Mendelian Genetics

Key Words • alleles • dominant • recessive • genotype • phenotype • homozygous • heterozygous • probability • Punnett square • law of segregation • law of independent assortment

Getting the Idea

In the mid-1800s, an Austrian monk named Gregor Mendel made discoveries that led to today's understanding of genetics. Using pea plants, Mendel studied how traits passed from one generation to the next. Although his work was ignored until 1900, Mendel's ideas eventually formed the foundation for the modern science of genetics. These ideas are now known as Mendelian genetics.

Mendel's Experiments with Pea Plants

Mendel developed true-breeding pea plants for his experiments. True-breeding plants can self-pollinate to produce offspring that are identical with their parent. Then Mendel began to cross, or interbreed, different true-breeding strains of peas. In one experiment, Mendel crossed purebred green-pod plants with purebred yellow-pod plants. All offspring resulting from the cross had green pods. This result was unexpected.

Mendel's Pea Plants

From his experiments, Mendel concluded that an organism has two factors for each trait and receives one factor from each parent. Today we know that these factors are genes. The genes from each parent may be the same, or they may code for different forms of a trait, such as green or yellow pods. The different forms of the gene for a specific trait are called **alleles**.

Mendel's true-breeding pea plants had identical alleles for each trait. The plants with green pods had two alleles for green pods, and the plants with yellow pods had two alleles for yellow pods. When they were crossed, each parent contributed one allele to each offspring. Therefore, all the offspring had two different alleles for pod color, one for green and one for yellow. If each offspring had both alleles, why were all the pods green (just like one parent plant) instead of greenish yellow (or some other combination, such as yellow with green patches)?

Having just one green pea pod allele was the same as having two green pea pod alleles. In contrast, having just one yellow pea pod allele had the same effect as having none at all. Mendel concluded that the allele for green pods masked or covered the allele for yellow pods. He described the allele for green pods as *dominant*. A **dominant**

allele is always expressed in an organism. If a dominant allele is present, the organism shows that trait. The organism does not exhibit the trait coded for by the other allele.

If two matching alleles are required to express a trait, that allele is called **recessive**. To express yellow pea pods, the pea plants must have two matching recessive alleles for yellow pod color. A recessive allele is expressed only when paired with another recessive allele.

Genotype and Phenotype

The set of alleles an organism has for a particular gene is called its **genotype**. The trait that results from those alleles is the organism's **phenotype**. An organism's phenotype depends on its genotype. An organism with a genotype made up of two matching alleles, either dominant or recessive, is **homozygous** for that gene. An organism with two different alleles is **heterozygous**.

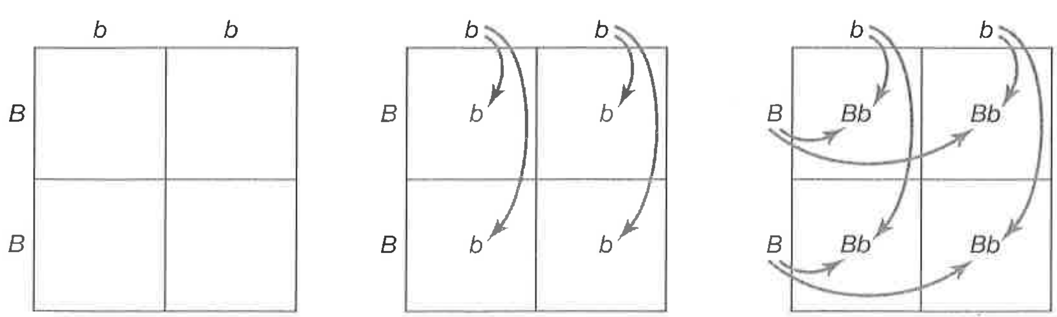
We often represent dominant alleles with uppercase letters and recessive alleles with lowercase letters. For example, green pea pod color is dominant over yellow. A pea plant's genotype could be described as *GG* (two dominant alleles), *Gg* (one dominant and one recessive allele), or *gg* (two recessive alleles).

In Mendel's experiment, the possible alleles for pod color were green or yellow. The parent plants were true-breeding, so they were homozygous. The homozygous green-pod pea plants had two alleles for green color (*GG*), and the homozygous yellow-pod plants had two alleles for yellow color (*gg*). When Mendel crossed the two types of plants, each parent contributed one allele to the offspring (first generation, or F_1). The results were heterozygous offspring, each of which had two different alleles for pod color (*Gg*).

Punnett Squares

We can predict the probability that different genotypes and phenotypes will result from a cross between two organisms. A **probability** is the mathematical chance that some event will occur. A *ratio* is the proportion of one quantity to another. Using a Punnett square can help determine the probability of a trait being passed to offspring and the probable ratios of different phenotypes and genotypes. A **Punnett square** is a diagram used to show possible combinations of dominant and recessive alleles in offspring based on the genotypes of the parents.

To create a Punnett square, divide a square into four sections. Write the genotype of one parent across the top of the square, placing one allele per column. Write the genotype of the other parent down the side, placing one allele per row. To complete the square, combine the alleles of one parent with those of the other parent in each box.



Recall that Mendel crossed pea plants that were homozygous for green pods (*GG*) and homozygous for yellow pods (*gg*). The Punnett square below shows the results of this cross.

		Green-pod parent	
		G	*G*
Yellow-pod parent	*g*	*Gg* green	*Gg* green
	g	*Gg* green	*Gg* green

The F_1 plants can have only one genotype—*Gg*. The probability of inheriting this phenotype is 1, or 100 percent. Similarly, the only possible phenotype of the offspring is green, for a probability of 1 or 100 percent. How would these probabilities differ if we crossed two of the offspring from the F_1 generation? The Punnett square below shows this outcome for the second, or F_2, generation.

F_1 Cross

	G	*g*
G	*GG* Green	*Gg* Green
g	*Gg* Green	*gg* Yellow

In this cross, both parents are heterozygous for the pod color gene. Each parent has one of each allele. The result is a variety of offspring. The possible genotypes are *GG*, *Gg*, and *gg*, in a ratio of 1:2:1 (25 percent *GG*, 50 percent *Gg*, 25 percent *gg*). The possible phenotypes are green (*GG* or *Gg*) and yellow (*gg*). A plant will have green pea pods if it has at least one dominant allele. Because three of the four boxes contain a dominant allele (*G*), the offspring have a three-fourths or 75 percent probability of having green pea pods. The phenotypic ratio is 3:1 (75 percent green, 25 percent yellow).

Notice that the probability that any offspring will have the genotype *GG* is one out of four, or one-fourth. To express this as a percentage, divide the numerator by the denominator. Then multiply the answer by 100.

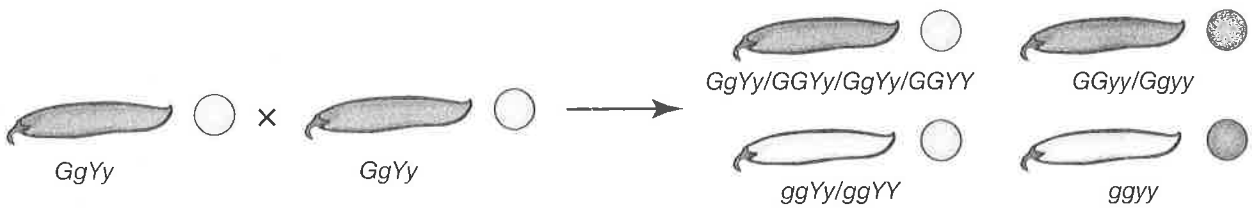
$$\frac{1}{4} = 0.25 \times 100 = 25 \text{ percent}$$

Keep in mind that a 25 percent probability does not mean that exactly 25 out of 100 offspring will have the *GG* genotype. It means you can predict that about one-fourth of the offspring will have this genotype. The more offspring, the closer the actual percentages will be to the predicted percentages.

Mendel's Laws of Segregation and Independent Assortment

Notice that each parent plant gives only one of its alleles to any offspring. Mendel's **law of segregation** states that alleles separate when gametes (sex cells) are formed, so each gamete contains only one allele of each gene. You will learn more about this in the next lesson.

Mendel also studied how multiple traits are inherited. For example, the allele for yellow peas (*Y*) is dominant to the allele for green peas (*y*). A plant that is heterozygous for both genes (*GgYy*) has green pods containing yellow peas. If two such parent plants are crossed, will the offspring "match" for both traits, having either two dominant phenotypes or two recessive phenotypes? Or will they produce new combinations, such as green pods and green peas (*Ggyy*)?



Mendel's crosses produced offspring with all four possible combinations of phenotypes. This led Mendel to the **law of independent assortment**, which states that the alleles for different genes separate independently of each other when gametes form. You will learn more about how genes separate and about how gametes form in the next lesson.

Discussion Question

Which of Mendel's laws of genetics predicts that a parent with the genotype *Aa* can have a child with the genotype *aa*? Explain.

Lesson Review

1. Which of the following combinations of alleles represent the same phenotype but different genotypes?

   A. *Aa* and *AA*

   B. *Aa* and *aa*

   C. *AA* and *aa*

   D. *Aa* and *Aa*

2. A heterozygous parent and a homozygous dominant parent have offspring. What is the probability that any one offspring will be homozygous?

A. 25 percent

B. 50 percent

C. 75 percent

D. 100 percent

3. Which of the following **best** summarizes the law of independent assortment?

A. A parent can pass on only one allele of each gene to any one offspring.

B. A recessive trait will only be expressed if two recessive alleles are present.

C. The chance of inheriting an allele is not affected by inheriting any other allele.

D. The probability of offspring inheriting either allele from a parent is 50 percent.

4. Two parents with genotypes *Aa* and *aa* have offspring. What is the probability that any one offspring will express the dominant allele?

A. 25 percent

B. 50 percent

C. 75 percent

D. 100 percent

5. In fruit flies, the allele for normal wings (*V*) is dominant to the allele for small, vestigial wings (*v*). A fruit fly with normal wings is crossed with a fruit fly with vestigial wings.

What are the possible phenotypic ratios in the offspring?

A. 4 normal : 0 vestigial *or* 2 normal : 2 vestigial

B. 4 normal : 0 vestigial *or* 3 normal : 1 vestigial

C. 3 normal : 1 vestigial *or* 1 normal : 3 vestigial

D. 3 normal : 1 vestigial *or* 2 normal : 2 vestigial