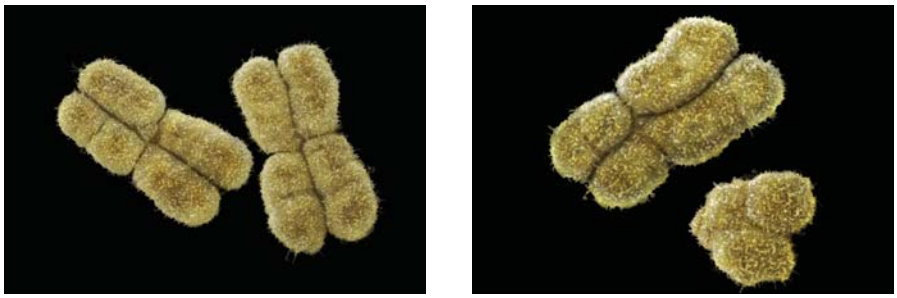
Sex-Linked Inheritance

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?