

Genetics

AS YOU READ

What You'll Learn

- Explain how traits are inherited.
- Identify Mendel's role in the history of genetics.
- Use a Punnett square to predict the results of crosses.
- Compare and contrast the difference between an individual's genotype and phenotype.

Why It's Important

Heredity and genetics help explain why people are different.

Review Vocabulary

meiosis: reproductive process that produces four haploid sex cells from one diploid cell

New Vocabulary

- heredity
- Punnett square
- allele
- genotype
- phenotype
- hybrid
- homozygous
- dominant
- heterozygous
- recessive

Inheriting Traits

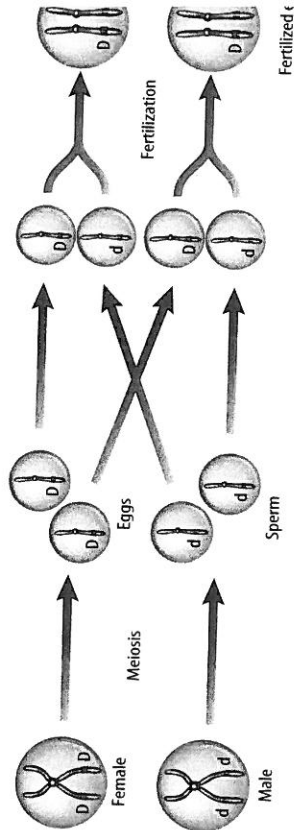
Do you look more like one parent or grandparent? Do you have your father's eyes? What about Aunt Isabella's cheekbones? Eye color, nose shape, and many other physical features are some of the traits that are inherited from parents, as **Figure 1** shows. An organism is a collection of traits, all inherited from its parents. **Heredity** (huh REH duh tee) is the passing of traits from parent to offspring. What controls these traits?

What is genetics? Generally, genes on chromosomes control an organism's form and function. The different forms of a trait that a gene may have are called **alleles** (uh LEEELZ). When a pair of chromosomes separates during meiosis (mi OH sus), alleles for each trait also separate into different sex cells. As a result, every sex cell has one allele for each trait, as shown in **Figure 2**. The allele in one sex cell may control one form of the trait, such as having facial dimples. The allele in the other sex cell may control a different form of the trait—not having dimples. The study of how traits are inherited through the interactions of alleles is the science of **genetics** (juh NE tihks).



Figure 1 Note the strong family resemblance among these four generations.

Figure 2 An allele is one form of a gene. Alleles separate into separate sex cells during meiosis. In this example, the alleles that control the trait for dimples include *D*, the presence of dimples, and *d*, the absence of dimples.



The alleles that control a trait are located on each duplicated chromosome.

During meiosis, duplicated chromosomes separate.

During fertilization, each parent donates one chromosome. This results in two alleles for the trait of dimples in the new individual formed.

Mendel—The Father of Genetics

Did you know that an experiment with pea plants helped scientists understand why your eyes are the color that they are? Gregor Mendel was an Austrian monk who studied mathematics and science but became a gardener in a monastery. His interest in plants began as a boy in his father's orchard where he could predict the possible types of flowers and fruits that would result from crossbreeding two plants. Curiosity about the connection between the color of a pea flower and the type of seed that same plant produced inspired him to begin experimenting with garden peas in 1856. Mendel made careful use of scientific methods, which resulted in the first recorded study of how traits pass from one generation to the next. After eight years, Mendel presented his results with pea plants to scientists.

Before Mendel, scientists mostly relied on observation and description, and often studied many traits at one time. Mendel was the first to trace one trait through several generations. He was also the first to use the mathematics of probability to explain heredity. The use of math in plant science was a new concept and not widely accepted then. Mendel's work was forgotten for a long time. In 1900, three plant scientists, working separately, reached the same conclusions as Mendel. Each plant scientist had discovered Mendel's writings while doing his own research. Since then, Mendel has been known as the father of genetics.















Science online

Topic: Genetics

Visit books.msscience.com for Web links to information about early genetics experiments.

Activity List two other scientists who studied genetics, and what organism they used in their research.

Table 1. Traits Compared by Mendel

Traits	Shape of Seeds	Color of Seeds	Color of Pods	Shape of Pods	Plant Height	Position of Flowers	Flower Color
Dominant trait	Round 	Yellow 	Green 	Full 	Tall 	At leaf junctions 	Purple 
Recessive trait	Wrinkled 	Green 	Yellow 	Flat, constricted 	short 	At tips of branches 	White 

Genetics in a Garden

Each time Mendel studied a trait, he crossed two plants with different expressions of the trait and found that the new plants all looked like one of the two parents. He called these new plants **hybrids** (HI brudz) because they received different genetic information, or different alleles, for a trait from each parent. The results of these studies made Mendel even more curious about how traits are inherited.

Garden peas are easy to breed for pure traits. An organism that always produces the same traits generation after generation is called a purebred. For example, tall plants that always produce seeds that produce tall plants are purebred for the trait of tall height. **Table 1** shows other pea plant traits that Mendel studied.

Reading Check Why might farmers plant purebred crop seeds?

Dominant and Recessive Factors In nature, insects randomly pollinate plants as they move from flower to flower. In his experiments, Mendel used pollen from the flowers of purebred tall plants to pollinate by hand the flowers of purebred short plants. This process is called cross-pollination. He found that tall plants crossed with short plants produced seeds that produced all tall plants. Whatever caused the plants to be short had disappeared. Mendel called the tall form the **dominant** (DAH muh nunt) factor because it dominated, or covered up, the short form. He called the form that seemed to disappear the **recessive** (rih SE sihv) factor. Today, these are called dominant alleles and recessive alleles. What happened to the recessive form? **Figure 3** answers this question.



Comparing Common Traits

Procedure

1. Safely survey as many dogs in your neighborhood as you can for the presence of a solid color or spotted coat, short or long hair, and floppy or upright ears.
2. Make a data table that lists each of the traits. Record your data in the data table.

Analysis

1. Compare the number of dogs that have one form of a trait with those that have the other form.
2. What can you conclude about the variations you noticed in the dogs?



Using Probability to Make Predictions If you and your sister can't agree on what movie to see, you could solve the problem by tossing a coin. When you toss a coin, you're dealing with probabilities. Probability is a branch of mathematics that helps you predict the chance that something will happen. If your sister chooses tails while the coin is in the air, what is the probability that the coin will land tail-side up? Because a coin has two sides, there are two possible outcomes, heads or tails. One outcome is tails. Therefore, the probability of one side of a coin showing is one out of two, or 50 percent.

Mendel also dealt with probabilities. One of the things that made his predictions accurate was that he worked with large numbers of plants. He studied almost 30,000 pea plants over a period of eight years. By doing so, Mendel increased his chances of seeing a repeatable pattern. Valid scientific conclusions need to be based on results that can be duplicated.

Punnett Squares Suppose you wanted to know what colors of pea plant flowers you would get if you pollinated white flowers on one pea plant with pollen from purple flowers on a different plant. How could you predict what the offspring would look like without making the cross? A handy tool used to predict results in Mendelian genetics is the **Punnett (PUH nut) square**. In a Punnett square, letters represent dominant and recessive alleles. An uppercase letter stands for a dominant allele. A lowercase letter stands for a recessive allele. The letters are a form of code. They show the **genotype** (JEE nuh tipe), or genetic makeup, of an organism. Once you understand what the letters mean, you can tell a lot about the inheritance of a trait in an organism.

The way an organism looks and behaves as a result of its genotype is its **phenotype** (FEE nuh tipe), as shown in **Figure 4**. If you have brown hair, then the phenotype for your hair color is brown.

Alleles Determine Traits Most cells in your body have two alleles for every trait. These alleles are located on chromosomes within the nucleus of cells. An organism with two alleles that are the same is called **homozygous** (hoh muh ZI gus). For Mendel's peas, this would be written as *TT* (homozygous for the tall-dominant trait) or *tt* (homozygous for the short-recessive trait). An organism that has two different alleles for a trait is called **heterozygous** (he tuh roh ZI gus). The hybrid plants Mendel produced were all heterozygous for height, *Tt*.

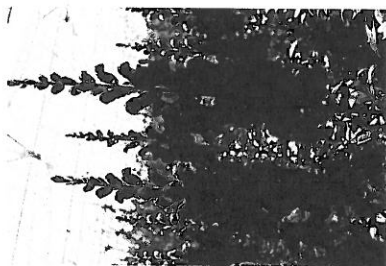


Figure 4 This snapdragon's phenotype is red.

Determine Can you tell what the flower's genotype for color is? Explain your answer.

Reading Check What is the difference between homozygous and heterozygous organisms?

Making a Punnett Square In a Punnett square for predicting one trait, the letters representing the two alleles from one parent are written along the top of the grid, one letter per section. Those of the second parent are placed down the side of the grid, one letter per section. Each square of the grid is filled in with one allele donated by each parent. The letters that you use to fill in each of the squares represent the genotypes of possible offspring that the parents could produce.

Applying Math

Calculate Percentages

PUNNET SQUARE One dog carries heterozygous, black-fur traits (Bb), and its mate carries homogeneous, blond-fur traits (bb). Use a Punnett square to determine the probability of one of their puppies having black fur.

Solution

- This is what you know:
 - dominant allele is represented by B
 - recessive allele is represented by b
- This is what you need to find out:
 - What is the probability of a puppy's fur color being black?
- This is the procedure you need to use:
 - Complete the Punnett square.
 - There are two Bb genotypes and four possible outcomes.
 - $\%$ (black fur) = $\frac{\text{number of ways to get black fur}}{\text{number of possible outcomes}} = \frac{2}{4} = \frac{1}{2} = 50\%$
- Check your answer:
 - $\frac{1}{2}$ of 4 is 2, which is the number of black dogs.

	Black dog	
	B	b
Blond dog	b	Bb
	b	bb

Genotypes of offspring:
2Bb, 2bb
Phenotypes of offspring:
2 black, 2 blond

Practice Problems

- In peas, the color yellow (Y) is dominant to the color green (y). According to the Punnett square, what is the probability of an offspring being yellow?
- What is the probability of an offspring having the yy genotype?

	Parent (Yy)	
	Y	y
Parent (Yy)	Y	YY
	y	Yy

For more practice, visit booka.msscience.com/math_practice

Principles of Heredity Even though Gregor Mendel didn't know anything about DNA, genes, or chromosomes, he succeeded in beginning to describe and mathematically represent how inherited traits are passed from parents to offspring. He realized that some factor in the pea plant produced certain traits. Mendel also concluded that these factors separated when the pea plant reproduced. Mendel arrived at his conclusions after years of detailed observation, careful analysis, and repeated experimentation. **Table 2** summarizes Mendel's principles of heredity.

Table 2 Principles of Heredity

1	Traits are controlled by alleles on chromosomes.
2	An allele's effect is dominant or recessive.
3	When a pair of chromosomes separates during meiosis, the different alleles for a trait move into separate sex cells.



SECTION 1 REVIEW

Summary

- Inheriting Traits**
- Heredity is the passing of traits from parent to offspring.
 - Genetics is the study of how traits are inherited through the interactions of alleles.
- Mendel—The Father of Genetics**
- In 1856, Mendel began experimenting with garden peas, using careful scientific methods.
 - Mendel was the first to trace one trait through several generations.
 - In 1900, three plant scientists separately reached the same conclusions as Mendel.
- Genetics in a Garden**
- Hybrids receive different genetic information for a trait from each parent.
 - Genetics involves dominant and recessive factors.
 - Punnett squares can be used to predict the results of a cross.
 - Mendel's conclusions led to the principles of heredity.

Self Check

- Contrast** Alleles are described as being dominant or recessive. What is the difference between a dominant and a recessive allele?
- Describe** how dominant and recessive alleles are represented in a Punnett square.
- Explain** the difference between genotype and phenotype. Give examples.
- Infer** Gregor Mendel, an Austrian monk who lived in the 1800s, is known as the father of genetics. Explain why Mendel has been given this title.
- Think Critically** If an organism expresses a recessive phenotype, can you tell the genotype? Explain your answer by giving an example.

Applying Math

- Use Percentages** One fruit fly is heterozygous for long wings, and another fruit fly is homozygous for short wings. Long wings are dominant to short wings. Use a Punnett square to find the expected percent of offspring with short wings.

