ESSENTIAL QUESTION

How are patterns of inheritance studied?

By the end of this lesson, you should be able to explain how patterns of heredity can be predicted by Punnett squares and pedigrees.

These cattle are bred for their long, curly hair, which keeps them warm in cold climates. This trait is maintained by careful breeding of these animals.
1 Infer  Why do you think that children look like their parents?

2 Apply  Color or label each circle with the color that results when the two paints mix. As you read the lesson, think about how this grid is similar to and different from a Punnett square.

3 Apply  Use context clues to write your own definition for the words occur and outcome.

Example sentence
Tools can be used to predict the likelihood that a particular genetic combination will occur.

occur:

Example sentence
A Punnett square can be used to predict the outcome of a genetic cross.

outcome:

4 Apply  As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Vocabulary Terms
- Punnett square
- ratio
- probability
- pedigree
How are Punnett squares used to predict patterns of heredity?

When Gregor Mendel studied pea plants, he noticed that traits are inherited in patterns. One tool for understanding the patterns of heredity is a diagram called a Punnett square. A Punnett square is a graphic used to predict the possible genotypes of offspring in a given cross. Each parent has two alleles for a particular gene. An offspring receives one allele from each parent. A Punnett square shows all of the possible allele combinations in the offspring.

The Punnett square below shows how alleles are expected to be distributed in a cross between a pea plant with purple flowers and a pea plant with white flowers. The top of the Punnett square shows one parent’s alleles for this trait (F and F). The left side of the Punnett square shows the other parent’s alleles (f and f). Each compartment within the Punnett square shows an allele combination in potential offspring. You can see that in this cross, all offspring would have the same genotype (Ff). Because purple flower color is completely dominant to white flower color, all of the offspring would have purple flowers.

Key:
F  Purple flower allele
f  White flower allele

Genotype: FF
Phenotype: purple flower

Genotype: ff
Phenotype: white flower

Active Reading

5 Identify In a Punnett square, where are the parents’ alleles written?

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This Punnett square shows the possible offspring combinations in pea plants with different flower colors.
**6 Apply** Fill in the genotypes and phenotypes of the parents and offspring in this Punnett square. Sketch the resulting offspring possibilities in the white boxes below. (Hint: Assume complete dominance.)

**Key:**
- **R** Round pea allele
- **r** Wrinkled pea allele

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**Genotype:** ________  
**Phenotype:** ________

**Genotype:** ________  
**Phenotype:** ________

**Genotype:** ________  
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**Genotype:** ________  
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**7 Analyze** What does each compartment of the Punnett square represent? Support your claim with evidence.

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How can a Punnett square be used to make predictions about offspring?

A Punnett square does not tell you what the exact results of a certain cross will be. A Punnett square only helps you find the probability that a certain genotype will occur. **Probability** is the mathematical chance of a specific outcome in relation to the total number of possible outcomes.

Probability can be expressed in the form of a ratio (RAY•shee•oh), an expression that compares two quantities. A ratio written as 1:4 is read as “one to four.” The ratios obtained from a Punnett square tell you the probability that any one offspring will get certain alleles. Another way of expressing probability is as a **percentage**. A percentage states the number of times a certain outcome might happen out of a hundred chances.

**Do the Math**  
Sample Problem

In guinea pigs, the dominant $B$ allele is responsible for black fur, while the recessive $b$ allele is responsible for brown fur. Use the Punnett square to find the probability of this cross resulting in offspring with brown fur.

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<td>$b$</td>
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1. **Identify**
   - **A.** What do you know?
     - Parent genotypes are $Bb$ and $bb$. Possible offspring genotypes are $Bb$ and $bb$.
   - **B.** What do you want to find out?
     - Probability of the cross resulting in offspring with brown fur

2. **Plan**
   - **C.** Count the total number of offspring allele combinations: 4
   - **D.** Count the number of allele combinations that will result in offspring with brown fur: 2

3. **Solve**
   - **E.** Write the probability of offspring with brown fur as a ratio: 2:4
   - **F.** Rewrite the ratio to express the probability out of 100 offspring by multiplying each side of the ratio by the same number (such as 25): 50:100
   - **G.** Convert the ratio to a percentage: 50%

**Answer:** 50% chance of offspring with brown fur
8 Calculate This Punnett square shows a cross between two $Bb$ guinea pigs. What is the probability of the cross resulting in offspring with black fur?

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Identify

A. What do you know?

B. What do you want to find out?

Plan

C. Count the total number of offspring allele combinations:

D. Count the number of allele combinations that will result in offspring with black fur:

Solve

E. Write the probability of offspring with black fur as a ratio:

F. Rewrite the ratio to express the probability out of 100 offspring by multiplying each side of the ratio by the same number:

G. Convert the ratio to a percentage:

Answer:

Graph

In the cross above, what is the ratio of each of the possible genotypes? Show your results by filling in the pie chart at the right. Fill in the key with color or shading to show which pieces of the chart represent the different genotypes.
How can a pedigree trace a trait through generations?

A pedigree is another tool used to study patterns of inheritance. A **pedigree** traces the occurrence of a trait through generations of a family. Pedigrees can be created to trace any inherited trait—even hair color!

Pedigrees can be useful in tracing a special class of inherited disorders known as **sex-linked disorders**. Sex-linked disorders are associated with an allele on a sex chromosome. Many sex-linked disorders, such as hemophilia and colorblindness, are caused by an allele on the X chromosome. Women have two X chromosomes, so a woman can have one allele for colorblindness without being colorblind. A woman who is heterozygous for this trait is called a **carrier**, because she can carry or pass on the trait to her offspring. Men have just one X chromosome. In men, this single chromosome determines if the trait is present.

The pedigree below traces a disease called **cystic fibrosis**. Cystic fibrosis causes serious lung problems. Carriers of the disease have one recessive allele. They do not have cystic fibrosis, but they are able to pass the recessive allele on to their children. If a child receives a recessive allele from each parent, then the child will have cystic fibrosis. Other genetic conditions follow a similar pattern.

**Pedigree for Cystic Fibrosis**

**Generation**

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**Prep and Visualize**

**11 Analyze** Does anyone in the third generation have cystic fibrosis? Explain.

**12 Calculate** What is the probability that the child of two carriers will have cystic fibrosis?
Why It Matters

Saving the European Mouflon

The European mouflon is an endangered species of sheep. Scientists at the University of Teramo in Italy used genetic tools and techniques to show how the population of mouflon could be preserved.

Maintaining Genetic Diversity

When a very small population of animals interbreeds, there is a greater risk that harmful genetic conditions can appear in the animals. This is one issue that scientists face when trying to preserve endangered species. One way to lower this risk is to be sure that genetically-similar animals do not breed.

Genetics to the Rescue!

Researchers combined the sperm and egg of genetically-dissimilar European mouflons in a laboratory. The resulting embryo was implanted into a mother sheep. By controlling the combination of genetic material, scientists hope to lower the risk of inherited disorders.

Extend

13 Claims • Evidence • Support Why are small populations difficult to preserve? State your claim and explain your reasoning.

14 Research Research another population of animals that has been part of a captive breeding program.

15 Describe Describe these animals and the results of the breeding program by doing one of the following:
- make a poster
- write a short story
- draw a graphic novel
Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. Then use the key below to check your answers. You can use this page to review the main concepts of the lesson.

Punnett squares can be used to make predictions about possible offspring.

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16 A Punnett square shows combinations of different alleles received from each parent.

Pedigrees trace a trait through generations.

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17 An allele responsible for a sex-linked disorder is found on a sex chromosome.

18 Compare How is a heterozygous individual represented in the Punnett square and pedigree shown above?
Lesson Review

**Vocabulary**

Circle the term that best completes the following sentences.

1. A Punnett square / ratio is a tool that can be used to predict the genotypes of potential offspring in a given cross.

2. The results from a Punnett square can be used to find the pedigree / probability that a certain allele combination will occur in offspring.

3. A mathematical expression that compares one number to another is called a pedigree / ratio.

**Key Concepts**

Use this diagram to answer the following questions.

4. Analyze What is gene G responsible for in these fruit flies?

5. Analyze What is the ratio of heterozygous offspring to total offspring in the Punnett square?

6. Define What is a sex-linked disorder?

7. Infer Imagine a pedigree that traces an inherited disorder found in individuals with two recessive alleles for gene D. The pedigree shows three siblings with the genotypes DD, Dd, and dd. Did the parents of these three children have the disorder? Explain your reasoning.

8. Explain A Bb guinea pig crosses with a Bb guinea pig, and four offspring are produced. All of the offspring are black. Explain how this could happen.

9. Synthesize You have developed a pedigree to trace dimples or freckles, a recessive trait, in a friend's family. You have found out which of her family members have dimples or freckles and which do not. After completing this model, what information have you obtained about members of your friend's family that you could not tell just by looking at them?