Reflect

In a monastery garden, a curious monk discovered some of the basic principles of genetics. The monk, Gregor Mendel (1822–1884), laid the groundwork for the study of **genetics**, which has advanced our understanding of many related areas of science, including the genetics of certain diseases and the process of selective breeding. Scientists have built upon the discoveries of Mendel, answering such important questions as why organisms look and act the way they do.

genetics: the study of how traits are passed from parents to offspring

Why do offspring resemble their parents? What role can technology play in genetics? Let's explore the answers to these questions.

Genotypes, Phenotypes, and Punnett Squares

An organism's traits can be predicted based on its parents' traits. Mendel conducted breeding experiments with pea plants and concluded that some characters were determined by two factors. For example, the peas he worked with had either a smooth or wrinkled texture. These different values for the texture character are called traits. Traits are determined by alleles, which are different versions of a gene. Offspring inherit one allele from each parent in sexual reproduction. The combination of the two alleles is the offspring's *genotype*, which determines the trait the organism will have for a character.

In Mendelian genetics, two letters, such as *Ss* (one letter for each allele), represent genotypes. A capital letter means the allele is **dominant**. A lowercase letter means the allele is **recessive**. One possible genotype for the texture of the peas in Mendel's breeding experiments was *Ss*, meaning that the offspring could have inherited one dominant allele and one recessive allele. Smooth texture (*S*) is dominant and wrinkled texture (*s*) is recessive. A pea plant with the genotype *Ss* has smooth peas because the dominant allele masks the recessive one. The smooth texture is the phenotype. The **phenotype** is the physical expression of the alleles. It is the outward appearance of the genotype. Therefore, a pea with a genotype *SS* will also have smooth peas, but a pea with the genotype *ss* will express the recessive trait, wrinkled peas.

When the genotypes of both parents are known, it is possible to predict the genotypes and resulting phenotypes of the offspring. A **Punnett square**, named after Professor Reginald C. Punnett (1875–1967), is used to find and analyze the possible gene combinations of the offspring.

Reflect

The Punnett square on the right shows a **monohybrid** cross for a single trait represented by a blue *A* for the dominant allele and a purple *a* for the recessive allele. In this monohybrid cross, the parents have one of each allele for the trait, allowing us to examine all possible combinations of the alleles. Therefore, the parents are both **heterozygous**, meaning that each parent has two different forms of an allele for a particular trait. Their genotypes are written across the top and down the side of the Punnett square. The genotypes inside the squares represent the possible allele combinations for the offspring. Notice that two possible genotypes in the offspring are **homozygous**, meaning that they have two of the same forms of an allele for a particular trait: *AA* and *aa*.

	A	a
A	AA	Aa
a	Aa	aa

In this Punnett square, the offspring have a 75% chance (3 out of 4) of expressing the dominant trait and a 25% chance (1 out of 4) of expressing the recessive trait.

Mendelian genetic crosses include **dihybrid** crosses as well, which examine the possible inheritance of two specific sets of alleles. The Punnett square below shows the possible genotypes and their frequencies for a trait represented by the letter *A* (*a* for the recessive form) and a trait represented by the letter *B* (*b* for the recessive form).

	AB	Ab	aB	ab
AB	AABB	AAbB	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

What Do You Think?

For the dihybrid cross on the previous page, calculate the frequency of each phenotype. For example, combinations containing at least one *A* and one *B* appear 9 out of 16 times, giving offspring a 56% probability of expressing both dominant traits. What is the probability of the offspring expressing both recessive traits?

Non-Mendelian Genetic Crosses

Geneticists soon discovered that some traits do not follow Mendel's patterns of inheritance. These **non-Mendelian traits** include phenotypes that are coded by multiple alleles or do not follow the normal rules of dominance. Some alleles display **co-dominance** in which a heterozygous genotype results in both traits being expressed in the phenotype. Erminette chicken feathers display co-dominance. A chicken that has one allele for black feathers and another allele for white feathers displays both black and white feathers.

Another type of non-Mendelian genetics is **incomplete dominance**. In this case, a heterozygous genotype results in a blend of both traits. For example, a certain breed of snapdragon plant produces white flowers and red flowers. When they are crossed, a heterozygous offspring is produced with a third phenotype: pink flowers. Incomplete dominance can be a desired outcome when breeding plants and animals for the purpose of obtaining a blend of desired traits.

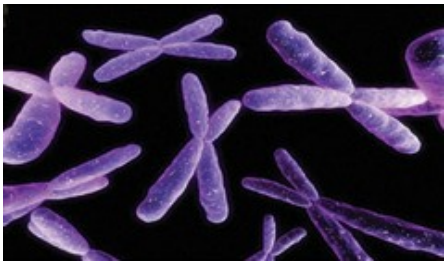
Look Out!

Other influences on gene expression could be in the environment an organism exist or develops, such as hormones, metabolism, and temperature. Case studies show that the presence or absence of particular drugs or chemicals in a developing embryo's environment can affect the number of eyes developed by certain fish. Temperature can have a direct effect on the color of rabbit fur, as another example of environmental influences on gene expression.

Try Now

What Do You Know?

Genetic outcomes are the result of combining chromosomes from two different parents who reproduce sexually. The processes that take place during meiosis help contribute to genetic variation among offspring. Use what you have learned about genetic outcomes and Punnett squares to solve the following mystery.



A newborn child was brought to the hospital nursery before he was marked with his parents' names. The hospital workers must use what they know about genetic outcomes to determine to whom the child belongs. They use his traits in this process. The baby has freckles (*F* dominant) and attached earlobes (*l* recessive). They believe that the baby most likely belongs to a couple in which the man has attached earlobes, but no freckles. It is known that the woman is heterozygous for freckles and earlobe type.

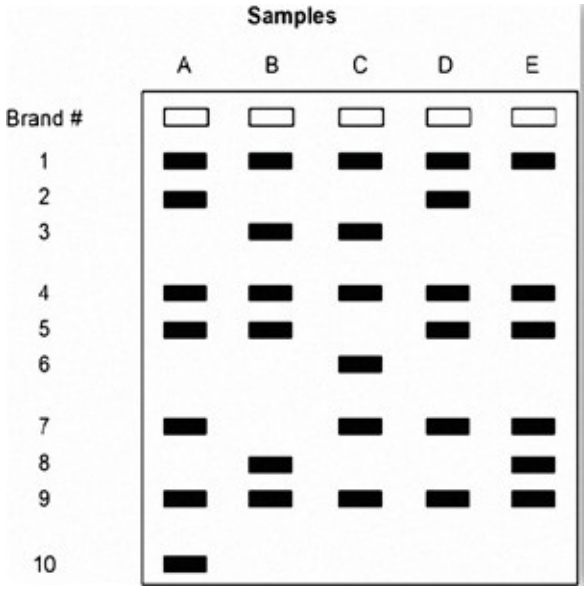
Complete the Punnett square on the next page to determine the probability that the child belongs to this couple. List the possible combinations of the father's alleles across the top and the possible combinations of the woman's alleles down the left side. Then write your answer in the space below. Include a brief statement that explains how you reached your answer.

Write your answer in the chart below.

	fl	**fl**	**fl**	**fl**
FL				
F l				
f L				
fl				

Try Now

To be more certain, the hospital workers performed a gel electrophoresis to compare the DNA from four fathers against the baby's DNA, shown in column A in the picture below. The results are shown below with the four fathers' DNA, labeled B, C, D, and E. According to the data in the gel, which sample most likely belongs to the baby's father? Write your answer in the space provided and include an explanation.



Connecting With Your Child

Studying a Genetic Disease

To help your child learn more about genetic outcomes, have him or her create an informational brochure about a genetic disease.

Begin by conducting online research to find a list of commonly known genetic diseases and have your child choose one of them to research further. Instruct your child to gather specific information about the disease, such as its symptoms, treatment and management, potential cures, and the type of chromosomal abnormality that causes the disease.

Have your child organize the information in a colorful trifold brochure that might be distributed in a doctor's office or by a health organization. Make sure two Punnett squares are included in the brochure to illustrate the chances that a child will inherit the disease if one parent carries the disease and if both parents carry the disease.

Here are some questions to discuss with child:

- What causes the disease in your brochure?
- How can doctors use what they know about the disease to counsel couples that want to have children, knowing that one or both of them carry an allele for the disease?
- What technologies are under development regarding the treatments and/or cures for the disease?