environment. How much of the variation that you studied could be the result of environmental differences?

You and your class may decide to do this work as a class (to distribute the work involved) or work in small groups. You will report your work to the class and possibly to other AP® Biology classes in a manner agreed upon by you and your instructor. Posters,

lab reports, online reports, and oral presentations are all possible effective means of submitting your work for review.

■ Where Can You Go from Here?

An essential component of this investigation is to take it beyond the simple selection experiment. With the skills and knowledge gained in the selection experiment, you should be able to design new experiments to investigate the adaptive characteristics of the trait you studied.

Start with a question of your own regarding hairs or some other variable quantitative trait, such as plant height, stem color, or flower number. For instance, in a closely related plant, one investigation demonstrated that herbivore damage early in the plant's development led to increased trichome numbers in later leaves. Could herbivore damage influence the hairy trait expression? Design and carry out an investigation to answer your question.