BIOTECHNOLOGY

# Genetic improvement method: hybridization

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| **Focus questions** | How are breeding techniques being used in agriculture to solve problems? What is the genetic basis of hybrid vigor or heterosis? |
| **Learning target** | Students consider information about pork breeds to determine the best combinations for hybrid vigor. |
| **Vocabulary** | Breed, hybrid vigor, heterosis, crossbred, terminal line, inbreeding |

## HS-LS1-1: From Molecules to Organisms: Structures and Processes

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| **Performance expectation**<br>HS-LS1-1 | **Classroom connection:** Students receive information concerning the eight major pork breeds in the United States and are challenged to produce a market hog with hybrid vigor. They construct an explanation of the best way to produce offspring with the hybrid vigor specific to certain requirements. |

## 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 that are involved in hybrid crosses. Genes code for the traits that help animals to demonstrate hybrid vigor. |

## Cross-cutting concepts

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| **Structure and Function** | **Classroom connection:** Students are encouraged to determine how the structure and function of gene interaction plays a role in heterosis. |

This lesson is one in a series that describes genetic improvement methods. The lessons can be used as a group to compare the methods once all are completed or each lesson can be used to provide a new lens to teach a familiar concept.

## Background

This lesson asks students to act as a hog breeder to determine how they might cross different breeds to get desired traits. A market hog is one that will be sold for slaughter. A hog weighing 230 pounds on average will produce a carcass that is about 70% of its live weight, or about 160 pounds, resulting in around 130 pounds that are sold as retail cuts.

**Heterosis,** commonly known as **hybrid vigor,** is an important breeding strategy in agriculture that results in the improved performance of offspring produced by crossing genetically different plants or animals. These hybrids often show advantages such as faster growth, higher yields, improved fertility, and greater resistance to disease compared to their parent lines. Farmers and breeders use hybrid vigor to increase productivity and efficiency in crops and livestock, making it a valuable tool for meeting food production demands. Hybrid vigor is valued in both crop and animal breeding.

## Prior knowledge

- Basics of meiosis; be familiar with the idea of hybrid vigor and the impacts of inbreeding.
- Genes occur as alleles for traits which control the making of proteins to perform most cellular functions.
- Changes in organisms can result from genetic recombinations.

## Suggested timing

1 class period (45–50 min)

## Materials

- Pork breed cards

## Teacher preparation

1. Copy student lesson.
2. Print pork breed cards and cut for student use. Each student group will need a full set of cards to complete the information.

## Procedure

1. Discuss hybrid vigor versus in-breeding.
    - Inbreeding in animals may result in poor reproductive ability due to higher mortality rates, lower growth rates in offspring and more frequent hereditary abnormalities.
2. Using pork as an example, have students review the most common pork breeds in the United States.
3. Assign students one of the four scenarios and have them determine how they might breed a market hog to meet the conditions in the scenario, following the steps on the student handout.
4. Review results and answers as a class.
5. Ask students to respond to the reflection questions and complete the rubric.

## Differentiation

Other ways to connect with students with various needs:

- **Local community:**
  - Visit local farms or agricultural research stations that use improved breeding methods.
  - Invite a plant/animal breeder, agricultural scientist, or extension agent to discuss crop or animal breeding methods.
  - Find a virtual visit to a pig farm online to show students and discuss biosecurity.
- **Students with special needs:**
  - Reading support: Pre-teach vocabulary with visual supports; provide audio recordings of background text.
  - Auditory learners: Use verbal explanations with visual demonstrations; encourage students to read DNA sequences aloud; provide video resources showing transcription/translation.
- **Extra support:** Introduce vocabulary and concepts in a small group to pre-teach before lesson.
- **Extensions:**
  - Students may research other forms of heterosis utilized in agriculture. Provide visual or video examples of heterosis in animal breeds such as dogs, etc. and have students explain the beneficial traits in the hybrid.
  - Students may conduct additional research of pork breeding strategies from the Iowa Pork Industry Center: `youtu.be/C985BJPd6mw`

# Student handout

## Procedure

1. Review the eight common pork breeds and their traits. Fill these traits into the table below.

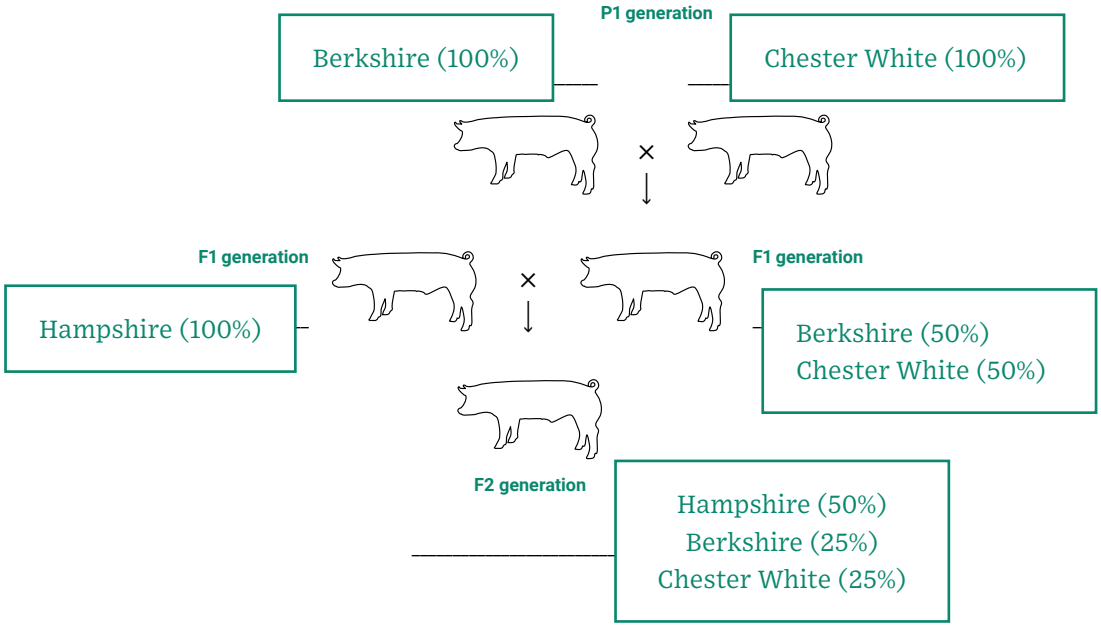
| Pork breed | Breed traits |
|---|---|
| Berkshire | Fast and efficient growth, reproductive efficiency, cleanness, meat flavor and value |
| Chester White | Mothering ability, durability, soundness, muscle quality |
| Duroc | Product quality, carcass yield, fast growth, lean gain efficiency, prolific, longevity in female line |
| Hampshire | Lean muscle, high carcass quality: minimal backfat, high muscle content, mothering ability, longevity in sow herd |
| Landrace | Heavy milkers, farrow large pigs, cross well with other breeds, long body, ideal carcass finish |
| Poland China | Frame, length of body, leanness, muscle, excellent feeders, quiet disposition |
| Spotted | Feed efficiency, rate of gain, carcass quality, females are productive, docile, durable |
| Yorkshire | Muscle, lean meat and low backfat, soundness, durability |

2. Carefully review the pork breed traits and read your assigned scenario. Select the pork breeds that best match the traits described in the scenario.
3. Create a breeding diagram showing how the selected breeds are crossed to produce a market hog. Clearly label each breed in the diagram.

# Student handout

4. Explain which traits each breed contributes and how they help meet the requirements of the scenario. Make sure your final crossbred market hog fits all traits outlined in the scenario.

   a. Create a female crossbred with **durability, fast growth, and good mothering ability.**

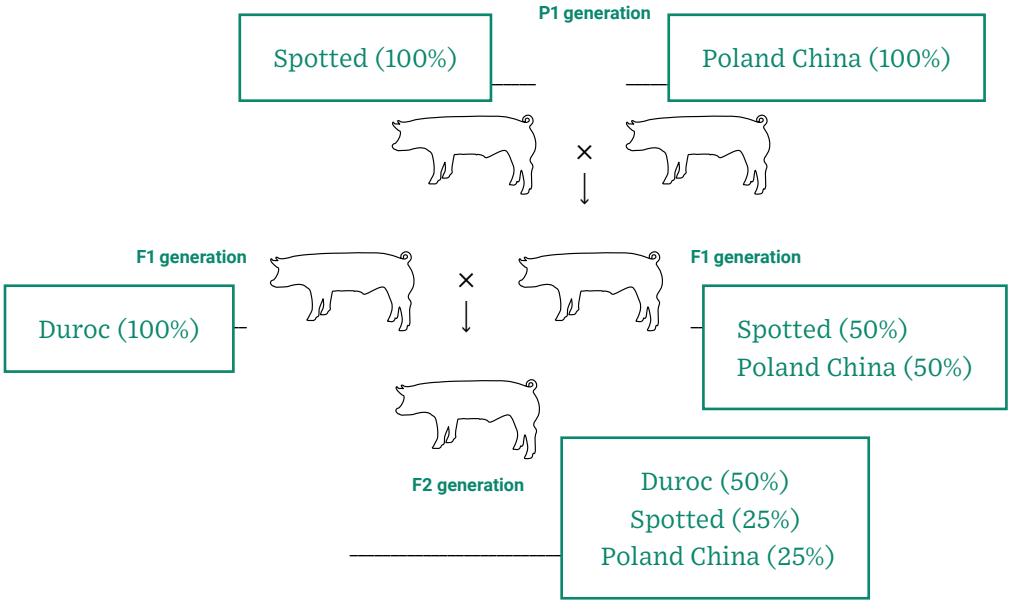



- Why did you use these breeds in this breeding scenario?

Answers may vary.
- Berkshire: fast and efficient growth
- Chester White: durability
- Hampshire: good mothering ability

# Student handout

b. Create a female crossbred with **good carcass yield, leanness, muscle, and docility.**

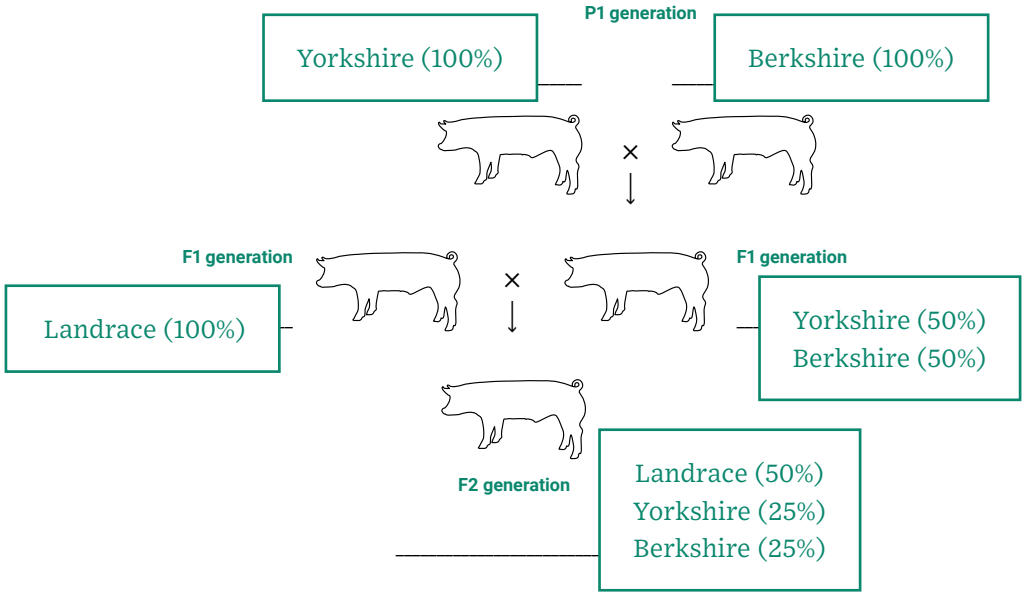



- Why did you use these breeds in this breeding scenario?

Answers may vary.
- Spotted: docility
- Poland China: leanness and muscle
- Duroc: good carcass yield

# Student handout

c. Create a female crossbred with **low backfat, meat flavor, long body, and ideal carcass finish.**

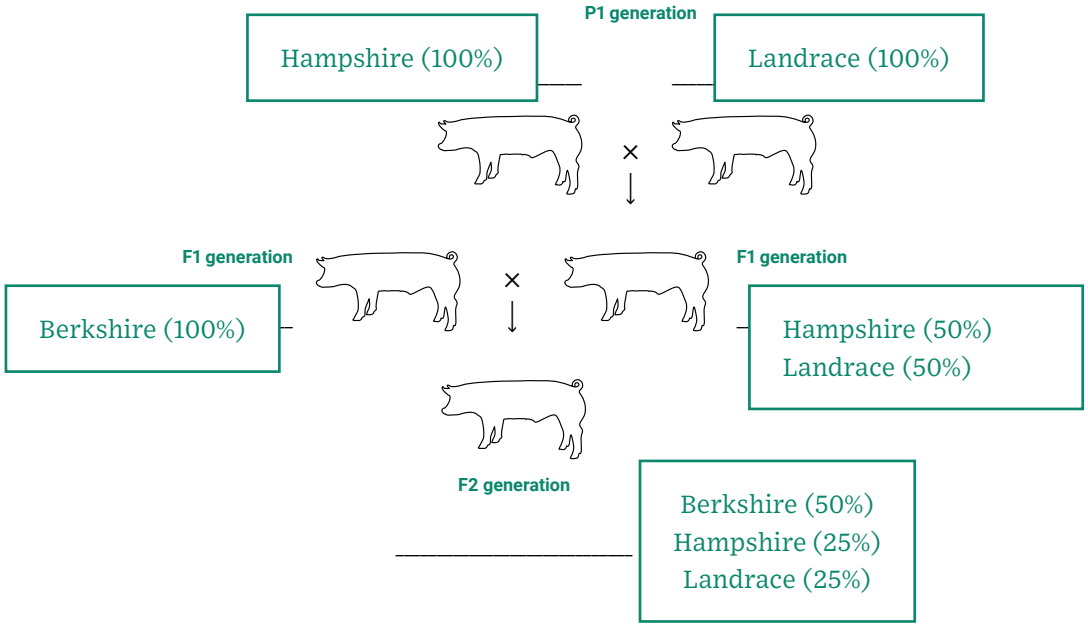



- Why did you use these breeds in this breeding scenario?

Answers may vary.
- Yorkshire: low backfat
- Berkshire: meat flavor
- Landrace: long body with ideal carcass finish

# Student handout

d. Create a female crossbred with **three traits that you consider to be necessary in market hog production.**




- Why did you use these breeds in this breeding scenario?

Answers may vary.

- Hampshire: Lean muscle, mothering ability, high carcass quality: minimal backfat, high muscle content, and longevity in sow herd
- Landrace: Heavy milkers, farrow large pigs, cross well with other breeds, long body, ideal carcass finish
- Berkshire: Fast & efficient growth, reproductive efficiency, cleanness, meat flavor and value

# Student handout

## Reflection

1. Why is it important to breed the crossbred female to a terminal purebred male line?

Hybrid vigor is maintained when breeding to a purebred line in order to continue to receive the beneficial traits from that line. It is important to rotate pork breeds when breeding back to the crossbred female so that the beneficial traits are not diluted in the subsequent progeny.

2. What happens to hybrid vigor if you breed a male crossbred to a female crossbred?

Hybrid vigor is lost to subsequent generations when crossbreds are bred to one another because their genes recombine randomly, demonstrating more of the less fit parental breeding traits. This results in inbreeding which often weakens the offspring.

3. Which alleles are responsible for each of the traits in the breeds? Why do only some show up in the offspring?

Different alleles are responsible for the various traits. Some of those alleles may recombine to create “dominant” traits or characteristics depending on the recombination of the alleles.

4. What are the limitations of using heterosis in agriculture? What other techniques may be used to achieve more precise results?

The limitations to using hybridization in agricultural breeding are loss of genetic diversity, loss of hybrid vigor (inbreeding) if not done properly, potential dependence on breeders, higher costs, and lack of consistency.

Potentially using gene editing would be more precise, once the genetic basis for the characteristics are discovered.

## Assessments

### Rubric for assessment

| Skill | Developing | Satisfactory | Exemplary |
|---|---|---|---|
| **Construct an explanation of heterosis** | Describes the activity but does not make a connection to heterosis. | Describes the activity and includes a connection to heterosis. | Describes the activity and explains how it connects to heterosis. Accurately uses breeding percentages within the simulation. |
| **Trait selection and justification** | Selects breeds with limited consideration of required traits. Provides weak or incomplete justifications. Shows limited understanding of how traits are inherited. | Selects appropriate breeds for assigned scenarios. Provides clear justifications linking breeds to desired traits. Makes basic connections between genetics and observable characteristics. Shows understanding of trait combination in offspring. | Provides scientifically accurate justifications connecting breed genetics to desired phenotypes. Explains how specific genes/ proteins might influence traits like growth rate, muscle development, or milk production. Shows strategic thinking about how traits combine in crossbred offspring. |
| **Understanding genetic mechanisms** | Provides a simplistic explanation of inheritance without using hybrid vigor or heterosis. Shows limited understanding of how genetic material from different parents creates improved offspring. Uses genetic vocabulary inconsistently or incorrectly. | Explains that offspring inherit genes from both parents that result in improved traits. Describes how genetic diversity from different breeds leads to hybrid vigor. Uses appropriate genetic terminology. Makes basic connections between genes and observable traits. | Accurately describes how different alleles from each parent breed contribute to enhanced traits in offspring. Connects specific breed traits to underlying genetic variation and protein expression. Uses precise scientific vocabulary (alleles, genotype, phenotype, genetic diversity, gene expression). |

## Rubric for self-assessment

| Skill | Yes | No | Unsure |
|---|---|---|---|
| I can describe the benefits and drawbacks of heterosis. | | | |
| I can describe why the F2 generation has 100% heterosis after crossing with the terminal line. | | | |
| I can connect specific breed traits to underlying genetic variation and protein expression. | | | |
| I can describe how genetic diversity from different breeds leads to hybrid vigor. | | | |
| I can justify the reasoning for using the chosen breeds to obtain desired traits. | | | |