Chapter 4

Genetics: The Science of Heredity

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Interactive Textbook

These spaniel puppies and their mother resemble each other in many ways.

Section 1

Mendel's Work

Reading Preview

Key Concepts

- What were the results of Mendel's experiments, or crosses?
- What controls the inheritance of traits in organisms?

Key Terms

- heredity • trait • genetics
- fertilization • purebred • gene
- alleles • dominant allele
- recessive allele • hybrid

Target Reading Skill

Outlining As you read, make an outline about Mendel's work. Use the red headings for the main ideas and the blue headings for the supporting ideas.

Mendel's Work
I. Mendel's experiments
A. Crossing pea plants
B.
C.

Lab zone Discover Activity

What Does the Father Look Like?

1. Observe the colors of the kitten in the photo. Record the kitten's coat colors and pattern. Include as many details as you can.
2. Observe the mother cat in the photo. Record her coat color and pattern.

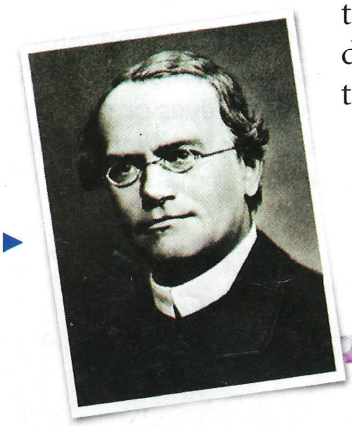
Think It Over

Inferring Based on your observations, describe what you think the kitten's father might look like. Identify the evidence on which you based your inference.

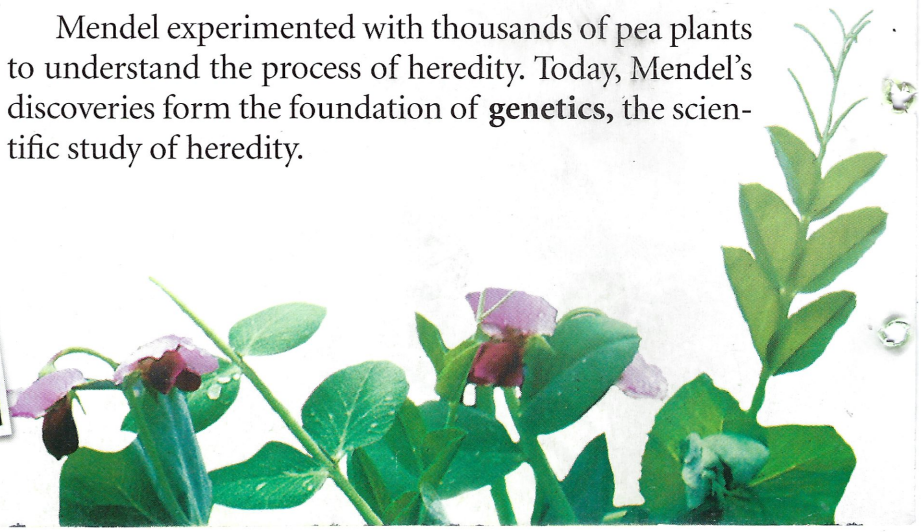
In the mid nineteenth century, a priest named Gregor Mendel tended a garden in a central European monastery. Mendel's experiments in that peaceful garden would one day revolutionize the study of heredity. **Heredity** is the passing of physical characteristics from parents to offspring.

Mendel wondered why different pea plants had different characteristics. Some pea plants grew tall, while others were short. Some plants produced green seeds, while others had yellow seeds. Each different form of a characteristic, such as stem height or seed color, is called a **trait.** Mendel observed that the pea plants' traits were often similar to those of their parents. Sometimes, however, the plants had different traits from those of their parents.

Mendel experimented with thousands of pea plants to understand the process of heredity. Today, Mendel's discoveries form the foundation of **genetics,** the scientific study of heredity.



Gregor Mendel ▶



Mendel's Experiments

Figure 1 shows a pea plant's flower. The flower's petals surround the pistil and the stamens. The pistil produces female sex cells, or eggs. The stamens produce pollen, which contains the male sex cells, or sperm. A new organism begins to form when egg and sperm join in the process called **fertilization.** Before fertilization can happen in pea plants, pollen must reach the pistil of a pea flower. This process is called pollination.

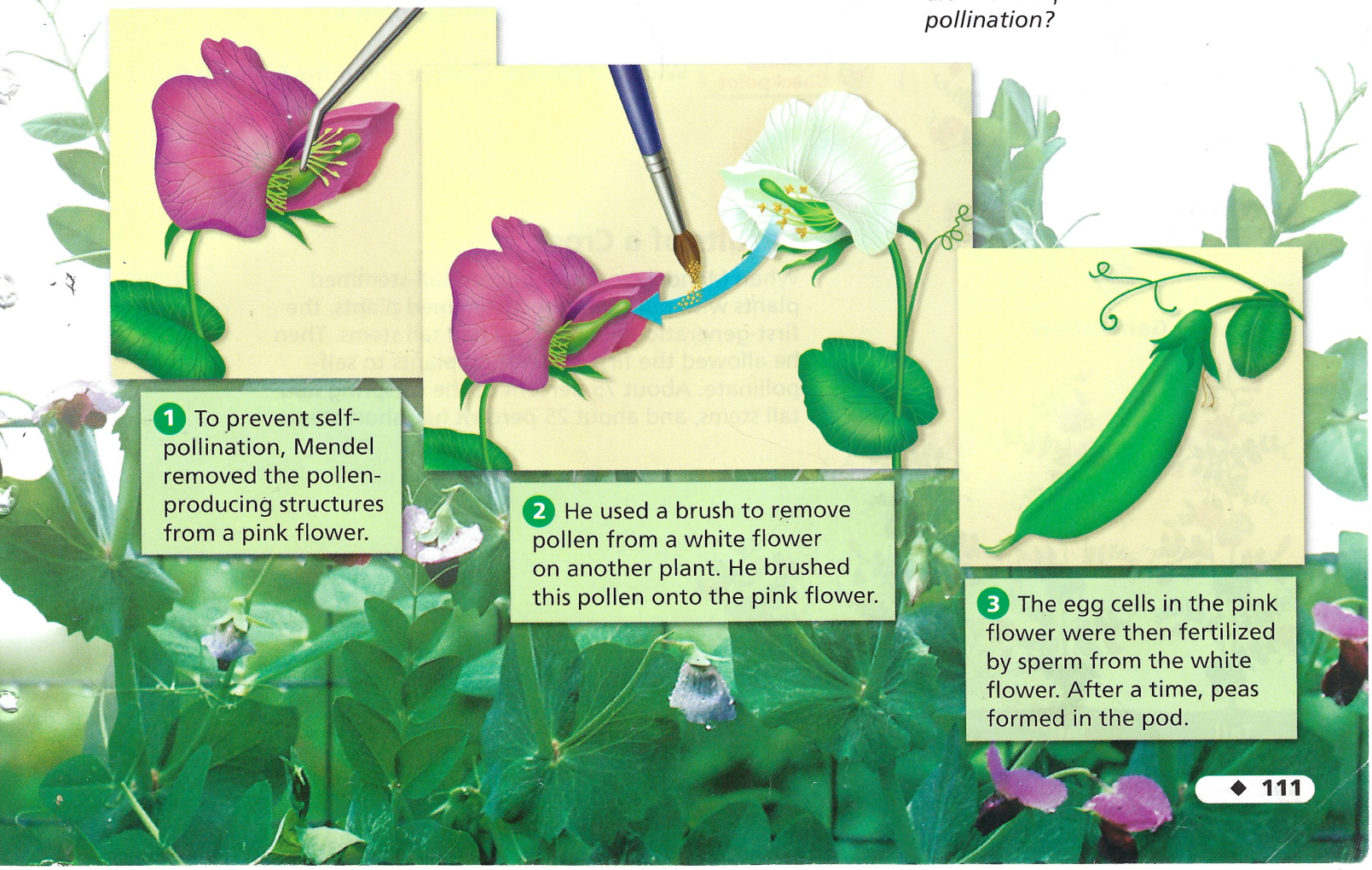
Pea plants are usually self-pollinating. In self-pollination, pollen from a flower lands on the pistil of the same flower. Mendel developed a method by which he cross-pollinated, or "crossed," pea plants. To cross two plants, he removed pollen from a flower on one plant. He then brushed the pollen onto a flower on a second plant.

Crossing Pea Plants Suppose you wanted to study the inheritance of traits in pea plants. What could you do? Mendel decided to cross plants with contrasting traits—for example, tall plants and short plants. He started his experiments with purebred plants. A **purebred** organism is the offspring of many generations that have the same trait. For example, purebred short pea plants always come from short parent plants.

FIGURE 1

Crossing Pea Plants

Gregor Mendel crossed pea plants that had different traits. The illustrations show how he did this. **Interpreting Diagrams** *How did Mendel prevent self-pollination?*



The F_1 Offspring In one experiment, Mendel crossed purebred tall plants with purebred short plants. Scientists today call these parent plants the parental generation, or P generation. The offspring from this cross are the first filial (FIL ee ul) generation, or the F_1 generation. The word *filial* comes from *filia* and *filius*, the Latin words for "daughter" and "son."

In Figure 2, notice that all the offspring in the F_1 generation were tall. Even though one of the parent plants was short, none of the offspring were short. The shortness trait seemed to disappear!

The F_2 Offspring When the plants in the F_1 generation were full-grown, Mendel allowed them to self-pollinate. Surprisingly, the plants in the F_2 (second filial) generation were a mix of tall and short plants. The shortness trait had reappeared, even though none of the F_1 parent plants were short. Mendel counted the tall and short plants. About three fourths of the plants were tall, while one fourth were short.

Experiments With Other Traits Mendel also crossed pea plants with other contrasting traits. Compare the two forms of each trait in Figure 3. **In all of Mendel's crosses, only one form of the trait appeared in the F_1 generation. However, in the F_2 generation, the "lost" form of the trait always reappeared in about one fourth of the plants.**

Reading Checkpoint **What did Mendel observe about the F_2 plants?**

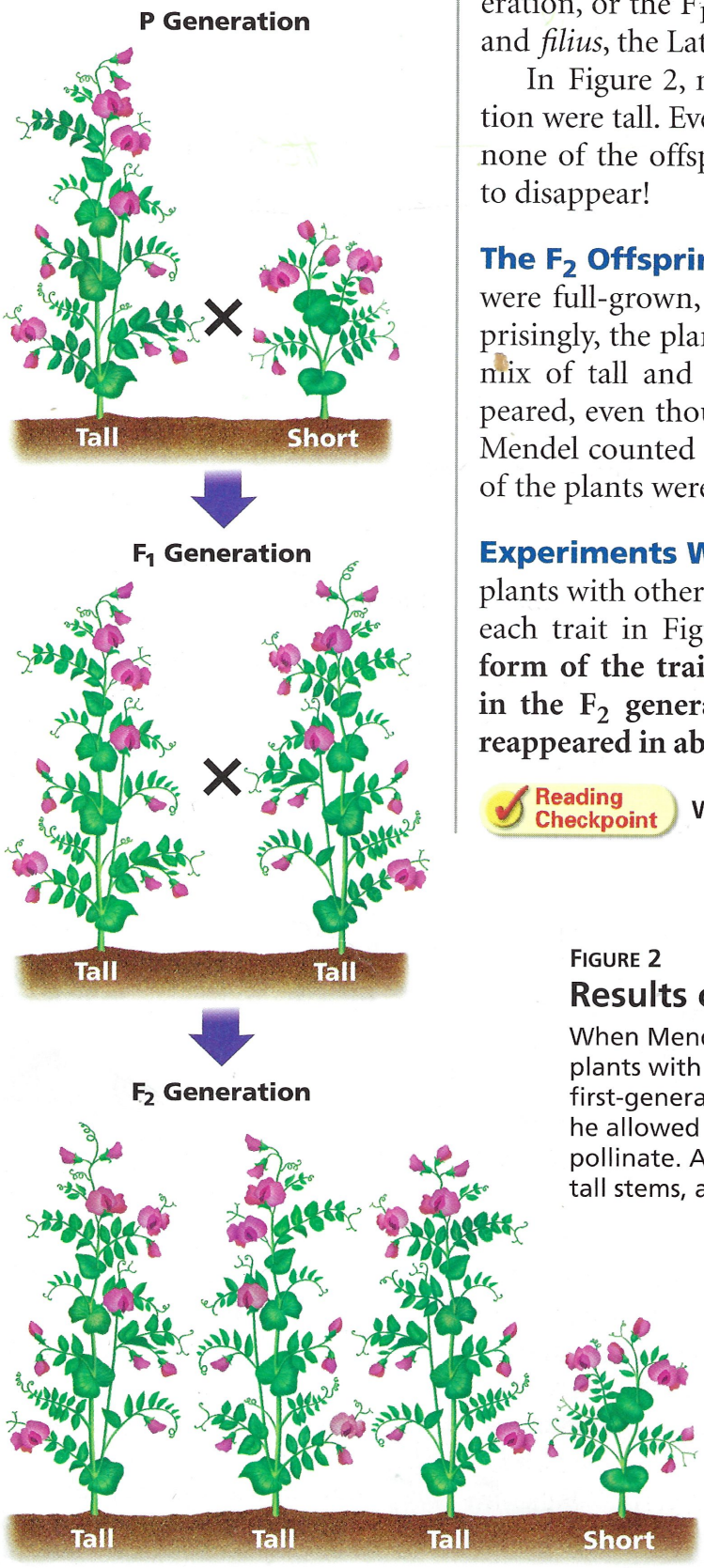


FIGURE 2
Results of a Cross
When Mendel crossed purebred tall-stemmed plants with purebred short-stemmed plants, the first-generation offspring all had tall stems. Then he allowed the first-generation plants to self-pollinate. About 75 percent of the offspring had tall stems, and about 25 percent had short stems.

Genetics of Pea Plants							
Traits	Seed Shape	Seed Color	Seed Coat Color	Pod Shape	Pod Color	Flower Position	Stem Height
Controlled by Dominant Allele	Round	Yellow	Gray	Smooth	Green	Side	Tall
Controlled by Recessive Allele	Wrinkled	Green	White	Pinched	Yellow	End	Short

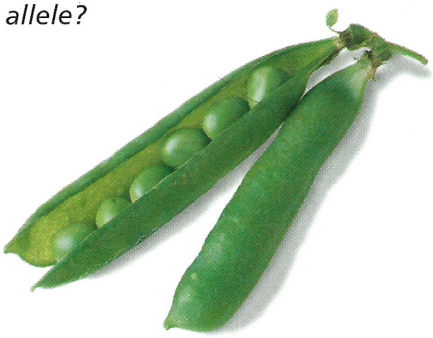
Dominant and Recessive Alleles

Mendel reached several conclusions on the basis of his experimental results. He reasoned that individual factors, or sets of genetic "information," must control the inheritance of traits in peas. The factors that control each trait exist in pairs. The female parent contributes one factor, while the male parent contributes the other factor. Finally, one factor in a pair can mask, or hide, the other factor. The tallness factor, for example, masked the shortness factor.

Genes and Alleles Today, scientists use the word **gene** for the factors that control a trait. **Alleles** (uh LEELZ) are the different forms of a gene. The gene that controls stem height in peas, for example, has one allele for tall stems and one allele for short stems. Each pea plant inherits two alleles from its parents—one allele from the egg and the other from the sperm. A pea plant may inherit two alleles for tall stems, two alleles for short stems, or one of each.

An organism's traits are controlled by the alleles it inherits from its parents. Some alleles are dominant, while other alleles are recessive. A **dominant allele** is one whose trait always shows up in the organism when the allele is present. A **recessive allele,** on the other hand, is hidden whenever the dominant allele is present. A trait controlled by a recessive allele will only show up if the organism does not have the dominant allele. Figure 3 shows dominant and recessive alleles in Mendel's crosses.

FIGURE 3
Mendel studied several traits in pea plants.
Interpreting Diagrams *Is yellow seed color controlled by a dominant allele or a recessive allele?*



Lab zone Skills Activity

Predicting

In fruit flies, long wings are dominant over short wings. A scientist crossed a purebred long-winged male fruit fly with a purebred short-winged female. Predict the wing length of the F_1 offspring. If the scientist crossed a hybrid male F_1 fruit fly with a hybrid F_1 female, what would their offspring probably be like?

In pea plants, the allele for tall stems is dominant over the allele for short stems. Pea plants with one allele for tall stems and one allele for short stems will be tall. The allele for tall stems masks the allele for short stems. Only pea plants that inherit two recessive alleles for short stems will be short.

Alleles in Mendel's Crosses In Mendel's cross for stem height, the purebred tall plants in the P generation had two alleles for tall stems. The purebred short plants had two alleles for short stems. The F_1 plants each inherited an allele for tall stems from the tall parent and an allele for short stems from the short parent. Therefore, each F_1 plant had one allele for tall stems and one for short stems. The F_1 plants are called hybrids. A **hybrid** (HY brid) organism has two different alleles for a trait. All the F_1 plants are tall because the dominant allele for tall stems masks the recessive allele for short stems.

When Mendel crossed the F_1 plants, some of the offspring in the F_2 generation inherited two dominant alleles for tall stems. These plants were tall. Other F_2 plants inherited one dominant allele for tall stems and one recessive allele for short stems. These plants were also tall. The rest of the F_2 plants inherited two recessive alleles for short stems. These plants were short.

Symbols for Alleles Geneticists use letters to represent alleles. A dominant allele is represented by a capital letter. For example, the allele for tall stems is represented by *T*. A recessive allele is represented by the lowercase version of the letter. So, the allele for short stems would be represented by *t*. When a plant inherits two dominant alleles for tall stems, its alleles are written as *TT*. When a plant inherits two recessive alleles for short stems, its alleles are written as *tt*. When a plant inherits one allele for tall stems and one allele for short stems, its alleles are written as *Tt*.

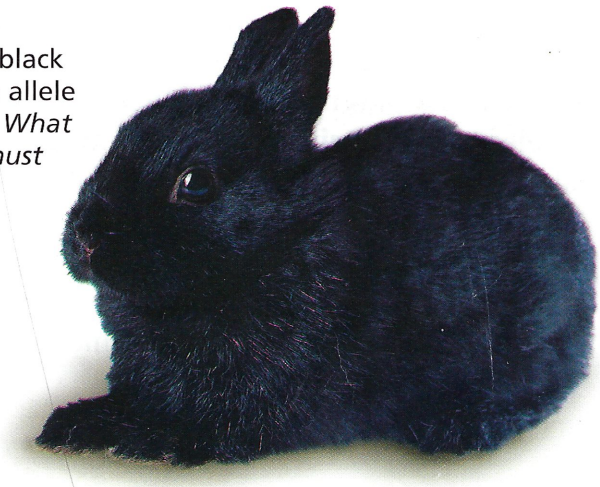


FIGURE 4
Black Fur, White Fur
In rabbits, the allele for black fur is dominant over the allele for white fur. **Inferring** *What combination of alleles must the white rabbit have?*

Significance of Mendel's Contribution Mendel's discovery of genes and alleles eventually changed scientists' ideas about heredity. Before Mendel, most people thought that the traits of an individual organism were simply a blend of their parents' characteristics. According to this idea, if a tall plant and a short plant were crossed, the offspring would all have medium height.

However, when Mendel crossed purebred tall and purebred short pea plants, the offspring were all tall. Mendel's experiments demonstrated that parents' traits do not simply blend in the offspring. Instead, traits are determined by individual, separate alleles inherited from each parent. Some of these alleles, such as the allele for short height in pea plants, are recessive. If a trait is determined by a recessive allele, the trait can seem to disappear in the offspring.

Unfortunately, the importance of Mendel's discovery was not recognized during his lifetime. Then, in 1900, three different scientists rediscovered Mendel's work. These scientists quickly recognized the importance of Mendel's ideas. Because of his work, Mendel is often called the Father of Genetics.

Reading Checkpoint **If an allele is represented by a capital letter, what does this indicate?**

FIGURE 5
The Mendel Medal
Every year, to honor the memory of Gregor Mendel, an outstanding scientist is awarded the Mendel Medal.

Section 1 Assessment

Target Reading Skill **Outlining** Use the information in your outline about Mendel's work to help you answer the questions below.

Reviewing Key Concepts

1. a. **Identifying** In Mendel's cross for stem height, what contrasting traits did the pea plants in the P generation exhibit?
   b. **Explaining** What trait or traits did the plants in the F_1 generation exhibit? When you think of the traits of the parent plants, why is this result surprising?
   c. **Comparing and Contrasting** Contrast the offspring in the F_1 generation to the offspring in the F_2 generation. What did the differences in the F_1 and F_2 offspring show Mendel?
2. a. **Defining** What is a dominant allele? What is a recessive allele?
   b. **Relating Cause and Effect** Explain how dominant and recessive alleles for the trait of stem height determine whether a pea plant will be tall or short.
   c. **Applying Concepts** Can a short pea plant ever be a hybrid for the trait of stem height? Why or why not? As part of your explanation, write the letters that represent the alleles for stem height of a short pea plant.

Lab zone At-Home Activity

Gardens and Heredity Some gardeners save the seeds produced by flowers and plant them in the spring. If there are gardeners in your family, ask them how closely the plants that grow from these seeds resemble the parent plants. Are the offspring's traits ever different from those of the parents?