# Selective breeding vs. genetic modification

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| **Focus questions** | What are the advantages of selective breeding? How does selective breeding differ from genetic modification? |
| **Vocabulary** | Genetics, trait, drought, meiosis, genetic modification, strong root system, rootworm resistance, seedling disease resistance |
| **Learning target** | Students model selective breeding and evaluate the strengths and weaknesses. |

## HS-LS1: From Molecules to Organisms: Structures and Processes
## HS-ESS3: Earth and Human Activity

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| **Performance expectation**<br>HS-LS1-1 | **Classroom connection:** Students are given three traits of corn. They are challenged to make the most drought-resistant corn. They construct an explanation of the best way to obtain offspring with the drought-resistant corn traits. |
| **Performance expectation**<br>HS-ESS3-4 | **Classroom connection:** Students evaluate the method of selective breeding. |

## Science and engineering practices

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| **Constructing Explanations and Designing Solutions** | **Classroom connection:** Students explain the process they followed in the activity, then describe another method that may be more precise (genetic modification). |

## Disciplinary core ideas

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| **LS1.A: Structure and Function** | **Classroom connection:** Students realize that there are many traits and chromosomes that are involved in this particular characteristic (drought resistance). DNA codes for the traits that help corn to be drought resistant. |
| **ESS3.C: Human Impacts on Earth Systems** | **Classroom connection:** Students see why GMO crops have been modified and gain a better understanding of the process. |

## Cross-cutting concepts

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| **Structure and Function**<br>**Stability and Change**<br>**Influence of Science, Engineering, and Technology on Society and the Natural World** | **Classroom connection:** Students are encouraged to determine how the structure and function of gene interaction plays a role, how the process of meiosis may impact plant breeding and efficiency of obtaining the desired traits and to consider the costs and benefits of modifications to plants. |

# Background

Humans have been selectively breeding animals and plants for thousands of years, choosing the ones with the most favorable characteristics and breeding them to achieve amazing results. Look around at the various dog breeds that have resulted from domesticating wolves or watch the video Popped Secret: The Mysterious Origin of Corn at **hhmi.org/biointeractive/popped-secret-mysterious-origin-corn**. Up until the late 1970s, that was the only way to get desired traits, but many other traits occur due to the sorting of chromosomes and crossing over that takes place during meiosis during sexual reproduction. Plant breeders have been able to overcome some of these obstacles by using selective breeding and genetic modification to improve crop characteristics, making them insect resistant (i.e. corn borer), herbicide resistant (glyphosate), less prone to enzymatic browning (apples and potatoes), disease resistant (gray leaf spot) or providing them with a health benefit (high oleic oil).

The lesson, **Selective Breeding vs. Genetic Modification,** and the accompanying slide deck leads students through a modeling activity to allow them to see how trying to get a specific set of traits is not as easy as it seems, even when they are allowed to select for the traits by choosing the offspring they want to cross.

# Materials

- Starburst® candies* in red, yellow and orange (these have no allergens and are individually wrapped): 3 per student
- Opaque cups (foam cups or colored plastic that students cannot see through): 1 per every 2 students
- Slide deck
- Electronic device for researching information

*Each candy represents a trait or phenotype. This activity does not intend to model allele combinations.

# Teacher preparation

1. Copy student lesson
2. Count out a random number of starbursts
3. An extension could include differing numbers of each of the “traits” to see if the desired population frequency changes.

# Prior knowledge

In order to successfully understand this activity, students need to have some background in the process of meiosis, familiarity with the vocabulary (genetics, trait, drought, meiosis, genetic modification) and a general familiarity with the idea of selective breeding. Additional material can be supplemented by reviewing material from the middle school Biotechnology unit.

6. Select another corn plant at your table that has some or all of the desired traits. Cross your plant with that plant by repeating steps 2-4. How many offspring in the class have all three of the desired traits? (Report as the number that do out of the total possible.)

There will be less than 100% that have all three of the desired traits (unless they choose while looking).

7. Why didn't choosing the parents result in all of the offspring having the desired traits?

There will be six candies in the cups and the probability of drawing out one of each color will be determined by the number of each color and the mixing that will take place.

8. How does meiosis affect the outcome? What are the limitations of this model?

Meiosis allows for different chromosomes from the parents to end up in different gametes, one from each parent, but not all gametes will have all the same information. Unless the parents are genetically identical, the offspring will show some traits from both parents.

This model does not allow for the separation of these traits to show up on separate chromosomes (i.e. the colors represent different traits, but these traits are on different chromosomes or are influenced by multiple genes. The candies do not represent genes, just the resulting traits.

9. How might plant breeders overcome these obstacles?

Research on which genes influence these traits can be done. Scientists may be able to isolate which genes and modify the genes through gene editing (CRISPR) or they may find the trait in different species, isolate, and transfer those genes to plants to give them the traits to make them drought resistant.

10. How much might it cost (in dollars and time) to make these modifications? What are the environmental costs and benefits?

Economic and time: On average, GMOs take 13 years and $130 million of research and development before coming to market. See more info about the costs at: **gmoanswers.com/ask/what-average-cost-associated-research-production-and-testing-single-genetically-modified**.

Environmental costs are: 1) a monocrop with the same genetic modifications can be more susceptible to a disease due to the lack of genetic diversity in the crop, 2) some weeds in fields have become resistant to the use of herbicides after many years of use of that herbicide, 3) some crops that do not have resistance to an herbicide may be harmed if the herbicide is used in an adjacent field.

Benefits: 1) the amount and concentration of harmful herbicides has decreased, 2) the amount of harmful insecticides is greatly reduced since the plants make their own insecticide, 3) some crops are disease resistant which saved the industry of rainbow papaya (research papaya and ringspot virus), and is also used in potatoes and zucchini, 4) health benefits have been added to some plants, such as high oleic oil from soybeans which is similar to olive oil, but still has the ability to fry for longer periods with less residue than regular soybean oil (soybean oil is sold as vegetable oil).

## Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students may investigate local plants that resist drought for additional testing.
- **Students with special needs (language/reading/auditory/visual):** Students may plant different seeds and water with various amounts to determine the characteristics that lead to drought resistance.
- **Extra support:** Students might read: "Pioneer Research to Develop Drought-tolerant Corn Hybrids" **pioneer.com/CMRoot/Pioneer/US/products/seed_trait_technology/see_the_difference/corn_drought.pdf** or "Drought-Tolerant Corn Hybrids Yield More in Drought-Stressed Environments with No Penalty in Non-stressed Environments" **frontiersin.org/articles/10.3389/fpls.2016.01534/full**
- **Extensions:** Students can research the development of corn by viewing: Popped Secret: The Mysterious Origin of Corn from HHMI Biointeractive: **hhmi.org/biointeractive/popped-secret-mysterious-origin-corn** to determine how corn might be bred to be more drought resistant.

## Assessments

### Rubric for assessment

| Skill | Developing | Satisfactory | Exemplary |
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| **Construct an explanation of selective breeding** | Student can describe the activity but does not make a connection to selective breeding. | Student can describe the activity and includes a connection to selective breeding. | Student can describe the activity and explain how it connects to selective breeding. Student can describe limitations within the simulation. |
| **Evaluate or refine a technological solution that considers structure and function, stability and change and the impact of human activities on natural systems.** | Student can explain that genetic modification is a technological advance but cannot describe the advantages over selective breeding nor the impact either has on natural systems. | Student can explain that genetic modification is a technological advance, describes the advantages over selective breeding and the impact either has on natural systems. | Student can explain how genetic modification is a technological advance over selective breeding, describe the costs and benefits of genetic modification, and the impact of genetic modification on natural systems. |

## Rubric for self-assessment

| Skill | Yes | No | Unsure |
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| **Constructing Explanations:** I constructed an explanation of the selective breeding process and the obstacles to it. | | | |
| Evaluate or refine a technological solution that considers structure and function, stability and change and the impact of human activities on natural systems: I can list the costs (both economic and time) and benefits of genetic modification | | | |
| I can explain how structure and function of genes and chromosomes impacts selective breeding. | | | |
| I can explain how selective breeding and genetic modification may have an impact on natural systems. | | | |