BIOTECHNOLOGY (HS)

Punnett squares

Focus question	How do breeders predict which traits will be in offspring? How might biotechnology methods improve the process?
Learning target	Students complete Punnett squares to compare theoretical ratios to actual ratios on corn cobs and determine the amount of time it might take to get a desired outcome.
Vocabulary	Genotype, phenotype, alleles, homozygous, heterozygous, dominant, recessive, Law of Independent Assortment

HS-LS3: Heredity: Inheritance and Variation of Traits

Performance expectation HS-LS3-1	**Classroom connection:** Punnett squares are used to predict the offspring ratios from various crosses. Students complete the squares, determine the genotype and phenotype ratios, and compare to a real plant.

Science and engineering practices

Asking Questions and Defining Problems	**Classroom connection:** Students discover that Punnett squares can help to determine ratios of offspring, but in reality those predictions are not always accurate.

Disciplinary core ideas

LS1.A: Structure and Function **LS3.A: Inheritance of Traits**	**Classroom connection:** Students see the result of crossing genes and the resulting genotypes and phenotypes that result from the different proteins that are produced based on the gene combinations.

Cross-cutting concepts

Cause and Effect	**Classroom connection:** The different gene combinations in the Punnett squares result in different seed color and shape on the corn cob.

Materials

- Carolina Biological Supply 17-6810 Monohybrid cross
- Carolina Biological Supply 17-6900 Dihybrid cross

Note: The activity can be completed without the Carolina corn, however, having the actual cobs allow students the added check to see that sometimes, the expected ratio is not what results in reality. (For example: although there is a 50-50 chance that human offspring will be male or female, there are many instances where there are families of all girls or all boys.) The percent chance resets each time a cross occurs. Each kernel of corn is a separate offspring that results from a single silk.

Prior knowledge

Students need to understand how to show a cross using a Punnett square. This should be part of a middle school science course. Students will need to know the definition of alleles, the difference between a genotype and a phenotype, homozygous and heterozygous, and dominant and recessive traits. Mendel's Law of Independent Assortment is also applied for these two traits.

Teacher preparation

1. Make copies of the student handout.
2. Have corn from Carolina on hand for students to examine or make copies of a photo like this:

Student handout

BIOTECHNOLOGY (HS) LESSON 4

Punnett squares

Focus question	How do breeders predict which traits will be in offspring? How might biotechnology methods improve the process?
Vocabulary	Genotype, phenotype, alleles, homozygous, heterozygous, dominant, recessive, Law of Independent Assortment, F1, F2

Use Punnett squares to show results from a hybrid cross and determine the genotypic ratios and phenotypic ratios of a hybrid. If a plant breeder is interested in creating a better corn plant, one with some traits from one variety and some traits from another, the traditional method is to cross these two varieties and look for the plants that exhibit the combination of traits desired.

Procedure

Monohybrid Cross: A cross looking at one gene for a trait

1. Cross Colored Aleurone with the **genotype** (RR) corn with Colorless Aleurone, genotype (rr), in the Punnett square below to show the **F1** results. Circle the correct words below:
   The R R genotype is *homozygous / hetrerozygous and dominant / recessive.*

	R	R
r		
r		

R R × r r

- What are the resulting genotypes? What is the percent?

  100% R r

- What are the resulting **phenotypes?** What is the percent?

  100% colored aleurone

2. When you cross two of the offspring from above, what will be the result in the **F2** generation? Circle the correct word in the sentence below:
   The R r genotype is *homozygous / heterozygous.*

	R	r
R		
r		

R r × R r

- What are the resulting genotypes? What are the percents?

  25% R R; 50% R r; 25% r r

- What are the resulting phenotypes? What are the percents?

  75% colored aleurone; 25% colorless aleurone

3. Count the kernels on the cob to determine the actual ratio.

Student handout

Dihybrid cross: Looking at two genes that are on two different chromosomes

Use the model *Carolina Biological Supply 17-6900 Dihybrid cross* to complete the activity below.

4. Cross Colored Aleurone (RR), Starchy (SU/SU) corn with Colorless Aleurone (rr), Sweet Endosperm (su/su), in the Punnett square below to show the F1 results.

	r su	r su	r su	r su
R Su				
R Su				
R Su				
R Su				

R R SU / SU × r r su / su

- What are the resulting genotypes?

100% R r Su / su

- What are the resulting phenotypes?

100% colored aleurone, starchy corn

5. When you cross two of the offspring from above, what will be the result in the F2 generation?

	R SU	R su	r SU	r su
R SU				
R su				
r SU				
r su				

R R SU / SU × r r su / su

- What are the resulting genotypes?

From this cross, only 1 of the 16 possibilities will be colorless and sweet. If those offspring are crossed, 100% of the offspring will be colorless and sweet.

- What are the resulting phenotypes?

Considering time for growing and the generations, it might take up to 3 years before the corn with the desired traits would be able to be harvested.

6. How might you get 100% colorless and sweet offspring?

From this cross, only 1 of the 16 possibilities will be colorless and sweet. If those offspring are crossed, 100% of the offspring will be colorless and sweet.

Student handout

Reflection

1. How long would it take for a farmer to accomplish this amount of crossing on his/her own?

Considering time for growing and the generations, it might take up to 3 years before the corn with the desired traits would be able to be harvested.

2. What are some traits that farmers may value that could be a result of two different corn varieties?

Traits of value include: drought resistance, strong root systems (to prevent wind blowing the plants down (lodging) and to increase nutrient uptake), disease resistance, pest resistance, etc.

3. Seed chipping is a technique originally discovered by Monsanto. Watch this video DEKALB® Breeding HQ: Seed Chipping Technology **youtu.be/gCb9TSpuxUU**. How much time does this technique take off of the typical hybridization cycle?

Plants can be chipped, the genomes sequenced to find the genes of interest, then bred within one season, cutting the time in half or more compared to that of traditional breeding.

4. Look for other techniques being used to cut the time it takes to make new hybrids (i.e. TALEN, gene silencing, CRISPR). Describe how these methods are helping reduce the time to create new lines that will have increased resistance to weed pressure, pests, and drought.

Answers will vary. They might research TALEN, gene silencing, CRISPR, etc.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students may visit a local plant breeder at a greenhouse (horticulture-related or produce-based) to learn how the breeder chooses different varieties for breeding.
- **Students with special needs (language/reading/auditory/visual):** Students may use different-colored chips to represent the genes and add the chips to an enlarged Punnett square, making combinations and moving the chips.
- **Extra support:** If students are struggling, they may watch Learn Biology: How to Draw a Punnett Square **youtu.be/prkHKjfUmMs**
- Students may read the Khan Academy article that explains Independent Assortment **khanacademy.org/science/high-school-biology/hs-classical-genetics/hs-introduction-to-heredity/a/the-law-of-independent-assortment**
- **Extensions:** Students may talk with a corn breeder or other plant breeder to see what other traits are of value to a farmer or grower of other plants (poinsettias, hydrangeas, lilies or other plants that are sold during different seasons give students several applications to their lives).Students may investigate additional plant breeding techniques: seed chipping (DEKALB® Breeding HQ: Seed Chipping Technology **youtu.be/gCb9TSpuxUU**), TALEN, gene silencing, CRISPR

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.	Student can complete a monohybrid cross using a Punnett square, but struggles with the dihybrid cross. Student cannot explain how the process of meiosis and independent assortment affects results.	Student can complete monohybrid and dihybrid crosses. Student can clarify the relationship of independent assortment of chromosomes on the outcome of multiple crosses.	Student can complete monohybrid and dihybrid crosses. Student can clarify the relationship of independent assortment of chromosomes on the outcome of multiple crosses. Student can also explain the impact of technology on traditional breeding.

Rubric for self-assessment

Skill	Yes	No	Unsure
I correctly completed a Punnett square for a monohybrid cross.			
I correctly completed a Punnett square for a dihybrid cross.			
I understand Mendel's Law of Independent Assortment and its impact on the traits in these crosses.			
I discovered at least one new technique in breeding that has impacted the development of new hybrids.			