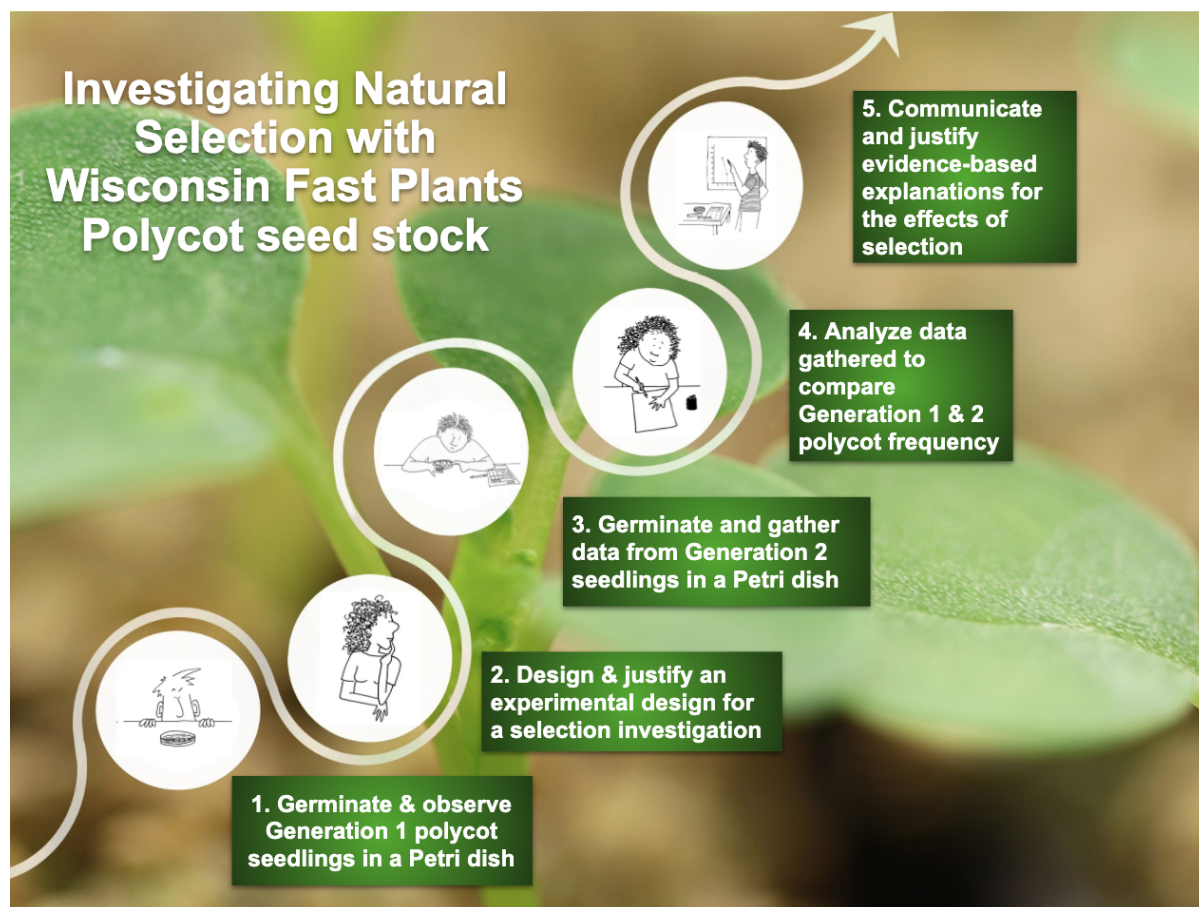
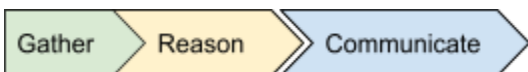




Polycots have more than two cotyledons, which is observable immediately after germination. This advanced research stock was developed to investigate the heritability of the easily observable seedling trait (three or more cotyledons) in a population of Fast Plants. The generation resulting from these seeds will express approximately 30% polycots. Selection for the polycot trait will produce increased polycot frequency in subsequent generations.





Investigating Artificial Selection with Fast Plants®

3D-Student Science Performance *Author: Wisconsin Fast Plants Program*

Grade: High School

Investigation Topic: Evolution and selection

Investigation Title

Investigating Artificial Selection with Fast Plants®

HS-LS4-3 Biological Diversity: Unity and Diversity

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

Investigation Performance Expectations:

- Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

Engage: Observing variation in cotyledons among a wide variety of plant types (photos), then observe 100 three-four day old Fast Plants seedlings from a ~28% polycot population and discuss the variations noted.

Explore: Student-centered discussion about model selection graphs sets the stage for wondering if extreme selection can change expression of the polycot trait in a population in one generation. Design and conduct (or use pre-prepared second-generation seed) an experiment for testing the effects of selecting for the polycot trait.

Explain: Use data analysis to determine the effects of polycot selection on a second generation population of polycots.

Student Science Performance

Phenomenon: Although Fast Plants are classified as “dicots,” there is variation in the number of cotyledons that 3-day-old Fast Plants seedlings have--about ¼ of the seedlings have 3, some have 4 cotyledons (polycotyledons).

Teaching Suggestions: You may wish to refer to the [Fast Plants’ program’s blog post](#) about this investigation, which includes video segments, describing the investigation and explaining the data analysis. To help with preparations, we’ve also included an [implementation calendar](#) at the end of this lesson.

Also, You may wish to set the stage for this investigation by showing images of polydactyly in humans as included in the [optional teacher slides](#). This variation in humans is interesting and similar to the polycotyledon trait because it occurs during embryonic development, is relatively rare, and doesn’t appear to be necessarily advantageous or disadvantageous.

In addition, there are [supporting interactive student materials](#) for use throughout this investigation.

Gather

- Students observe seedlings germinated from first generation Fast Plants Polycot seeds, then [develop questions to investigate](#) what underlying processes could [cause](#) variation in the number of cotyledons that Fast Plants seedlings develop.

(Distance-learning Suggestion: Small packs of 15 Generation 1 Polycot seeds and petri dishes can be sent to students learning from home for germination on paper toweling 4-5 days in advance of starting the investigation. Students can also view photographs of seedlings remotely, if needed.)

- Students discuss typical selection [models](#) to gather and make public their ideas about the roles and interdependence of variation, inheritance, and survival of individuals in a population in nature. [Based on these models](#), students [predict](#) what could [cause](#) changes in the frequency [patterns](#) of the polycotyledon trait across generations of Fast Plants.
- Students [plan and conduct an investigation collaboratively](#) to produce data that can serve as evidence to support or refute their prediction about what can [cause](#) differences in the frequency of a trait in a population across generations. With guidance, the investigation is designed to increase the frequency of polycots by inter-mating only the first generation polycots.

(Distance-learning Suggestion: Students can design the experiment collaboratively, planning how they would select and inter-mate only polycots; then, use the second generation seeds provided in place of producing those seeds from first generation plants. Experimental designs can include video and photos gleaned from the Fast Plants website, also. We’ve created an [idealized, sample experimental design created with Google Slides](#) to show how reasoning can be included explicitly, so it is possible to check for understanding.)

- Students work independently to germinate second generation seeds and share data to a combined class data set.

(Distance-learning Suggestion: Each student can germinate 15 second generation Fast Plants seeds on paper toweling in a petri dish in a windowsill or under a desk lamp with a CFL or LED bulb--not incandescent, which is too hot. Then, in three days, all students can contribute their observed polycot counts to a shared class spreadsheet.)

Elaborate: Read an analogous selection story: [The development of Fast Plants as a model organism](#), and compare/contrast it to the polycot selection experiment.

Evaluate: Students compare and evaluate competing arguments, evaluating the claims, evidence and reasoning and respectfully providing critiques on their peers' conclusions and explanations for the effects of differences in polycot frequency between first and second generations.

Reason

1. Students **analyze data** collected from their second generation Fast Plants, **applying concepts of statistics and probability, using digital tools**, to **make claims** that support or refute their predictions about the **effects** of extreme selection on the change in expression of a quantitative trait in the population--in one generation.
2. Students **apply scientific reasoning and use models** to link evidence to **claims** that explain the relationships among observed traits, selection, chromosome inheritance, and evolution.
3. Students apply their data analysis skills and tools to **analyze data** and **make claims** about how their polycot selection experiment compares to the selective breeding done to develop Fast Plants.

Teaching Suggestion: Five "articles" written in the style of a scientific article were written by the Wisconsin Fast Plants Program, describing the discovery and amplification of some of the most popular Fast Plants seed stocks. You may choose to have all students read the same article or use all five as examples for comparison to polycot selection. [These articles are available as an Open Education Resource here](#) for use in this elaborate or similar lessons.

Communicate Reasoning

1. Students **compare and evaluate competing arguments, evaluating the claims, evidence and reasoning and respectfully providing critiques on their peers' conclusions and explanations** for the **effects** of differences in polycot frequency between first and second generations.

Assessment for Student Learning

Students who demonstrate understanding can:

HS-LS4-3. **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Disciplinary Core Ideas

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

LS4.C: Adaptation

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Adaptation also means that the distribution of traits in a population can change when conditions change.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Implementation Calendar

Fast Plants Polycots: Variation & Selection Investigation

Key
 Green text = work with seedlings
 Blue text = research & analyses

Monday
 Work in pairs or small teams to start 10-15 Gen 1 Polycot seeds on wet paper towel system.
 start 1st germination

Tuesday
 Check seeds for signs of germination & variation; refill reservoirs/re-wet paper towels.
 day 1 after starting germination

Wednesday
 Observe germinating seeds & discuss types of variation present.
 Option: Germinating seed sponge model.
 day 2

Thursday
 Optional research: seed structures and functions; energy & matter transformation processes in germination.
 day 3

Friday
 materials prep day.
 *Observe & discuss visible structures and their functions. Wonder about consequences of variation.
 day 4

Monday
 Teams record data: Each seedlings' number of cotyledons & notice other variation, too.
 day 7

Tuesday
 Double-check cotyledon data (use sharp pencils or toothpicks to separate cotyledons while counting). Teams analyze their own data.
 day 8

Wednesday
 Teams share analyses (e.g. what % tricots, dicots?). Repeat w/ combined class data. Assignment: Design selection experiments.
 day 9

Thursday
 Share & critique experiment designs. Discuss how Gen 2 results may/may not be evidence of selection.
 day 10

Friday
 *Work in pairs or small teams to start 10-15 Gen 2 Polycot seeds on wet paper towel system.
 start 2nd germination

Monday
 Discuss potential impact of selection for/against polycots.
 day 14

Tuesday
 Optional research:
 • Reproduction in plants.
 • Differential reproduction in nature
 • Heredity & variation in survival.
 • Variation & adaptation /agricultural selection
 days 15- 16

Wednesday
 Teams record data: Each seedlings' number of cotyledons & conduct initial data analyses.
 day 17

Thursday
 Teams share data & compare to Gen 1 data analyses. Develop evidence-based explanations for the impact of selection.
 day 18

***Note:** Germinating & keeping seedlings alive over weekends requires a water-wicking system with water reservoir. [Click to Learn more](#)

Spring 2021

For more specifics & resources, visit www.fastplants.org

