ANIMAL SCIENCE (HS)

Dairy cattle genetics

Focus questions	How do breeders predict which traits will be present in offspring? How might biotechnology methods improve the process?
Learning target	Students complete Punnett squares to compare theoretical ratios to actual ratios in cattle 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 real cattle examples.

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 genotypes and phenotypes that occur from the different proteins produced based on the gene combinations.

Cross-cutting concepts

Cause and Effect	**Classroom connection:** The different gene combinations in the Punnett squares result in polled or horned traits and different coat colors.

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 alleles, and dominant and recessive traits. Mendel's Law of Independent Assortment is also applied for these two traits.

Suggested timing

40–80 minutes

Materials

Student lesson

Teacher preparation

1. Make copies of the student lesson.
2. Have photos of dairy traits on hand for students to examine (polled, horned; color traits: black, red, white, and roan).

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students may visit a local cattle breeder at a farm to learn how the breeder chooses different polled or color traits for breeding results.
- **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 dairy breeder or other livestock breeder to see what other traits are of value to a livestock farmer. Students may investigate additional breeding techniques: TALEN, gene silencing, CRISPR, etc.

Student handout

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

Using Punnett squares to show results from a hybrid cross, you can determine the genetic and phenotypic ratios of the offspring. If an animal breeder is interested in creating a better dairy cow, 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 offspring that exhibit the combination of traits desired.

Cattle breeders look for specific traits in cattle to predict the potential for desirable traits in offspring. Specifically, breeders may prefer polled (hornless) cattle and specific coat color patterns in certain breeds. Polled cattle are often preferred to horned cattle because they do not need to be dehorned, so they pose less of a safety risk to other cows and their caretakers. Coat colors often distinguish dairy breeds and help farmers to predict milk production due to previous knowledge of such dairy breeds. Cattle primarily have three coat color genes: black, red, and white. Black is dominant to red, and black and red are codominant to white. Roan is an equal blending of white hairs with black or red hairs as determined by the animal's genotype.

Genetic traits

- **P:** polled (dominant allele for hornless cattle)
- **h:** horn (recessive allele for horned cattle)
- **B:** black coat color (dominant to red coat color, co-dominant with white coat color)
- **b:** red coat color (recessive to black coat color, co-dominant with white coat color)
- **W:** white coat color (codominant to black and red coat color)

Procedure

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

1. Cross a polled bull with a genotype (PP) with a horned cow with a genotype (hh) in the Punnett square below to show the F1 results. Circle the correct words below:
   The P P genotype is *homozygous / heterozygous and dominant / recessive.*

	P	P
h	P h	P h
h	P h	P h

P P × h h

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

  P h; 100%

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

  Polled cattle; 100%

Student handout

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 P h genotype is *homozygous / heterozygous.*

	P	h
P	P P	P h
h	P h	h h

P h × P h

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

  P P, P h, h h; 25% 50% 25%

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

  Polled cattle, horned cattle; 75%, 25%

3. Cross a red bull (bb) with a black roan cow (BW) in the Punnett square below to show the F1 results. Circle the correct words below:

   The b b genotype is *homozygous / heterozygous.*

   The B W genotype is *dominant / recessive / co-dominant.*

	b	b
B	B b	Bb
W	bW	bW

b b × B W

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

  B b, b W; 50% each

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

  Black, white; 50% each

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

4. Cross black polled (BB PP) cattle with red horned (bb hh) cattle in the Punnett square below to show the F1 results.

	BP	BP	BP	BP
bh	BbPh	BbPh	BbPh	BbPh
bh	BbPh	BbPh	BbPh	BbPh
bh	BbPh	BbPh	BbPh	BbPh
bh	BbPh	BbPh	BbPh	BbPh

BB PP × bb hh

- What are the resulting genotypes?

  B b P h

- What are the resulting phenotypes?

  Black polled cattle

Student handout

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

	BP	Bh	bP	bh
BP	BBPP	BBPh	BbPP	BbPh
Bh	BbPh	BBhh	BbPh	Bbhh
bP	BbPP	BbPh	bbPP	bbPh
bh	BbPh	Bbhh	bbPh	bbhh

Bb Ph × Bb Ph

- What are the resulting genotypes?

  BBPP, BbPh, BbPP, BbPh, BBhh, Bbhh, bbPP, bbPh, bbhh

- What are the resulting phenotypes?

  Black polled; black horned; red polled; red horned

Reflection

1. What are some traits that farmers may value that could be a result of two different cattle breeds?

Student answers will vary.

2. How long might it take for a farmer to know if the cross they have made will result in the desired traits being passed on in offspring?

Cows give birth after 9 months. Depending on the trait (for example: higher milk production), it may not be clear if the trait is present until maturity (i.e. after the cow gives birth to produce milk). So it could be up to 2+ years later.

3. Look for other techniques being used to cut the time required to make new breeds of cattle (i.e., TALEN, gene silencing, CRISPR). Describe how these methods can reduce the time to create new lines that will have increased red coats with polled traits

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

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.			