7.3

Traits and Probability

The color of corn, *Zea mays*, is an inherited trait.

CAN YOU SOLVE IT?

FIGURE 1: A cat breeder crossed an orange female cat with a black male cat.

a Female cat

b Male cat

c Tortoiseshell kitten from the litter

Gather Evidence What can you determine from the fact that only male kittens inherited the mother's phenotype?

Animal breeders select animals to cross based on desired characteristics. Imagine a cat breeder who wants a litter of kittens—half with solid orange fur and half with solid black fur. The breeder decides to cross a female orange cat with a male black cat. The resulting litter has three orange male kittens and three tortoiseshell female kittens. Tortoiseshell is a mixture of orange and black fur. The breeder successfully bred solid orange kittens, but there were no black kittens in the litter.

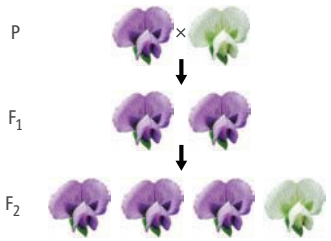
Predict Answer the following questions in your Evidence Notebook:

1. Why was the litter of kittens not half black and half orange?
2. Why were there only female tortoiseshell kittens?

Predicting Generations

Gregor Mendel's trials with purebred white-flowered (*pp*) and purple-flowered (*PP*) pea plants yielded a heterozygous purple (*Pp*) F_1 generation. When the F_1 plants self-pollinated, the white flowers reappeared. The F_2 plants were one-fourth *PP*, one-half *Pp*, and one-fourth *pp*.

FIGURE 2: Purple plants in the F_1 generation self-pollinated to produce the F_2 generation.



Predict If you crossed two plants from the F_2 generation, what procedure would you follow to determine the genotypes of the next generation?

Modeling Genetic Crosses

In the early 1900s, several British scientists expanded upon Mendel's work. One, R. C. Punnett, explored genetic crosses with chickens and other species. The model he developed tracks the alleles each parent can donate to predict the outcome of crosses.

FIGURE 3: The common vizsla has smooth hair, but the wirehaired vizsla has a wiry coat.

a Smooth vizsla

b Wirehaired vizsla

Coat texture in dogs is a heritable characteristic. Some dogs, like the vizsla, can have a smooth coat or a wiry coat, and this trait is controlled by one gene. The wire-coated allele is dominant, noted as *W*, and the smooth-coated allele is recessive, noted as *w*.

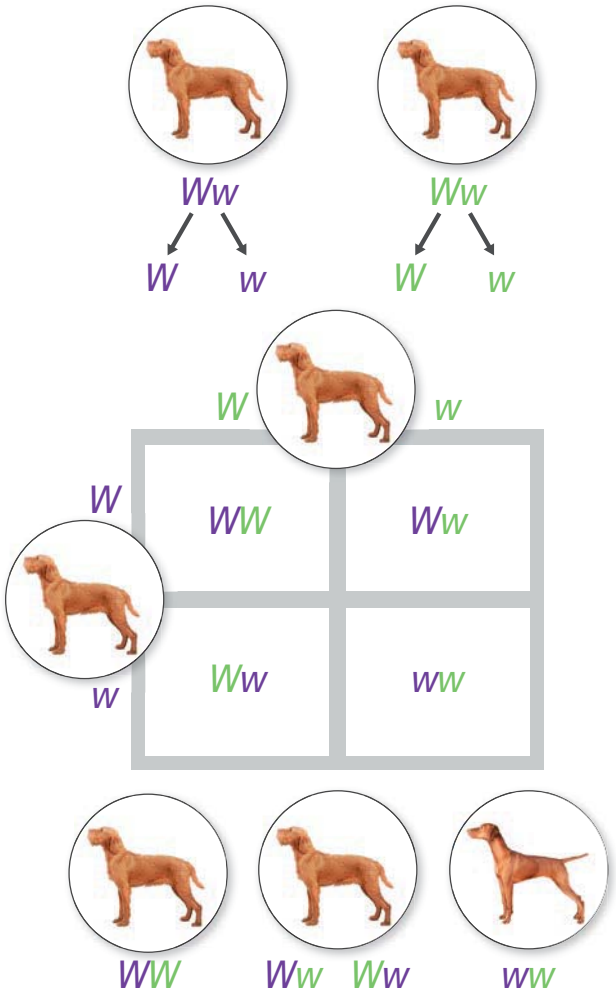
Imagine a dog breeder wants to cross two wirehaired vizslas and that both dogs are heterozygous for the trait. Each parent is heterozygous for the wirehaired trait, so each one has two different alleles for coat texture. The alleles are separated into gametes during meiosis. There are two possible gametes for each parent, one for each allele he or she carries.

Analyze What alleles can each heterozygous vizsla parent pass on in his or her gametes?

The genotype of an organism indicates which alleles the organism carries for a certain characteristic. Each gamete contains one allele for each trait in an organism's DNA. Punnett recognized a relationship between parental gametes and the genotypes of offspring. He used this relationship to develop a simple table, now known as a Punnett square, that predicts all possible offspring genotypes resulting from a specific cross. This model is a quick and easy way to determine the probable outcome of a cross.

FIGURE 4: A Punnett square is used to model the cross between two parents with known genotypes.

Explore Online



A model for the cross between two heterozygous, wirehaired vizslas is shown in Figure 4. Because each parent donates one gamete to each offspring, gametes will have either a dominant, wire-coated allele (*W*) or a recessive, smooth-coated allele (*w*).

To complete a Punnett square, divide a square into four equal sections. Write the alleles of each parent on the outside of the square, one set above the columns and one set to the left of the rows. Write the dominant allele first.

Next fill in each box in the Punnett square with the parent allele from the top of the column and the parent allele from the beginning of the row. When complete, each box will contain one allele from each parent.

The completed Punnett square shows three possible genotypes for coat type: homozygous dominant (*WW*), heterozygous (*Ww)*, or homozygous recessive *(ww*). From these genotypes, we can predict that there is a one in four chance that the *WW* genotype will occur. There is a two in four chance that the *Ww* genotype will occur. Finally, there is a one in four chance that the *ww* genotype will occur.

In this cross, both the homozygous dominant and heterozygous genotypes will have wire coats. Only the homozygous recessive genotype will have a smooth coat.

Math Connection The wire-coated allele (*W*) is dominant to the smooth-coated allele (*w*). Use the Punnett square to answer the following questions:

1. What percentage of puppies will have the same genotype as the parents, *Ww*?
2. What percentage of puppies will have the wire-coat phenotype?
3. What percentage of puppies will have the smooth-coat phenotype?

A Punnett square models complex processes by focusing on desired traits rather than a genome. Pulling the letters that represent the parental genotype apart and placing them along the outside of the Punnett square shows the segregation of homologous chromosomes and possibly different alleles during meiosis. Each gamete contains only one version of the gene, and there is an equal opportunity for a gamete to contain either allele.

The assignment of alleles to the empty boxes models fertilization. Just as haploid gametes join to make a diploid zygote, the parental alleles join to make letter pairs in the Punnett square. The letter pairs represent potential offspring genotypes. This is the real value of a Punnett square. Modeling these processes makes it possible to predict the genotypes of offspring from a specific cross.

Analyze What do the letters on the top and side of a Punnett square represent?

Calculating Probabilities

Scientists use a branch of mathematics called *probability* to determine the likelihood that offspring will be born with certain characteristics. Probability is the chance that an outcome will occur, such as the birth of a dog with a wire coat. The probability of an event occurring can be determined using the following equation:

$$\text{probability} = \frac{\text{number of ways a specific event can occur}}{\text{number of total possible outcomes}}$$

An easy way to explore probability is by flipping a coin. Each flip has two possible outcomes: the coin either lands heads up or it lands tails up. The probability of the coin landing heads up is one out of two, or $\frac{1}{2}$. The probability of the coin landing tails up is also one out of two, or $\frac{1}{2}$. Probability is usually expressed on a scale of 0 to 1, with 0 being an impossible outcome and 1 being a certain outcome.

Now, consider what happens when you flip two coins at the same time, as shown in Figure 5. The results of the two flips are independent, so the result of one coin flip does not impact the result of the other. Both coins are free to land heads up or tails up. Calculate the probability of two independent events occurring together by multiplying the probability of the individual events. The probability of flipping heads is $\frac{1}{2}$. Therefore, the probability of flipping two heads together is $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$.

FIGURE 5: A Punnett square reflects the probability of two independent events occurring at the same time.

Probabilities are averages, not exact numbers. If you flip a coin twice, you will not always get one heads and one tails. You may get two heads or two tails. The more you repeat an event, the closer you will get to the average described by probability.

Math Connection Determine each of the following probabilities using Figure 4.

1. What is the probability of a *Ww* genotype? Of a *WW* genotype?
2. What is the probability of a puppy with a smooth coat being born?

In the cross modeled in Figure 4, what events would have to occur to produce a heterozygous puppy? The father could donate the dominant allele (*W*) and the mother could donate the recessive allele (*w*). The reverse could also occur. Both of these events would produce a heterozygous puppy, and both are equally likely to occur.

The probability of an event that can occur in more than one way is equal to the probability of the individual events added together. So, the probability of a sperm with a dominant allele fertilizing an egg with a recessive allele is $\frac{1}{4}$. The probability of a sperm with a recessive allele fertilizing an egg with a dominant allele is also $\frac{1}{4}$. Therefore, the probability of producing a heterozygote can be calculated as $\frac{1}{4} + \frac{1}{4} = \frac{1}{2}$. In other words, there is a one in two chance that a puppy will be born that is heterozygous (*Ww*) for a wire coat.

Patterns

The pattern of inheritance observed in sexually reproducing organisms is explained by chance. This makes probabilities particularly useful for analyzing some of the mathematics behind inheritance.

Explain How can a Punnett square help you explain the phenotypes of the kittens discussed at the beginning of this lesson? Use your knowledge of meiosis to help support your answer.

Determining Types of Crosses

FIGURE 6: A Curly Bashkir Horse

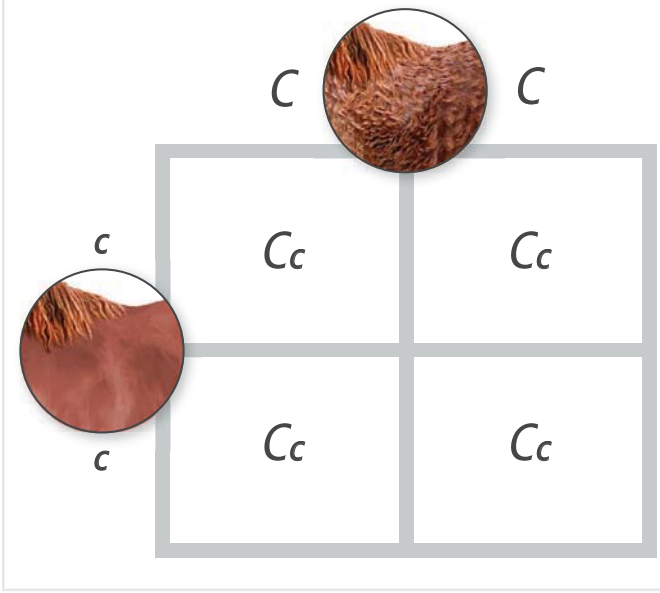
In most horse breeds, a smooth coat is dominant to a curly coat. The recessive allele is responsible for naturally curly coats that occasionally appear in some horse breeds. Because the gene is recessive, these occurrences are rare. In a few horse breeds, such as the Bashkir horse, the curly-coat allele, *C*, is dominant and the the smooth-coat allele, *c*, is recessive.

Predict Imagine you crossed a smooth-coated Bashkir horse with a curly-coated Bashkir horse. How could you determine the possible outcomes of this cross?

Analyzing the Inheritance of One Trait

All of the genetic crosses discussed so far have involved one trait, from flower color in pea plants to coat texture in dogs. A cross that examines one trait is a monohybrid cross. There are three basic types of monohybrid crosses: a homozygous-homozygous cross, a heterozygous-heterozygous cross, and a heterozygous-homozygous cross.

FIGURE 7: Homozygous-Homozygous Cross



Homozygous-Homozygous Cross

A homozygous-homozygous cross occurs when a homozygous dominant parent crosses with a homozygous recessive parent. Imagine that a Bashkir horse that is homozygous dominant for curly hair (*CC*) is crossed with a Bashkir horse that is homozygous recessive for smooth hair (*cc*).

The Punnett square in Figure 7 models the possible outcomes of the cross. As shown, a homozygous-homozygous cross always results in heterozygous offspring because one parent can donate only dominant alleles and the other can donate only recessive alleles. The sole possible outcome of the cross is one dominant allele and one recessive allele, which is a heterozygous combination. For the cross shown in Figure 7, all of the offspring would have the heterozygous genotype, *Cc*. They would have curly coats because the dominant curly-coat allele, *C*, is present in all genotypes. Each offspring would also carry the recessive smooth-coat allele, *c*.

Math Connection Probability is measured on a scale from 0 to 1. For a homozygous-homozygous cross, determine the following probabilities:

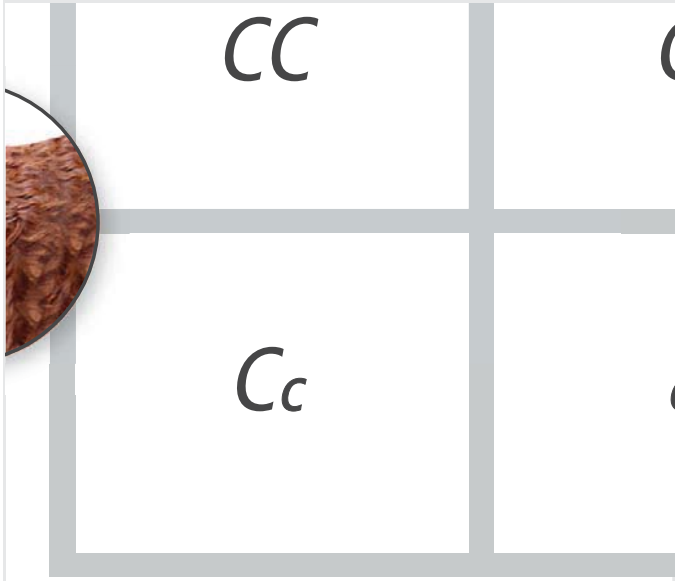
1. Probability of homozygous recessive offspring
2. Probability of homozygous dominant offspring
3. Probability of heterozygous offspring

Heterozygous-Heterozygous Cross

Imagine you wish to cross two curly-coated, heterozygous Bashkir horses. Each horse has the genotype *Cc* and can pass on either the dominant allele for curly hair or the recessive allele for smooth hair. The probability of each parent donating a dominant allele to the offspring is $\frac{1}{2}$. The probability of each parent donating a recessive allele to the offspring is also $\frac{1}{2}$.

Figure 8 shows the Punnett square for this heterozygous-heterozygous cross. From each parent, half the offspring receive a dominant allele (*C*) and half receive a recessive allele (*c*).

FIGURE 8: Heterozygous-Heterozygous Cross



Math Connection In the heterozygous-heterozygous cross modeled in Figure 8, what is the probability of offspring with homozygous dominant, heterozygous, or homozygous recessive genotypes?

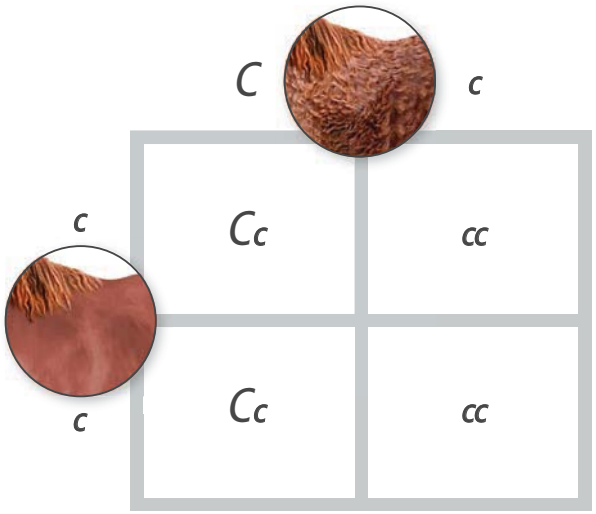
This type of cross for a single trait always results in a genotypic ratio of 1:2:1. This means that $\frac{1}{4}$ of offspring will have the homozygous dominant genotype, $\frac{2}{4}$ will have the heterozygous genotype, and $\frac{1}{4}$ will have the homozygous recessive genotype.The phenotypic ratio is 3:1 of dominant:recessive phenotypes. In other words, of the potential offspring phenotypes, $\frac{3}{4}$ will have the dominant phenotype and $\frac{1}{4}$ will have the recessive phenotype.

Heterozygous-Homozygous Cross

Now, imagine a heterozygous-homozygous cross between a heterozygous Bashkir horse with curly hair (*Cc*) and a homozygous recessive Bashkir horse with smooth hair (*cc*). From the homozygous parent, the offspring receive a recessive allele, *c*. From the heterozygous parent, half the offspring receive a dominant allele, *C*, and half receive a recessive allele, *c*.

Figure 9 shows the Punnett square for this heterozygous-homozygous cross. This cross results in two offspring with the genotype *Cc* and two offspring with the genotype *cc*.

FIGURE 9: Heterozygous-Homozygous Cross



Math Connection What is the probability the offspring in this cross will have a heterozygous genotype? What about a homozygous-recessive genotype?

A heterozygous-homozygous cross always produces parental genotypes in a 1:1 genotypic ratio. For the cross in Figure 9, the probability of offspring with the heterozygous genotype and the probability of offspring with the homozygous recessive genotype are both $\frac{1}{2}$. The phenotypic ratio in this instance is also 1:1, because the probability that each coat type will occur is $\frac{1}{2}$. So, in this cross, half of the offspring will have curly coats and half will have smooth coats.

Analyze In your Evidence Notebook, complete a cross between a heterozygous horse (*Cc*) and a homozygous-dominant horse (*CC*). Were your results the same?

Hands-On Activity

Determining a Genotype

FIGURE 10: Peaches and nectarines are the same species, *Prunus persica*.

MATERIALS

- paper
- pencil

Peaches have fuzzy skin. A nectarine is a variety of smooth-skinned peach. A dominant allele, *G*, causes fuzzy skin. All peaches have at least one copy of this allele. Nectarines come from trees that are homozygous recessive (*gg*) for fuzz.

Imagine your company sells peach and nectarine seedlings. You developed a new type of peach tree that is very popular. To meet demand, you must learn the genotypes of your breeding stock. You determine them by setting up a testcross between an individual that has a dominant phenotype but an unknown genotype and an individual that is homozygous recessive.

Predict How can a testcross help you find the unknown genotype of the plant?

PROCEDURE

1. Plant A produces peaches. You need to determine its genotype. Plant B produces nectarines that have smooth skin and a known genotype of *gg*. You cross Plant A with Plant B.
3. The resulting cross yields twelve plants. Six plants produce peaches upon the first fruiting and six plants produce nectarines upon the first fruiting.
4. Use Punnett squares to determine the genotype of Plant A.

ANALYZE

Answer the following questions in your Evidence Notebook:

1. What is the genotype of Plant A? Explain how you arrived at your answer.
2. Plant A is crossed with a plant that has a genotype of *GG*. What are the possible genotypes and phenotypes of the offspring?
3. Plant A is crossed with a plant that has a genotype of *Gg*. What is the ratio of dominant to recessive phenotypes of the offspring?
4. In terms of genotype, is Plant A the best plant to produce as many peach seedlings as possible? Why or why not? Which genotype would be best?

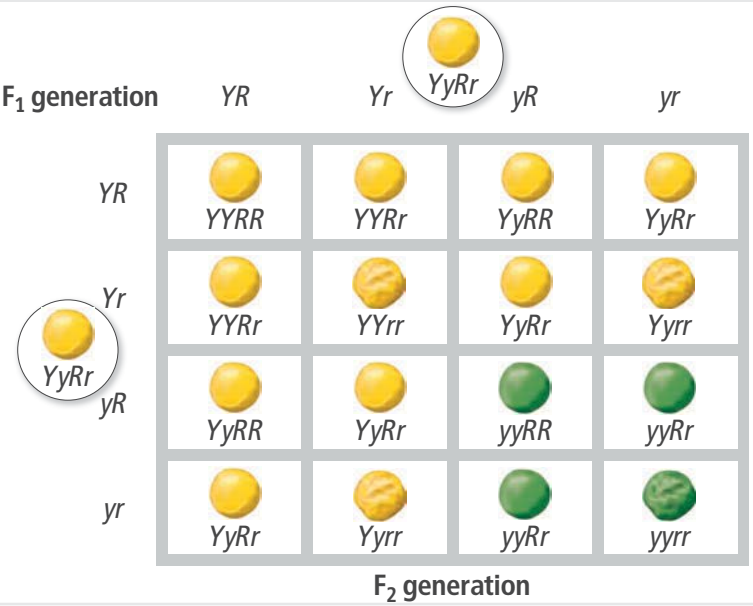
Image Credits: Georgia Department of Economic Development

Analyzing the Inheritance of Two Traits

A dihybrid cross examines the inheritance of two traits. Consider the peas shown in Figure 11, which can be yellow or green and round or wrinkled. The yellow allele, *Y*, is dominant to the green allele, *y*. The round allele, *R*, is dominant to the wrinkled allele, *r*. Figure 12 shows a cross between two heterozygous plants (*YyRr*). Each gamete receives one allele for pea color and one allele for pea shape. Each pea color allele has an equal probability of being paired with each pea shape allele. There are four possible combinations of alleles in heterozygous dihybrid gametes. The probability of producing any of the four gametes is one out of four.

FIGURE 11: Phenotypes of Peas

FIGURE 12: A dihybrid cross between two heterozygous pea plants.



Gather Evidence Determine the number of possible phenotypes in the dihybrid cross. What is the ratio for all the possibilities?

Math Connection Use the Punnett square to answer the following questions:

1. What is the probability that the cross will produce a plant that is heterozygous for both traits? What is the probability of producing a plant with yellow and round peas? Why are these two probabilities different?
2. Make a Punnett square for the dihybrid cross *YyRr* and *yyrr*. How are the probabilities of this cross different from those in Question 1?

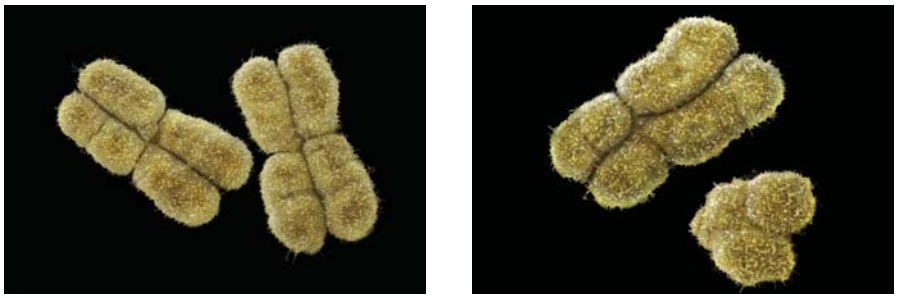
In this cross, the chance of producing offspring that exhibit both dominant traits (yellow and round) is $\frac{9}{16}$. The chance of producing offspring that exhibit one dominant trait and one recessive trait (yellow and wrinkled or green and round) is $\frac{3}{16}$. Finally, the chance of producing offspring that exhibit both recessive traits (green and wrinkled) is $\frac{1}{16}$. Using Figure 12, you can see these possibilities. There are nine yellow and round peas, three yellow and wrinkled peas, three green and round peas, and one green and wrinkled pea. Therefore, a heterozygous-heterozygous dihybrid cross results in a phenotypic ratio of 9:3:3:1.

Explain Why are Punnett squares a useful model for scientists studying traits and genetic disorders? In which other types of careers would this model be useful?

Sex-Linked Inheritance

Human offspring have an equal probability of being male (XY) or female (XX). The mother donates an X chromosome, so the chromosome donated by the father is the one that determines the sex of the offspring. The father could donate either an X chromosome, in which case the child would be female, or a Y chromosome, in which case the child would be male, as shown in Figure 13. The probability of either occurrence is $\frac{1}{2}$.

FIGURE 13: Females donate an X chromosome to offspring while males can donate either an X or a Y chromosome.



a Female Sex Chromosomes

b Male Sex Chromosomes

Predict How would the inherited traits discussed in this lesson be influenced if those alleles were on a sex chromosome? Would the probability of inheritance change?

Expressing Sex-Linked Traits

Genes located on sex chromosomes are sex-linked genes. These genes follow a pattern of inheritance called *sex-linked inheritance* and are not always connected to sexual characteristics. All other genes occur on autosomes, or non-sex chromosomes, and follow autosomal inheritance patterns. Few genes appear on both the X and Y chromosome, so males, with only one X chromosome, often express X-linked genes.

To prevent the double expression of sex-linked traits in females, female embryos go through the process of X inactivation. During this process, one X chromosome in each cell randomly becomes inactive very early in development. All descendants of these early cells have the same inactive X. This process does not impact the phenotype of homozygous females because both of their X chromosomes have the same allele. Heterozygous females can be impacted by X inactivation, depending upon the genes involved.

Analyze Imagine an X-linked recessive disease. X^A represents the dominant allele and X^a represents the recessive allele. What are the different kinds of gametes a heterozygous female and a male with a dominant allele can produce?

Explore Online

Hands-On Lab

Sex-Linked Inheritance Use a model to determine the pattern of inheritance for sex-linked traits.

Analyzing the Inheritance of Sex-Linked Traits

Cone cells in the human eye have color-sensing molecules called *photopigments* that normally respond to either red, blue, or green light. The most common type of color blindness, red-green color blindness, involves abnormalities in the photopigments in green or red cone cells. The genes responsible for red-green color blindness are located on the X chromosome, so red-green color blindness is a sex-linked trait.

Gather Evidence Which genotypes for males and females result in normal vision and which result in color blindness?

The dominant allele that produces normal vision is represented by the *C* superscript (X^C). The recessive allele that is responsible for red-green color blindness is represented by the *c* superscript (X^c). For heterozygous females, the presence of one dominant allele is enough to overcome the expression of the recessive allele.

When using a Punnett square to perform a sex-linked cross, place the female chromosomes at the top of the square and the male chromosomes to the left of the square. Sex-linked crosses track sex chromosomes *and* the trait of interest simultaneously. These characters are linked and therefore always appear together as a capital letter for the sex chromosome and a superscript for the trait of interest.

Math Connection Using the Punnett square in Figure 14, determine the probabilities that a couple will have a colorblind child, a colorblind son, or a colorblind daughter.

FIGURE 14: A cross between a female heterozygous for red-green color blindness and a male with normal vision.

	X^C	X^c
X^C	X^CX^C	X^CX^c
Y	X^CY	X^cY

Most sex-linked traits occur on the X chromosome. Thus, sex-linked inheritance patterns are mostly due to differences in expression of the X chromosome. An affected male offspring requires only a single recessive allele, while an affected female requires two recessive alleles. This decreases the likelihood that a female will be homozygous recessive. She is more likely to be a heterozygous carrier of the recessive trait.

Sex-linked crosses are similar to monohybrid crosses, but there is a key difference—the trait and the sex chromosome are inherited as one unit and cannot be separated. So, in a male unaffected by a sex-linked condition with genotype X^CY, the normal allele, *C*, and the X chromosome are always inherited together.

Engineering

For those affected by or are carriers of a heritable disorder, the decision of whether to have children can be monumental. Genetic counseling helps inform this decision by predicting the likelihood that a particular couple will have a child with an inherited disease. Genetic counselors use Mendelian genetics, pedigrees, and genetic tests to model the potential outcomes for prospective parents.

Explain How do the genotypic and phenotypic ratios of the sex-linked traits differ from those of a monohybrid cross?

Data Analysis

Pedigrees

Long before DNA testing made it possible to determine genotypes analytically, scientists constructed pedigrees to study inheritance patterns. A pedigree is a family tree that tracks a trait through multiple generations.

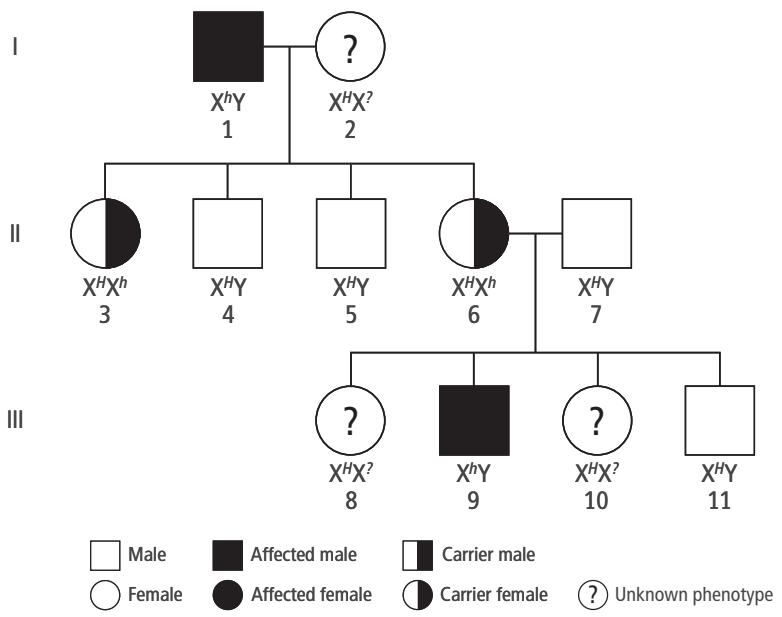
The inheritance pattern of hemophilia can be determined by analyzing a pedigree. Hemophilia is a sex-linked disorder that causes uncontrolled bleeding because the body fails to make one or more clotting factors. It can be fatal if untreated.

Pedigrees are built using symbols to represent relationships between individuals. Figure 15 is a pedigree following hemophilia through three generations. Males are represented by squares and females are represented by circles. A direct line between two individuals indicates a relationship. Siblings are listed from left to right in order from oldest to youngest, connected by a sibling relationship line. Parents and offspring are connected by a line of descent.

Fully shaded shapes represent individuals who are affected by the trait of interest—hemophilia. Affected males must have the hemophilia allele on the X chromosome, represented by X^h. Unaffected males must have a normal allele at this location, represented by X^H.

Half-shaded shapes represent carriers. No females in the second generation have hemophilia. Therefore, they all must have at least one normal allele for this gene. Also, their father can only pass along the hemophilia allele to his daughters. Therefore, all daughters in the second generation are heterozygous for this condition, X^HX^h. These females are carriers of the hemophilia gene.

FIGURE 15: A pedigree tracing hemophilia through three generations.



It is impossible to determine the genotype of Female 2. She may be a carrier for hemophilia who passed along a normal allele to all of her children. Or she could be homozygous dominant for this gene. This unknown allele on the X chromosome is represented by $X^?$.

It is also impossible to determine the genotypes of Females 8 and 10. The father can donate only a dominant allele. The mother can donate either a dominant or a recessive allele. Therefore, the daughters are either homozygous dominant or heterozygous at this location. Again, the unknown allele on the X chromosome is represented by $X^?$.

Data Analysis Use the pedigree to answer the following questions.

1. Is hemophilia a dominant or recessive trait? Use evidence to support your claim.
2. In the second generation, how many females are carriers of the gene? What is their genotype?
3. Imagine Male 9 married a female carrier. What is the probability that they will produce a female child with hemophilia? A child who does not have hemophilia? A child who has the parental phenotypes? Use evidence to support your answers.

PRACTICING GENETIC CROSSES | MODELING MONOHYBRID & DIHYBRID CROSSES | ANIMAL BREEDING | Go online to choose one of these other paths.

Lesson Self-Check

CAN YOU SOLVE IT?

FIGURE 16: Kittens with tortoiseshell fur resulted from crossing an orange cat with a black cat.

a Female cat

b Male cat

c Tortoiseshell kitten from the litter

Recall the cat breeder from the beginning of the lesson. The breeder hoped to produce a litter of kittens in which half the kittens were orange and half were black. To achieve this, the breeder crossed an orange female cat with a black male cat. When the kittens were born, three were male and three were female. As expected, half the kittens had orange fur. However, the remaining kittens had a mixture of orange and black fur called *tortoiseshell*. To complicate things further, the orange kittens were all males and the tortoiseshell kittens were all females.

Explain Refer to the notes in your Evidence Notebook to answer the following questions:

1. Why was the litter of kittens not half black and half orange?
2. Why were there only female tortoiseshell kittens?
3. Which alleles were passed on by each parent cat in this cross? Which alleles did the male offspring receive? Which alleles did the female offspring receive?

Tortoiseshell coloring in cats is usually expressed only in females. This tells us that the gene controlling black and orange color is located on the X chromosome. Males have one X chromosome with either an allele for orange fur (X^B) or one for black fur (X^b). This gives two possible genotypes for males: X^BY or X^bY. Because males have only one version of the allele, they will always express that allele. Females, however, have two X chromosomes. Thus, they can be homozygous for orange fur (X^BX^B), homozygous for black fur (X^bX^b), or heterozygous (X^BX^b).

Remember, in females one X chromosome in each cell is inactive. X inactivation does not impact homozygous females (X^BX^B and X^bX^b) because the same allele is expressed regardless of which X chromosome is active. X inactivation impacts heterozygous females (X^BX^b) because it is random. The color expressed by each cell depends on which of the two chromosomes is active. Black fur occurs on skin patches that have an inactive X^B allele. Orange fur occurs where the X^b allele is inactive. The patches of color occur randomly, giving these females their characteristic mosaic tortoiseshell pattern.

CHECKPOINTS

Check Your Understanding

Use the following information to answer Questions 1–3.

Two heterozygous, wirehaired vizslas were crossed. The genotypes of their potential offspring are shown in the Punnett square in Figure 17.

FIGURE 17: Heterozygous-Heterozygous Cross

	W	*w*
W	*WW*	*Ww*
w	*Ww*	*ww*

1. What is the phenotypic ratio of wire-coated to smooth-coated offspring?

2. What is the genotypic ratio of homozygous dominant to heterozygous to homozygous recessive offspring?

3. What genotype has a 100% chance of expressing a recessive allele?

Use the following information to answer Questions 4 and 5.

Duchenne muscular dystrophy is an X-linked recessive disease that causes degeneration and weakness in muscles. The normal condition is represented by the superscript *D,* and the allele that causes Duchenne muscular dystrophy is represented by the superscript *d*.

4. Draw a Punnett square to show a cross between a homozygous-dominant female and a male with Duchenne muscular dystrophy.

5. Which combination of parental genotypes is most likely to result in carrier daughters?

Use the following information and the Punnett square in Figure 18 to answer Questions 6–8.

The trait for purple flowers in pea plants (*P*) is dominant to the trait for white flowers (*p*).

FIGURE 18: Heterozygous-Homozygous Recessive Cross

	P	*p*
p	*Pp*	*pp*
p	*Pp*	*pp*

6. What is the probability that the heterozygous parent will donate a recessive *p* allele?

7. What is the probability that the homozygous-recessive parent will donate a recessive *p* allele?

8. What is the probability of both parents donating a recessive *p* allele?

9. Why is the known genotype in a testcross always homozygous recessive? Provide an example to support your claim.

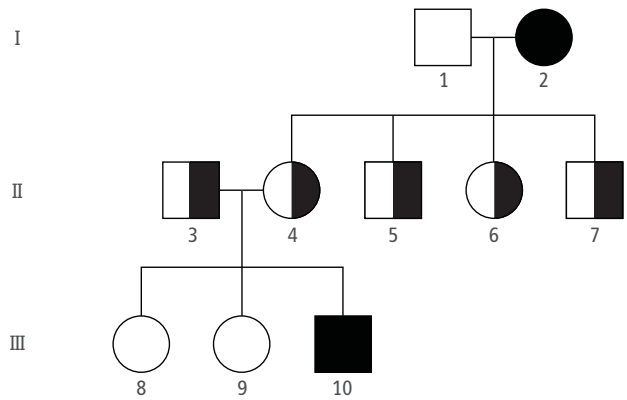
10. For each pair, calculate the probability of producing a homozygous recessive genotype. Then place the pairs in order of increasing probability.
    a. $Aa \times aa$
    b. $aa \times aa$
    c. $Aa \times Aa$

11. Parents of genotype *AABB* and *aabb* were crossed and produced all heterozygotes with the genotype *AaBb*. Heterozygotes from the F_1 generation were crossed and produced a phenotypic ratio of 9:3:3:1. How does this sequence of events support the law of independent assortment?

Use the following information and the pedigree in Figure 19 to answer Questions 12–14.

This simple pedigree traces an autosomal-recessive disorder across three generations. This disorder is not sex-linked and follows Mendelian patterns of inheritance. The dominant allele is *A,* and the recessive allele that causes the disorder is *a*.

FIGURE 19: Autosomal-Recessive Pedigree



12. The four siblings in the second generation have the same genotype. What is it?

13. What is the most likely genotype of the father in the first generation?

14. What is the genotype of both affected individuals?

15. Imagine a plant can have striped flower petals or solid flower petals. Solid coloring (*Z*) is dominant to stripes (*z*). Which parental cross would yield the following ratio of offspring: 1 homozygous dominant (*ZZ*): 2 heterozygotes (*Zz*): 1 homozygous recessive (*zz*)?

a. homozygous dominant–homozygous recessive

b. homozygous dominant–homozygous dominant

c. homozygous dominant–heterozygous

d. heterozygous-heterozygous

Use following information to answer Questions 16–18. Make a Punnett square for each cross to support your answers.

In pea plants, yellow seed color (*Y*) is dominant to green seed color (*y*); round seeds (*R*) are dominant to wrinkled seeds (*r*).

16. What is the probability that parents with the genotypes *YyRR* and *YYRR* will produce an offspring with the genotype *YYRR*?

17. What is the probability that parents with the genotypes *yyrr* and *YyRr* will produce offspring with the genotype *yyrr*?

18. What is the probability that parents with the genotypes *YYRR* and *yyrr* will produce offspring with the genotype *YyRr*?

MAKE YOUR OWN STUDY GUIDE

In your Evidence Notebook, design a study guide that supports the main ideas from this lesson:

The expression of genes determines an organism's phenotype.

Punnett squares can be used to determine the probability of offspring expressing certain traits.

If genes are sex-linked, males will express the allele found on the X chromosome while females express the allele on the active X chromosome. If the gene is located on the Y chromosome, it is expressed only in males.

Remember to include the following information in your study guide:

- Use examples that model main ideas.
- Record explanations for the phenomena you investigated.
- Use evidence to support your explanations. Your support can include drawings, data, graphs, laboratory conclusions, and other evidence recorded throughout the lesson.

There is a cause-and-effect relationship between an organism's DNA and its phenotype. Consider other cause-and-effect relationships, such as the effect a parent's DNA has on offspring.