

The Work of Gregor Mendel

Key Questions

- *Where does an organism get its unique characteristics?*
- *How are different forms of a gene distributed to offspring?*

Vocabulary

genetics • fertilization • trait • hybrid • gene • allele • principle of dominance • segregation • gamete

Taking Notes

Two-Column Chart Before you read, draw a line down the center of a sheet of paper. On the left side, write the main ideas in this lesson. On the right side, note the details and examples that support each of those ideas.

THINK ABOUT IT What is an inheritance? To many people, it is money or property left to them by relatives who have passed away. That kind of inheritance matters, of course, but there is another kind that matters even more. It is something we each receive from our parents—a contribution that determines our blood type, the color of our hair, and so much more. Most people leave their money and property behind by writing a will. But what kind of inheritance makes a person's face round or their hair curly?

The Experiments of Gregor Mendel

➤ *Where does an organism get its unique characteristics?*

Every living thing—plant or animal, microbe or human being—has a set of characteristics inherited from its parent or parents. Since the beginning of recorded history, people have wanted to understand how that inheritance is passed from generation to generation. The delivery of characteristics from parent to offspring is called heredity. The scientific study of heredity, known as **genetics**, is the key to understanding what makes each organism unique.

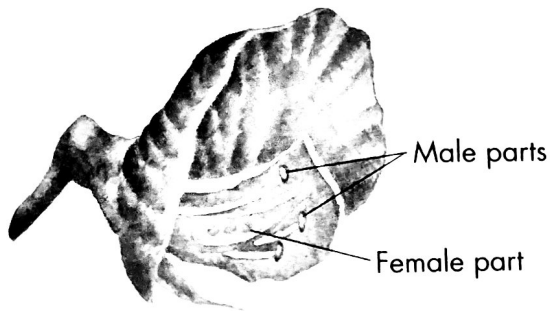
The modern science of genetics was founded by an Austrian monk named Gregor Mendel. Mendel, shown in **Figure 11-1**, was born in 1822 in what is now the Czech Republic. After becoming a priest, Mendel spent several years studying science and mathematics at the University of Vienna. He spent the next 14 years working in a monastery and teaching high school. In addition to his teaching duties, Mendel was in charge of the monastery garden. In this simple garden, he was to do the work that changed biology forever.

Mendel carried out his work with ordinary garden peas, partly because peas are small and easy to grow. A single pea plant can produce hundreds of offspring. Today we call peas a “model system.” Scientists use model systems because they are convenient to study and may tell us how other organisms, including humans, actually function. By using peas, Mendel was able to carry out, in just one or two growing seasons, experiments that would have been impossible to do with humans and that would have taken decades—if not centuries—to do with pigs, horses, or other large animals.

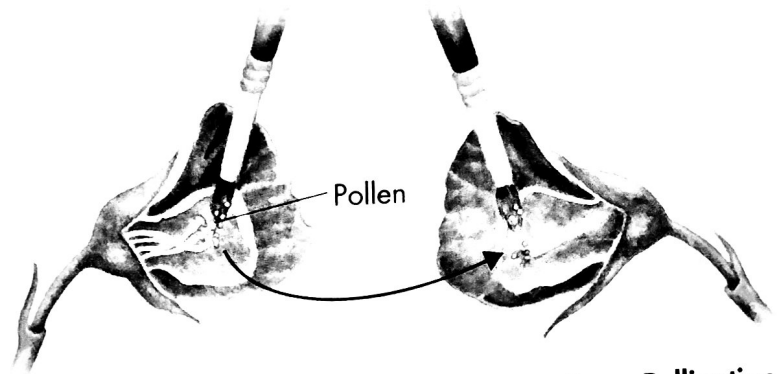
FIGURE 11-1 Gregor Mendel



Pea Flower



Cross-Pollination



The Role of Fertilization When Mendel began his experiments, he knew that the male part of each flower makes pollen, which contains the plant's male reproductive cells, called sperm. Similarly, Mendel knew that the female portion of each flower produces reproductive cells called eggs. During sexual reproduction, male and female reproductive cells join in a process known as **fertilization** to produce a new cell. In peas, this new cell develops into a tiny embryo encased within a seed.

Pea flowers are normally self-pollinating, which means that sperm cells fertilize egg cells from within the same flower. A plant grown from a seed produced by self-pollination inherits all of its characteristics from the single plant that bore it; it has a single parent.

Mendel's monastery garden had several stocks of pea plants. These plants were "true-breeding," meaning that they were self-pollinating, and would produce offspring identical to themselves. In other words, the traits of each successive generation would be the same. A **trait** is a specific characteristic, such as seed color or plant height, of an individual. Many traits vary from one individual to another. For instance, one stock of Mendel's seeds produced only tall plants, while another produced only short ones. One line produced only green seeds, another produced only yellow seeds.

To learn how these traits were determined, Mendel decided to "cross" his stocks of true-breeding plants—that is, he caused one plant to reproduce with another plant. To do this, he had to prevent self-pollination. He did so by cutting away the pollen-bearing male parts of a flower. He then dusted the pollen from a different plant onto the female part of that flower, as shown in **Figure 11-2**. This process, known as cross-pollination, produces a plant that has two different parents. Cross-pollination allowed Mendel to breed plants with traits different from those of their parents and then study the results.

Mendel studied seven different traits of pea plants. Each of these seven traits had two contrasting characteristics, such as green seed color or yellow seed color. Mendel crossed plants with each of the seven contrasting characteristics and then studied their offspring. The offspring of crosses between parents with different traits are called **hybrids**.

FIGURE 11-2 Cross-Pollination

To cross-pollinate pea plants, Mendel cut off the male parts of one flower and then dusted the female part with pollen from another flower. **Apply Concepts** How did this procedure prevent self-pollination?

In Your Notebook Explain, in your own words, what fertilization is.

MYSTERY CLUE

Parakeets come in four colors: white, green, blue, and yellow. How many alleles might there be for feather color?



Genes and Alleles When doing genetic crosses, we call each original pair of plants the P, or parental, generation. Their offspring are called the F₁, or first filial, generation. (*Filius* and *filia* are the Latin words for “son” and “daughter.”)

What were Mendel’s F₁ hybrid plants like? To his surprise, for each trait studied, all the offspring had the characteristics of only one of its parents, as shown in **Figure 11–3**. In each cross, the nature of the other parent, with regard to each trait, seemed to have disappeared. From these results, Mendel drew two conclusions. His first conclusion formed the basis of our current understanding of inheritance.

Key An individual’s characteristics are determined by factors that are passed from one parental generation to the next. Today, scientists call the factors that are passed from parent to offspring **genes**.

Each of the traits Mendel studied was controlled by a single gene that occurred in two contrasting varieties. These variations produced different expressions, or forms, of each trait. For example, the gene for plant height occurred in one form that produced tall plants and in another form that produced short plants. The different forms of a gene are called **alleles** (uh LEE LZ).

Dominant and Recessive Alleles Mendel’s second conclusion is called the **principle of dominance**. This principle states that some alleles are dominant and others are recessive. An organism with at least one dominant allele for a particular form of a trait will exhibit that form of the trait. An organism with a recessive allele for a particular form of a trait will exhibit that form only when the dominant allele for the trait is not present. In Mendel’s experiments, the allele for tall plants was dominant and the allele for short plants was recessive. Likewise, the allele for yellow seeds was dominant over the recessive allele for green seeds.

FIGURE 11–3 Mendel’s F₁ Crosses
When Mendel crossed plants with contrasting traits, the resulting hybrids had the traits of only one of the parents.

Mendel’s Seven F ₁ Crosses on Pea Plants							
	Seed Shape	Seed Color	Seed Coat	Pod Shape	Pod Color	Flower Position	Plant Height
P	Round	Yellow	Gray	Smooth	Green	Axial	Tall
	X	X	X	X	X	X	X
	Wrinkled	Green	White	Constricted	Yellow	Terminal	Short
	↓	↓	↓	↓	↓	↓	↓
F ₁	Round	Yellow	Gray	Smooth	Green	Axial	Tall

Classroom Variation

- 1 Copy the data table into your notebook.
- 2 Write a prediction of whether the traits listed in the table will be evenly distributed or if there will be more dominant than recessive traits.
- 3 Examine your features, using a mirror if necessary. Determine which traits you have for features A–E.
- 4 Interview at least 14 other students to find out which traits they have. Tally the numbers. Record the totals in each column.

Analyze and Conclude

1. **Calculate** Calculate the percentages of each trait in your total sample. How do these numbers compare to your prediction? **MATH**

Trait Survey				
Feature	Dominant Trait	Number	Recessive Trait	Number
A	Free ear lobes		Attached ear lobes	
B	Hair on fingers		No hair on fingers	
C	Widow's peak		No widow's peak	
D	Curly hair		Straight hair	
E	Cleft chin		Smooth chin	

2. **Form a Hypothesis** Why do you think recessive traits are more common in some cases?

In Your Notebook Make a diagram that explains Mendel's principle of dominance.

Segregation

How are different forms of a gene distributed to offspring?

Mendel didn't just stop after crossing the parent plants, because he had another question: Had the recessive alleles simply disappeared, or were they still present in the new plants? To find out, he allowed all seven kinds of F₁ hybrids to self-pollinate. The offspring of an F₁ cross are called the F₂ (second filial) generation. In effect, Mendel crossed the F₁ generation with itself to produce the F₂ offspring, as shown in Figure 11-4.

The F₁ Cross When Mendel compared the F₂ plants, he made a remarkable discovery: The traits controlled by the recessive alleles reappeared in the second generation. Roughly one fourth of the F₂ plants showed the trait controlled by the recessive allele. Why, then, did the recessive alleles seem to disappear in the F₁ generation, only to reappear in the F₂ generation?

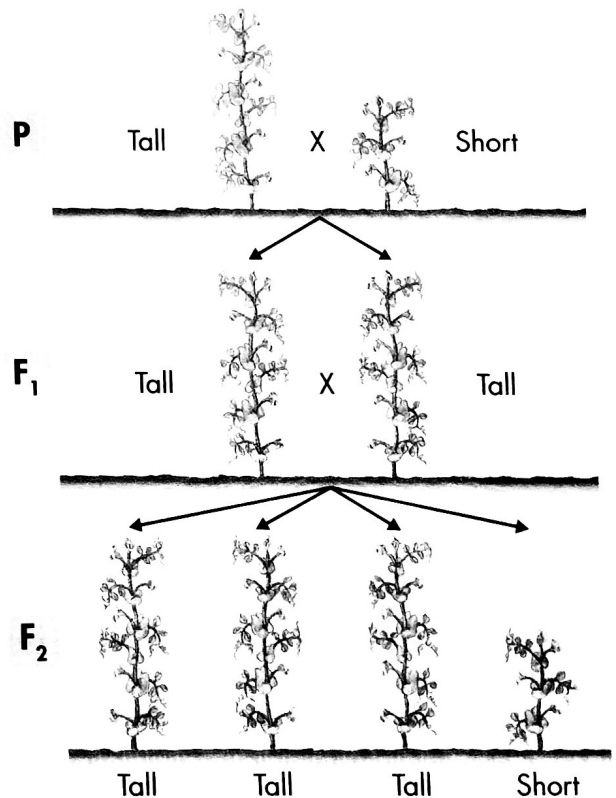


FIGURE 11-4 Results of the F₁ Cross When Mendel allowed the F₁ plants to reproduce by self-pollination, the traits controlled by recessive alleles reappeared in about one fourth of the F₂ plants in each cross. **Calculate** What proportion of the F₂ plants had a trait controlled by a dominant allele? **MATH**

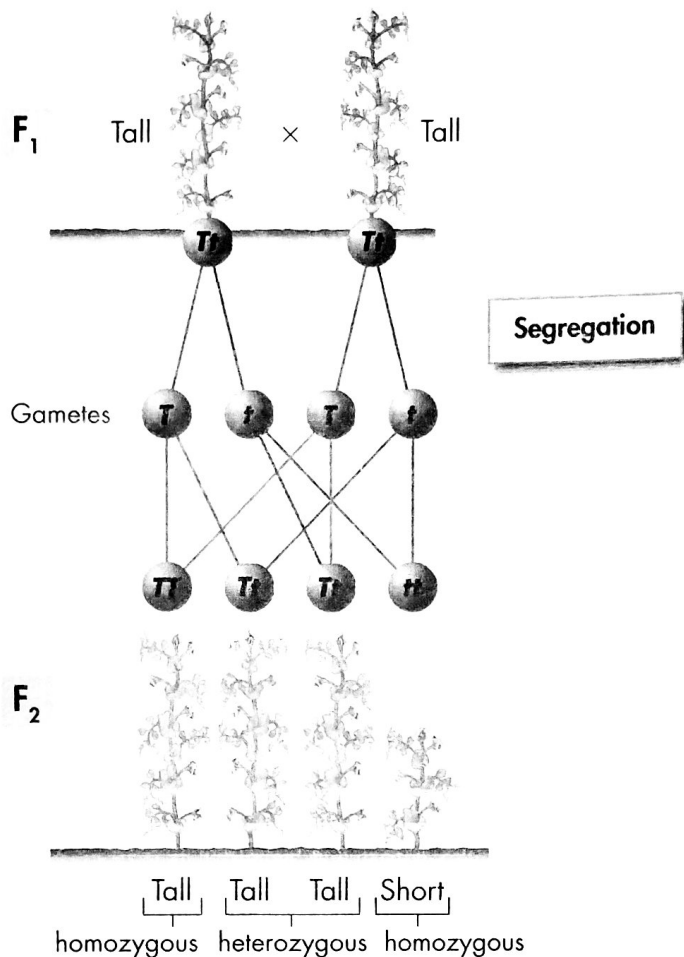


FIGURE 11-5 Segregation During gamete formation, alleles segregate from each other so that each gamete carries only a single copy of each gene. Each F₁ plant makes two types of gametes—those with the allele for tallness and those with the allele for shortness. The alleles are paired up again when gametes fuse during fertilization.

Explaining the F₁ Cross To begin with, Mendel assumed that a dominant allele had masked the corresponding recessive allele in the F₁ generation. However, the trait controlled by the recessive allele did show up in some of the F₂ plants. This reappearance indicated that, at some point, the allele for shortness had separated from the allele for tallness. How did this separation, or **segregation**, of alleles occur? Mendel suggested that the alleles for tallness and shortness in the F₁ plants must have segregated from each other during the formation of the sex cells, or **gametes** (GAM eetz). Did that suggestion make sense?

The Formation of Gametes Let's assume, as Mendel might have, that all the F₁ plants inherited an allele for tallness from the tall parent and one for shortness from the short parent. Because the allele for tallness is dominant, all the F₁ plants are tall. **During gamete formation, the alleles for each gene segregate from each other, so that each gamete carries only one allele for each gene.** Thus, each F₁ plant produces two kinds of gametes—those with the tall allele and those with the short allele.

Look at **Figure 11-5** to see how alleles separate during gamete formation and then pair up again in the F₂ generation. A capital letter represents a dominant allele. A lowercase letter represents a recessive allele. Now we can see why the recessive trait for height, t , reappeared in Mendel's F₂ generation. Each F₁ plant in Mendel's cross produced two kinds of gametes—those with the allele for tallness and those with the allele for shortness. Whenever a gamete that carried the t allele paired with the other gamete that carried the t allele to produce an F₂ plant, that plant was short. Every time one or both gametes of the pairing carried the T allele, a tall plant was produced. In other words, the F₂ generation had new combinations of alleles.

Assessment

Review Key Concepts

1. **a. Review** What did Mendel conclude determines biological inheritance?
- b. Explain** What are dominant and recessive alleles?
- c. Apply Concepts** Why were true-breeding pea plants important for Mendel's experiments?
2. **a. Review** What is segregation?
- b. Explain** What happens to alleles between the P generation and the F₂ generation?

- c. Infer** What evidence did Mendel use to explain how segregation occurs?

VISUAL THINKING

3. Use a diagram to explain Mendel's principles of dominance and segregation. Your diagram should show how alleles segregate during gamete formation.