ARTIFICIAL SELECTION

Background

Artificial selection serves many practical purposes. Animal breeders for centuries have identified favorable traits in domesticated dogs, pigeons, and even mice, with the intention of carrying those traits on through subsequent generations. Furthermore, enhancement of certain characteristics such as size, speed, temperament, or coat color was obtained through deliberate breeding of animals selected for those desirable qualities. Underlying the practice is the understanding that in a population, extremes at each end of the distribution are likely to be found.

As with animals, plants too carry traits that are accessible to the selection process. In many ways, artificial selection draws parallels to natural selection, the process by which species change over time, as a mechanism for producing genetic change within a population.

Driving Question

Do heritable traits, once selected, lead to directional change in the gene pool?

Materials and Equipment

Use the following materials to complete the initial investigation. For conducting an experiment of your own design, check with your teacher to see what materials and equipment are available.

- Wisconsin Fast Plants® seeds (18), standard
- Seed-starting soil or germinating mix (such as Jiffy Mix®)
- Fertilizer, Osmocote™ pellets (24) or a water-soluble fertilizer
- Wicking material (3), #18 nylon mason twine
- Recycled plastic bottles (3), 0.5 L to 1 L
- Soda bottle cap with hole (3)
- Plant vermiculite
- Labeling tape and markers
- Black plastic to cover the water reservoir (3) (optional)
- Water in a rinse bottle
- Lighting system with fluorescent lights (shared by the class)
- Bee sticks or cotton applicators (3)
- Plastic plant labels (3)
- Scissors
- 12-inch ruler
- Stakes and holders, as needed (wooden splints and plastic straws)
- Dechlorinated water or nutrient solution (for the reservoir)
- Hand-held plastic magnifier
- Petri dish lid
- Paper envelope, small

Safety

Follow these important safety precautions in addition to your regular classroom procedures:

- Wear safety goggles at all times.
- When handling scissors or other tools to cut plastic bottles, use them with care and work on a surface that can support sharp instruments.
- Keep water away from electrical outlets and all electronic equipment.

Initial Investigation

Complete the following investigation before designing and conducting your own experiment. Record all observations, data, explanations, and answers in your lab notebook.

1. Put on your safety goggles.

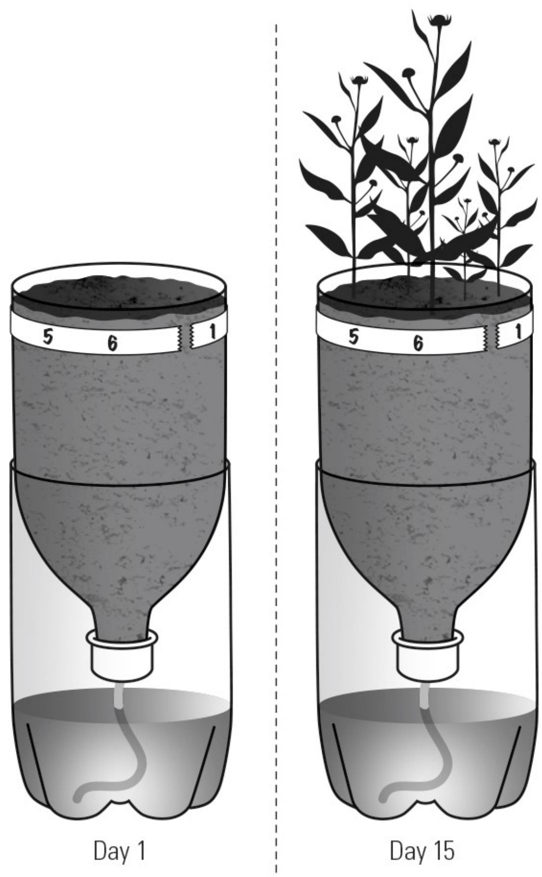
2. Before preparing the growing systems from reused plastic bottles, refer to the Wisconsin Fast Plants website (www.fastplants.org) for full instructions. A search of the website for "bottle growing system" will direct you to numerous relevant resources. The digital resource library also offers resources, such as this video: https://www.youtube.com/watch?v=eEOCRz0j6iA&feature=youtu.be.

3. Prepare the three growing systems, using recycled bottles that have been cut:

    a. Tie a knot in the wicking material, thoroughly wet the wick, and thread it through the hole of the bottle top. Screw the top onto the bottle and check that the wick will touch the bottom of the reservoir when the top piece of the growing system is placed (inverted) into the reservoir.

    b. Following instructions from the Wisconsin Fast Plants website resources—or your teacher's instructions, add starting soil, vermiculite, fertilizer (if not added to the reservoir), water, and seeds to each growing system. As you add the contents, be sure the wick remains in the center of the soil and does not extend above the soil surface.

    NOTE: **Before planting seeds** *in the growing system, wrap a piece of labeling tape around the cut edge of the top piece of each growing system. For the first one, write the numbers 1–6 on the tape, equally spacing the numbers around the circumference of the bottle. The numbers will be used to identify the seeds (plants) throughout the investigation.*

    Repeat the process, labeling the top piece of the second bottle with the numbers 7–12 and of the third bottle with 13–18.

    c. After adding the seeds, cover them with vermiculite and use the rinse bottle to wet the contents until water begins to drip from the wick.

    d. Add dechlorinated tap water or nutrient solution (water with fertilizer) to the water reservoir of the growing system. Place the top piece of the growing system into the reservoir to complete the system.

    e. Label three plastic plant labels with your group identification and the planting date; insert one label into the soil of each system.

4. Place your growing systems under the lighting system set up by your teacher.

   NOTE: The distance between the light source and the plants will need to be adjusted as the plants grow. Also, top off the water reservoir as needed due to water loss through evaporation.

5. Copy Tables 1 and 2 into your lab notebook to organize your observations (which are *not* limited to the “expected events”) of the plants over the next several weeks of data collection. Detailed observations and careful measurement are an important aspect of this lab, and a full page or more of your notebook should be devoted to each data table.

   Notable events are likely to occur daily in the first part of the plants’ life cycle. In the later weeks you may only need to make observations once or twice a week. Be sure to record specific seed (plant) ID numbers for certain observations.

Table 1: Observing growth and milestones in the Fast Plant life cycle

Week	Expected Events	Observation Date	Observations
1	Opening of cotyledons Emergence of true leaves		
2	Significant growth Development of flowers		
3	Select traits and plants for breeding Cross-pollination		
4–5	Appearance of seed pods		
6	Plant drying and seed harvesting		

Table 2: Quantitative trait measurement and breeding chart

Seed/Plant Number	Day 15 Height (cm)	Additional Quantitative Trait[1]: ______	Selected Trait: ______ Cross-pollinated?	Number of Pods	Number of Seeds Harvested
1					
2					
3					
4					
.					
.					
.					
16					
17					
18					

RECORD ANSWERS & DATA IN YOUR NOTEBOOK.

[1]Additional quantitative traits can include: germination time, size of cotyledons, time of appearance of true leaves, flowers, or seed pods, trichome density, number of leaves or distance between leaves (internode length), plant height at first flower or plant height at first seed pods, length of pods, and number of seeds per pod.

6. After observing the growth and development of the plants for two weeks, describe the variation you observe in the traits of the plants in your growing systems.

7. Measure the height of each of the individual plants on Day 15.

8. Create a histogram (frequency graph) that shows the height distribution at Day 15 for your population of Fast Plants®.

9. In your lab notebook, calculate and organize in a table the appropriate descriptive statistics about plant height for the first generation: mean, median, range, standard deviation, and standard error.

10. Plotting the means of two populations along with ±2 standard errors of the mean (SEM) is a good starting point to determine if any difference in the means is significant. Create such a graph in your lab notebook. Include the mean of your group's population of plants and the mean of a population of plants grown by another group in class.

❓ 11. Are the means of the two populations the same? If not, is the difference significant? Provide evidence to support your claim.

12. By Day 15 you need to make a selection decision, that is, you need to determine which trait to use as a criterion for selecting certain plants for cross-pollination. These selected plants will serve as the parents for the second generation. For example, one might choose to cross-pollinate plants that are 21 cm or taller to see if breeding the tallest plants changes the mean plant height in the second generation.

    Once you determine the trait you will select for, record this, as well as which plants you will keep to use for cross-pollination, in Table 2. To prevent unwanted pollination, remove and discard the non-selected plants from the growing systems.

13. When several flowers are present on each of the selected plants, cross-pollinate the plants with a single bee stick or a cotton applicator. Transfer pollen from the anthers of one plant to the stigma of another plant. Collect and distribute pollen from every flower on every selected plant. Repeat the cross-pollination procedure for 3 consecutive days.

    NOTE: Once the seed pods start to develop, trim away any additional flowers that grow on the plants. This will allow resources to be directed to the developing seeds. Replenish the water reservoirs as the seeds develop.

14. At Day 35, pour out the water from the reservoirs and allow the plants to dry for 3–5 days.

15. After the plants and seedpods have dried, harvest the seeds by breaking open the seedpods into the lid of a small Petri dish. Store the seeds in a small paper bag or envelope, labeled with your group identification and the date of harvest.

    NOTE: Remove the material from the growing systems and rinse the bottles. Keep the bottles to use for growing the second generation plants.

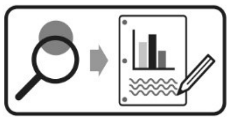
16. You now have a population of second-generation seeds. Plant the seeds as you did before, using fresh starting soil and other materials, and monitor the growth of the 2^{nd} generation, keeping detailed records of your observations and measurements. Create an appropriate histogram for the data and calculate the appropriate descriptive statistics regarding the selected trait in the 2^{nd} generation.

❓ 17. Did the selection process result in a significant change in phenotype distribution in the second generation compared to the first generation? Provide evidence to support your claim.

❓ 18. What factors were controlled over the duration of the 6-week experiment?

Design and Conduct an Experiment

Once you are experienced in the process of growing, pollinating, and harvesting seeds from Fast Plants, you may want to continue the selection experiment over multiple generations. Alternatively, you may want to test whether environmental conditions, such as acid rain, affect the results of the selection experiment. Yet another option is to explore if there is a relationship between two plant traits, such seedpod size and number of seeds.



Design and carry out your experiment using either the Design and Conduct an Experiment Worksheet or the Experiment Design Plan. Then complete the Data Analysis and Synthesis Questions.

1. From your observations and your data:

   a. Is your hypothesis for the driving question of your experiment supported? Justify your claim with evidence from your experiment.

   b. Based on the evidence you collected, explain why the results occurred.

2. Is there any evidence in your data or from your observations that experimental error or other uncontrolled variables affected your results? If yes, is the data reliable enough to determine if your hypothesis was supported?

3. Identify any new questions that have arisen as a result of your research.

Synthesis Questions

1. What do descriptive statistics such as the mean, median, range, standard deviation, and standard error tell the experimenter?

2. Refer to the graphs below. The data is from a study during which the investigators used artificial selection, selecting fish for breeding on the basis of brain size to create two distinctly different F_2 generations.[1] Figure 1 displays the change in brain size as a result of artificial selection, and the average brain size of four populations created for the purpose of the study: smaller-brained and larger-brained females, and smaller-brained and larger-brained males. The researchers developed a "learning test" to measure the cognitive ability of the fish and compared females of different brain sizes and males of different brain sizes.

Figure 1 / Artificial selection for small and large brain size

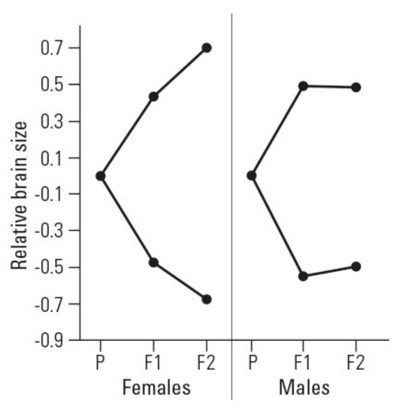


Figure 2 / Cognitive ability test

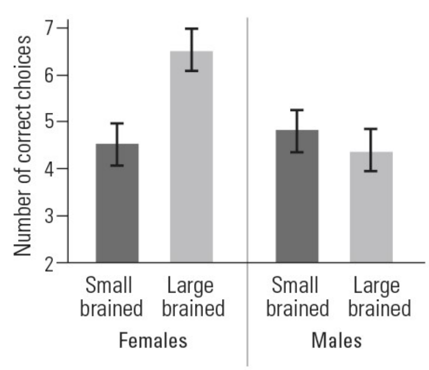
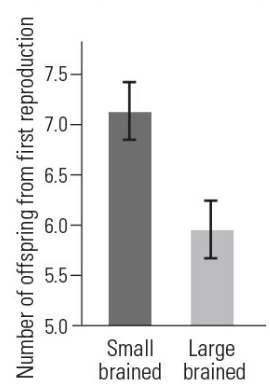


Figure 3 / Female fecundity



[1] Kotrschal et al., Artificial Selection on Relative Brain Size in the Guppy Reveals Costs and Benefits of Evolving a Larger Brain, Current Biology (2013), http://dx.doi.org/10.1016/j.cub.2012.11.058.

a. The scientists concluded that there is a correlation between brain size and cognitive ability for female guppies but that the correlation does not hold true for male guppies. Describe evidence from Figure 2 that supports the scientists' conclusion.

b. The scientists also compared the mean number of offspring produced by each category of female at first reproduction. The data are shown in Figure 3. The scientists used artificial selection in the laboratory to increase brain size in females. Do you predict natural selection will favor large-brained females? Provide evidence to support your prediction.

3. Quantitative traits in Wisconsin Fast Plants include plant height, number of seeds produced per seedpod, and time to flower.

   a. For humans, which is a quantitative trait, blood type or blood cholesterol level? Explain your reasoning for your answer.

   b. Many quantitative traits are polygenic. Explain the concept of a polygenic trait.

4. Since the advent of agriculture in ancient civilizations, humans have modified crops and domesticated animals through selective breeding, or more recently through biotechnology (genetic modification).

   a. Compare and contrast artificial selection and recombinant DNA technology.

   b. Considering the advantages and disadvantages of each technique, identify two instances in which artificial selection would be advantageous and two instances in which genetic modification technology would be advantageous for producing certain desired traits in organisms.

5. Natural selection works much like artificial selection.

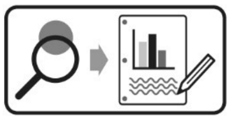
   a. Explain how Darwin's observations of artificial selection influenced his proposed theory of natural selection.

   b. Identify 3 abiotic factors and 3 biotic factors that influence natural selection. State a hypothesis for how EACH abiotic or biotic factor would have an effect on natural selection.

NAME PERIOD DATE

Design and Conduct an Experiment Worksheet

Once you are experienced in the process of growing, pollinating, and harvesting seeds from Fast Plants, you may want to continue the selection experiment over multiple generations. Alternatively, you may want to test whether environmental conditions, such as acid rain, affect the results of the selection experiment. Yet another option is to explore if there is a relationship between two plant traits, such seedpod size and number of seeds.



Develop and conduct your experiment using the following guide.

1. Create a driving question: choose one of the factors you've identified that can be controlled in the lab and develop a testable question for your experiment.

2. What is the justification for your question? That is, why is it biologically significant, relevant, or interesting?

3. What will be the independent variable of the experiment? Describe how this variable will be manipulated in your experiment.

4. What is the dependent variable of the experiment? Describe how the data will be collected and processed in the experiment.

5. Write a testable hypothesis (If…then…).

6. What conditions will need to be held constant in the experiment? Quantify these values where possible.

7. How many trials will be run for each experimental group? Justify your choice.

8. What will you compare or calculate? What analysis will you perform to evaluate your results and hypothesis?

9. Describe at least 3 potential sources of error that could affect the accuracy or reliability of data.

10. Use the space below to create an outline of the experiment. In your lab notebook, write the steps for the procedure of the lab. (Another student or group should be able to repeat the procedure and obtain similar results.)

11. Have your teacher approve your answers to these questions and your plan before beginning the experiment.