INVESTIGATION 1

ARTIFICIAL SELECTION

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

BACKGROUND

There are only a few possible laboratories available and appropriate for the high school classroom environment that can explore real-time natural selection with multicellular organisms. For reasons of time and resources, trying to measure natural selection is problematic. Many lab investigations that help students derive an understanding of natural selection are either computer simulations or structured simulations. However, a promising alternative is to have the students study and carry out an artificial selection investigation using Wisconsin Fast Plants (*Brassica*). Just as Darwin relied on examples of artificial selection in cattle, domestic pigeons, and other farm animals to make his case in *On the Origin of Species*, students can gain important insights into natural selection by studying artificial selection. In addition, this particular investigation on artificial selection provides an easy transition into student-generated explorations that look for possible advantages or disadvantages that selected traits might confer on individuals in different environmental conditions.

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

PREPARATION

Materials and Equipment

Per Class:

- Lighting: light box systems (as per the Wisconsin Fast Plants website, ***http://www.fastplants.org***)

Per Team/Student:

- Growing system: reused plastic soda or water bottles
- Wicking: #18 nylon 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 explained in The Investigations; it can be purchased through the catalog of the Rapid Cycling Brassica Collection [RCBC], ***http://www.fastplants.org/pdf/rcbc.pdf***. Other seed stocks, such as standard Fast Plant seeds that can be purchased from Carolina Biological or Nasco, work as well.)
- Bee sticks for pollination
- Digital cameras to record the investigation
- Plastic magnifiers
- Laboratory notebook

Timing and Length of Lab

The first part of this investigation, Procedure, minimally involves growing one generation of Wisconsin Fast Plants from seed to seed, followed by an additional 10-day growing period for the second generation of plants. The total time is approximately seven weeks. Almost all days will be short, with students taking care of plants and making notes. Occasionally, more time (5-10 minutes) will be needed — for planting, quantifying variation and selection, pollinating plants, and scoring the second generation.

The time needed to fully investigate questions generated by students in the second part of the investigation will need to be determined by you and your students. As in the first part, much of the work in the student-led part can be carried out in a part-time manner at the beginning and/or end of class. Another option would be after school.

Safety and Housekeeping

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

ALIGNMENT TO THE AP BIOLOGY CURRICULUM

This investigation can be conducted during the study of concepts pertaining to natural selection and evolution (big idea 1). As always, it is important to make connections between big ideas and enduring understandings, regardless of where in the curriculum the lab is taught. The concepts align with the enduring understandings and learning objectives from the AP Biology Curriculum Framework, as indicated below.

Enduring Understandings

- 1A1: Natural selection is a major mechanism of evolution.
- 1A2: Natural selection acts on phenotypic variations in populations.

Learning Objectives

- The student is able to convert a data set from a table of numbers that reflect 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 (1A1 & SP 1.5, SP 2.2).
- The student is able to evaluate evidence provided by data to qualitatively and quantitatively investigate the role of natural selection in evolution (1A1 & SP 2.2, SP 5.3).
- The student is able to apply mathematical methods to data from a real or simulated population to predict what will happen to the population in the future (1A1 & SP 2.2).
- The student is able to evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time (1A2 & SP 5.3).
- The student is able to connect evolutionary changes in a population over time to a change in the environment (1A1 & SP 7.1).

ARE STUDENTS READY TO COMPLETE A SUCCESSFUL INQUIRY-BASED, STUDENT-DIRECTED INVESTIGATION?

It is great to implement this investigation at the beginning of the year. Students need minimal content background to begin this investigation and complete the first part of the lab. In general, students find this lab to be very accessible and enjoyable. For the most part, skills are developed as the lab progresses. However, essential to the success of this investigation is the student's ability to make and record good observations. This is best done in a laboratory notebook.

Skills Development

The students can use this particular experience to build good laboratory notebook skills. A lab notebook should demonstrate originality and reflection while serving as a record of the investigator's work. Planting, quantifying variation, recording images/drawings of that variation, maintaining plants, and recording results all make for prime lab notebook subject matter. By tending their own population of plants each day and recording daily observations, students develop their own particular style and rhythm of writing in the lab notebook. These activities require only about 10 minutes of class time and are essential to the student-led part of the investigation. While working through the Procedure, students naturally generate questions regarding the traits they are working with and the variations they observe. Often these questions are not recorded and are soon forgotten. Encourage the students to record the questions that come to them as they work intimately with these plants and to reflect on those questions in writing.

The instructor needs to decide when to start this investigation. The students may benefit from having an understanding of natural selection prior to beginning this lab, but this lab might best be used to introduce the concept of natural selection. Think about how you wish to approach this as an instructor.

Potential Challenges

As with all long-term lab investigations, management of time and the calendar can be challenging. To coordinate with school calendars, start the investigation on a Monday or Tuesday. Make sure that the water reservoirs are full before every weekend. Keeping track of multiple sections and their various plants can present a challenge as well. You might want to consider smaller growth chambers for each class in order to keep the different populations separate.

In general, most classrooms have minimal plant pests, but if your classrooms have a large population of plants year-round, you may experience pest outbreaks in your Fast Plants®. Soapy water sponged on the plants controls some pests, such as white flies. Insecticidal soap comes in ready-to-use spray or in concentrate, and it is safe to use indoors. Another safe way to control insect pests is summer horticultural oil. There are two kinds of summer oil, one extracted from neem seeds and one from citrus peels. Mix them according to the package label directions. Another option is dusting plants with diatomaceous earth, which is simply mined, powdered glass skeletons of marine diatoms, you can control soft-bodied pests like aphids. The powder is not harmful to humans or pets.

With this size of plant population students can sometimes get in one another's way as they move plants in and out of growing areas. It is generally during these times that plants are damaged. Take care to minimize the movement of the plants or develop a system whereby the plants can be protected.

Trying to standardize trichome (plant hair) counting or measurement of other variable traits is another challenge. Present students with questions that will help them develop both a procedure for counting hairs and a method to ensure the fidelity of the counts.

THE INVESTIGATIONS

Getting Started: Prelab Assessment

Investigating biology requires a variety of skills. The skills reinforced and introduced vary across the laboratories in this manual. The skills emphasized in a laboratory dictate whether a prelab assessment is appropriate.

This particular investigation provides a lab environment, guidance, and a problem designed to help students understand how populations of organisms respond to selection. To gain the maximum benefit from this exercise, students should get started and not do too much background preparation so that they can build understanding from their own work.

Designing and Conducting Independent Investigations

To set the stage for student-centered investigations, consider presenting a number of probing questions to the class that center on artificial selection in agricultural crops or inadvertent natural selection, such as antibiotic resistance and pesticide resistance. Through questioning, focus on the common features of these events: extreme selection, rapid changes in populations, and preexisting variation in the population. Use questions to help students recognize appropriate quantitative traits in plants that are growing in the classroom. Likely you'll need to ask questions to help students develop an understanding of quantitative traits that are polygenic. They usually have little problem coming up with a design for a selection experiment once they have an appropriate trait selected. In Fast Plants, appropriate traits include number of trichomes, amount of purple anthocyanin, and plant height.

Logistically, the first part of the lab requires quite a bit of coordination and sharing of duties among all students in the class. Artificial selection experiments require a relatively large population of plants with ample phenotypic variation. The numbers involved are not very workable for the individual student or even for a small group of students. For this reason, it is recommended that the first step of this lab be conducted at the class level. The minimal population size for part one is about 120–180 plants per class. Require each student in your class to care for enough plants to achieve this population size. This size of population will generally express adequate phenotypic variation for a trait, such as trichomes. Consider directing your students toward this trait because trichomes are quantifiable. There is no need to count every hair — just a sample. One possible sampling procedure would be to count the hairs along the edge of the right side of the first true leaf. (See the following document for more information about Fast Plants: ***http://www.fastplants.org/pdf/activities/WFP_growth-development-06web.pdf***.)

For the trichome trait, if the top 10% of hairy plants are selected, that will generate a selected parent stock of about 12–15 plants — an adequate number to produce the seed for the next generation.

Your students will need a magnifier to study trichomes. Don't be surprised if many plants have few or no hairs. The hairs are often more visible if backlit and held against a dark background. Help your students develop a system to keep track of their counts. Somehow they will need to mark each individual plant. One possible method is to record the number of trichomes on a small plastic stake for each plant. Students record the number of hairs on a stake and place it near the appropriate plant. (Stakes can be created by cutting a plastic milk jug into 1 cm x 10 cm strips.)

As an instructor, you might consider utilizing Fast Plant seed stock C1-122 for this investigation. This stock offers a unique advantage in addition to expressing some variation in hairiness. That is, it is heterozygous for two Mendelian traits, green/light green leaves and with anthocyanin (purple stems) and without anthocyanin. In other words, these are F1 plants from a dihybrid cross. By using this stock and carefully managing the pollination and the offspring, your class can begin two separate investigations with one seed generation. Your class can investigate artificial selection with the quantitative trait of hairiness or stem color, and with the same plant population you can raise an F2 generation of a dihybrid cross for a classical Mendelian investigation on genetics. The advantage is that the 90% of the population not selected for hairs can continue to be grown by the individual students to produce an F2 generation. The seed from this cross can be used in a genetic cross demonstration/experiment, as described in the Fast Plant publication "Who's the Father?" (***http://www.fastplants.org/pdf/WTF_di.pdf***).

It is recommended that you build your own light racks and growing systems following the instructions available from the Wisconsin Fast Plant website. However, complete systems are available from supply companies. Light systems constructed by you are generally more cost effective than commercial products and can be custom designed for your room. Be sure to check with your school administration first.

Allow students to grapple with the data analysis and ways they will report their data. Refer students to Chapter 3 in their lab manual. In case they struggle, you might suggest that they graph the frequency distribution of the trait (the number of plants within a specific interval) by constructing histograms like Figures 1 and 2 in their report.

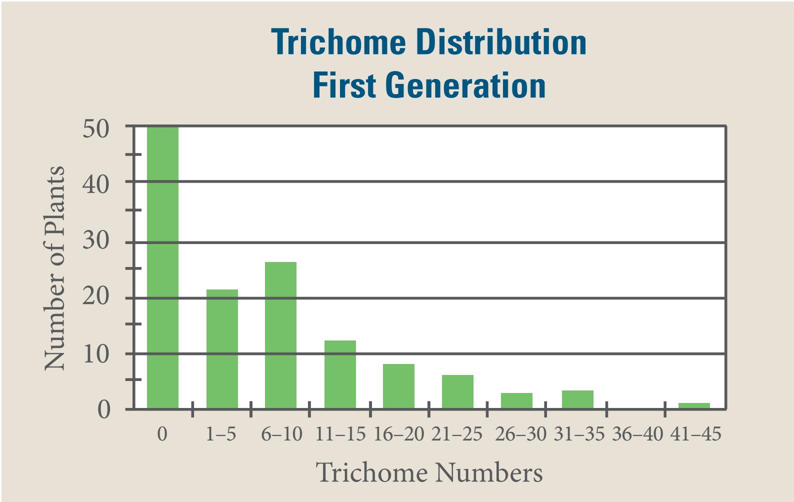

Figure 1. Trichome Distribution: First Generation

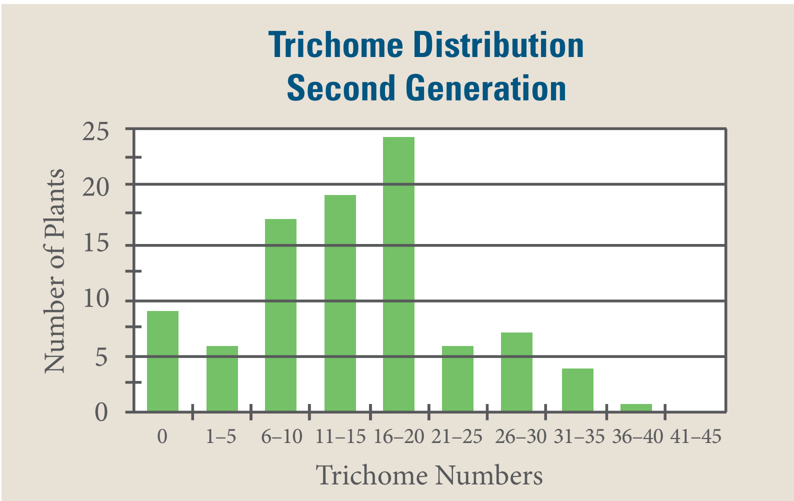

Figure 2. Trichome Distribution: Second Generation

Summative Assessment

For the first part of the investigation, you might want to have students or student groups develop individual online or digital presentations of the compiled work on artificial selection. While the class shares results and data collection methods, the data analysis and presentation of results are still the responsibility of the individuals or groups. This work would be enhanced if illustrated with digital images taken by students over the course of the selection experiment. The true summative assessment for this work will be revealed in the quality of the questions and work that the students propose for the final part of the investigation.

Consider having the students construct and present miniposters that represent their research as a summative assessment. First, have them present and defend posters to each other and provide peer review. Encourage the students to utilize the same rubric that you choose to evaluate their research project. Give them an opportunity to modify their posters before you evaluate the work with the same rubrics. (See the following website for a description of miniposters and the peer review process: ***http://www.nabt.org/blog/2010/05/04/mini-posters-authentic-peer-review-in-the-classroom/***.)

Miniposters have an advantage over traditional posters by not requiring quite so much time. If the students are working in research teams, you might consider emulating a professional society's poster session. When students put in this amount of work, it is appropriate to display their work publicly. Displaying posters in the science hall is an excellent way to provide a sense of authenticity to the research.

Where Can Students 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, students should be able to design new experiments to investigate the adaptive characteristics of the trait they studied — particularly if they selected for a quantitative trait like trichomes. For instance, they could select for the amount of purple color in the plants. This would involve students designing a system that would "quantify" color and look into the possible function(s) of purple pigment. The Supplemental Resources section includes the descriptions of a number of very accessible investigations related to the work that students conduct in the first part of the lab. Encourage students to explore concepts such as phenotypic plasticity or herbivore responses to trichomes. Cabbage white butterfly (*Pieris rapa*) larvae make a good herbivore for such a study.

A commonly asked question is *Why do these plants produce these small hairs?* It must take energy to produce the hairs. Is there an environment in the natural world where the hairs might serve as an advantage for those plants that express them? This is the start of a hypothesis that students can investigate.

Students may have other questions to investigate as well. They should start with a question of their 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?

Several hypotheses have been proposed as a possible explanation for the role that trichomes play. One hypothesis is that trichomes provide a degree of protection from herbivores — either by discouraging herbivores, such as insect larvae, or by discouraging egg laying. A common herbivore that feeds on Fast Plants is the cabbage white butterfly. Students could choose a question related to the trichomes and their importance to a plant, such as one that explores the relationship between herbivory and hair production, or they could choose a different trait and design and carry out an investigation to answer a question related to it.

SUPPLEMENTAL RESOURCES

The following resources are presented to provide students and teachers with examples of research that focus specifically on the concepts and organisms in this laboratory. The hope is that students and teachers will find inspiration for their own work in these references.

Agrawal, A. A., S. Y. Strauss, and M. J. Stout. 1999. Costs of Induced Responses and Tolerance to Herbivory in Male and Female Fitness Components of Wild Radish. *Evolution* 53, no. 4 (August): 1093–1104.

Agren, Jon, and Douglas W. Schemske. 1993. The Cost of Defense Against Herbivores: An Experimental Study of Trichome Production in *Brassica rapa*. *The American Naturalist* 141, no. 2 (February): 338–350.

———. 1994. Evolution of Trichome Number in a Naturalized Population of *Brassica rapa*. *The American Naturalist* 143, no. 1 (January): 1–13.

Bidart-Bouzat, M., Gabriela, Richard Mithen, and May R. Berenbaum. 2005. Elevated CO_2 Influences Herbivory-Induced Defense Responses of *Arabidopsis thaliana*. Oecologia 145, no. 3 (September): 415–424.

Callahan, Hilary S. 2005. Using Artificial Selection to Understand Plastic Plant Phenotypes. *Integrative and Comparative Biology* 45, no. 3 (June): 475–485.

Handley, R., B. Ekbom, and J. Agren. 2005. Variation in Trichome Density and Resistance Against a Specialist Insect Herbivore in Natural Populations of *Arabidopsis thaliana*. Ecological Entomology 30, no. 3 (June): 284–292.

Schmaedick, M. A., and A. M. Shelton. 2000. Arthropod Predators in Cabbage (*Cruciferae*) and Their Potential as Naturally Occurring Biological Control Agents for *Pieris rapae (Lepidoptera: Pieridae). Canadian Entomologist* 132, no. 5 (October): 655–675.

Siemens, David H., and Thomas Mitchell-Olds. 1998. Evolution of Pest-Induced Defenses in Brassica Plants: Tests of Theory. *Ecology* 79, no. 2 (March): 632–646.

Sleeman, Jonathan D., and Susan A. Dudley. 2001. Phenotypic Plasticity in Carbon Acquisition of Rapid Cycling *Brassica rapa* L. in Response to Light Quality and Water Availability. *International Journal of Plant Sciences* 162, no. 2 (March): 297–307.

Strauss, Sharon Y., David H. Siemens, Meika B. Decher, and Thomas Mitchell-Olds. 1999. Ecological Costs of Plant Resistance to Herbivores in the Currency of Pollination. *Evolution* 53, no. 4 (August): 1105–1113.

Traw, M. B., and T. E. Dawson. 2002. Differential Induction of Trichomes by Three Herbivores of Black Mustard. *Oecologia* 131, no. 4 (May): 526–532. DOI: 10.1007/s00442-002-0924-6.

Williams, Paul H., and Curtis B. Hill. 1986. Rapid-Cycling Populations of *Brassica*. Science 232, no. 4756, New Series (June 13): 1385–1389.

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INVESTIGATION 1

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 micronutri-ents
- 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.

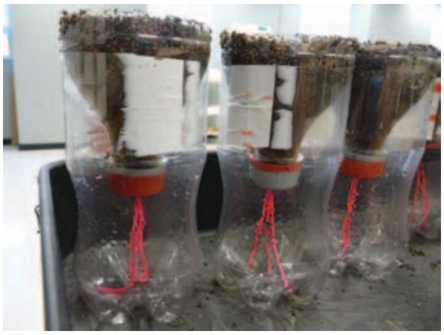

Figure 5. Mix fertilizer — one bottle cap of fertilizer in eight liters of water. Wet the soil gently until water drips from the wicks. Then fill the reservoirs with the dilute fertilizer solution. Plant the seeds carefully — about six to a bottle, uniformly spaced on the surface, not buried in the soil.

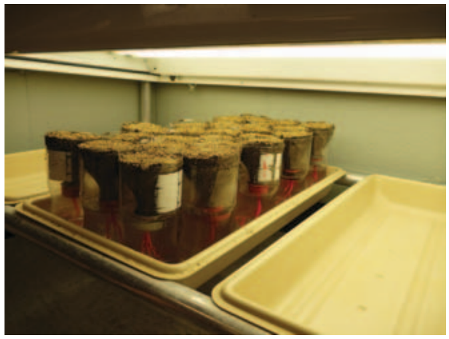

Figure 6. Cover with a light layer of vermiculite. Place the reservoirs — with fertilizer water, seeds on the surface of the soil, and a light layer of vermiculite on the soil — under the lights.

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.

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.