11–1 The Work of Gregor Mendel

What is an inheritance? To most people, it is money or property left to them by a relative who has passed away. That kind of inheritance is important, of course. There is another form of inheritance, however, that matters even more. This inheritance has been with you from the very first day you were alive—your genes.

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. More recently, however, scientists have begun to appreciate that heredity holds the key to understanding what makes each species unique. As a result, **genetics,** the scientific study of heredity, is now at the core of a revolution in understanding biology.

Guide for Reading

Key Concepts
- What is the principle of dominance?
- What happens during segregation?

Vocabulary
genetics • fertilization
true-breeding • trait • hybrid
gene • allele • segregation
gamete

Reading Strategy: Finding Main Ideas As you read, find evidence to support the following statement: Mendel's ideas about genetics were the beginning of a new area of biology.

Gregor Mendel's Peas

The work of an Austrian monk named Gregor Mendel, shown in **Figure 11–1,** was particularly important to understanding biological inheritance. Gregor Mendel 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 the monastery and teaching at the high school. In addition to his teaching duties, Mendel was in charge of the monastery garden. In this ordinary garden, he was to do the work that changed biology forever.

Mendel carried out his work with ordinary garden peas. He knew that part of each flower produces pollen, which contains the plant's male reproductive cells, or sperm. Similarly, the female portion of the flower produces egg cells. During sexual reproduction, male and female reproductive cells join, a process known as **fertilization.** Fertilization produces a new cell, which develops into a tiny embryo encased within a seed. Pea flowers are normally self-pollinating, which means that sperm cells in pollen fertilize the egg cells in the same flower. The seeds that are produced by self-pollination inherit all of their characteristics from the single plant that bore them. In effect, they have a single parent.

When Mendel took charge of the monastery garden, he had several stocks of pea plants. These peas were **true-breeding,** meaning that if they were allowed to self-pollinate, they would produce offspring identical to themselves. One stock of seeds would produce only tall plants, another only short ones. One line produced only green seeds, another only yellow seeds. These true-breeding plants were the basis of Mendel's experiments.

▲ **Figure 11–1** Gregor Mendel's experiments with pea plants laid the foundations of the science of genetics.

SECTION RESOURCES

Print:
- ***Teaching Resources,*** Lesson Plan 11–1, Adapted Section Summary 11–1, Adapted Worksheets 11–1, Section Summary 11–1, Worksheets 11–1, Section Review 11–1
- ***Reading and Study Workbook A***, Section 11–1
- ***Adapted Reading and Study Workbook B***, Section 11–1

Technology:
- ***iText,*** Section 11–1
- ***Animated Biological Concepts DVD***, 19
- ***Transparencies Plus,*** Section 11–1

Section 11–1

1 FOCUS

Objectives

11.1.1 ***Describe*** how Mendel studied inheritance in peas.
11.1.2 ***Summarize*** Mendel's conclusion about inheritance.
11.1.3 ***Explain*** the principle of dominance.
11.1.4 ***Describe*** what happens during segregation.

Guide for Reading

Vocabulary Preview

Help students become comfortable with the language of genetics by showing them how the Vocabulary words are related to one another. For example, a true-breeding individual is the opposite of a hybrid; an allele is one form of a gene, and genes specify particular traits. Construct a word web on the board to show these relationships.

Reading Strategy

Students should mention Mendel's research approach, as well as his results and interpretations, as support for the main idea.

2 INSTRUCT

Gregor Mendel's Peas

Build Science Skills

Observing Give students lilies, tulips, freesia, or other flowers with large stamens and pistils. Instruct them to cut off the stamens and pistils with small scissors and examine them under a dissecting microscope. If students carefully section the anther and the pistil, they may be able to observe pollen and egg cells on microscope slides with a compound microscope. Help them distinguish between pollen and sperm, and egg and ovule. Encourage students to draw labeled diagrams of their flowers. L1 L2

11–1 (continued)

Build Science Skills

Classifying Explain that much of Mendel's success came from his choice of experimental organism. Pea plants are useful for genetic study because they have many contrasting characters, they reproduce sexually, their crosses can be controlled, they have short life cycles, they produce a large number of offspring, and they are easy to handle in a laboratory. Invite students to apply these same criteria to other organisms, such as humans, fruit flies, bacteria, oak trees, dogs, and mice. For each organism, students should explain why it would or would not be useful for genetic study. *(Fruit flies, bacteria, and mice are most useful.)* L2

Genes and Dominance

Use Visuals

Figure 11–3 Review the results of Mendel's crosses. Make sure students can identify which traits are dominant and which are recessive. Ask: **Why was Mendel surprised when the offspring had the character of only one of the parents?** *(In Mendel's time, people thought that characters of the parents blended to form the offspring.)* Relate the terms *genes* and *alleles* to the results shown in the table. Make sure students are comfortable with the terminology. L1 L2

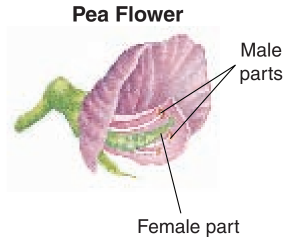
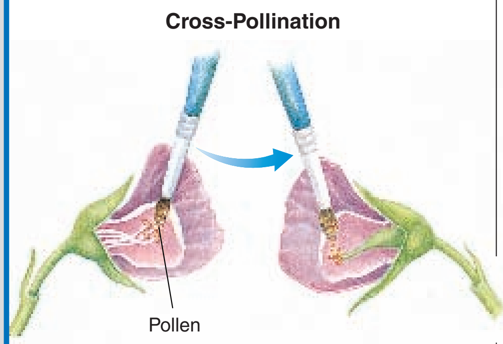


Figure 11– 2 To cross-pollinate pea plants, Mendel cut off the male parts of one flower and then dusted it with pollen from another flower. **Applying Concepts** *How did this procedure prevent self-pollination?*



Mendel wanted to produce seeds by joining male and female reproductive cells from two different plants. To do this, he had to prevent self-pollination. He accomplished this by cutting away the pollen-bearing male parts as shown in **Figure 11–2** and then dusting pollen from another plant onto the flower. This process, which is known as cross-pollination, produced seeds that had two different plants as parents. This made it possible for Mendel to cross-breed plants with different characteristics and then to study the results.

CHECKPOINT *What is fertilization?*

Genes and Dominance

Mendel studied seven different pea plant traits. A **trait** is a specific characteristic, such as seed color or plant height, that varies from one individual to another. Each of the seven traits Mendel studied had two contrasting characters, for example, green seed color and yellow seed color. Mendel crossed plants with each of the seven contrasting characters and studied their offspring. We call each original pair of plants the P (parental) generation. The offspring are called the F_1, or "first filial," generation. *Filius* and *filia* are the Latin words for "son" and "daughter." The offspring of crosses between parents with different traits are called **hybrids.**

Figure 11–3 When Mendel crossed plants with contrasting characters for the same trait, the resulting offspring had only one of the characters. **From these experiments, Mendel concluded that some alleles are dominant and others are recessive.**

Mendel's Seven F_1 Crosses on Pea Plants

	Seed Shape	Seed Color	Seed Coat Color	Pod Shape	Pod Color	Flower Position	Plant Height
P	Round X Wrinkled	Yellow X Green	Gray X White	Smooth X Constricted	Green X Yellow	Axial X Terminal	Tall X Short
F_1	Round	Yellow	Gray	Smooth	Green	Axial	Tall

ESL SUPPORT FOR ENGLISH LANGUAGE LEARNERS

Vocabulary: Prior Knowledge

Beginning Write the word *trait* on the board. Say *trait* and its definition aloud. Then, display photos of various kinds of organisms. For the first few photos, point to a trait and say the trait aloud in a simple sentence, such as "This bear has the trait of brown fur." Then, ask students to point to other traits exhibited by the organism. As they point, say the trait aloud. Finally, work with students to compose concept circles (cluster diagrams) of traits shown in additional photos. After the students understand the concept, call their attention to the pea-plant traits in Figure 11–3. L1

Intermediate Extend the activity for beginning students by having intermediate students work individually to write traits of organisms shown in photos in this book, such as the mammals on pages 831–832. L2

What were those F_1 hybrid plants like? Did the characters of the parent plants blend in the offspring? Not at all. To Mendel's surprise, all of the offspring had the character of only one of the parents, as shown in **Figure 11–3.** In each cross, the character of the other parent seemed to have disappeared.

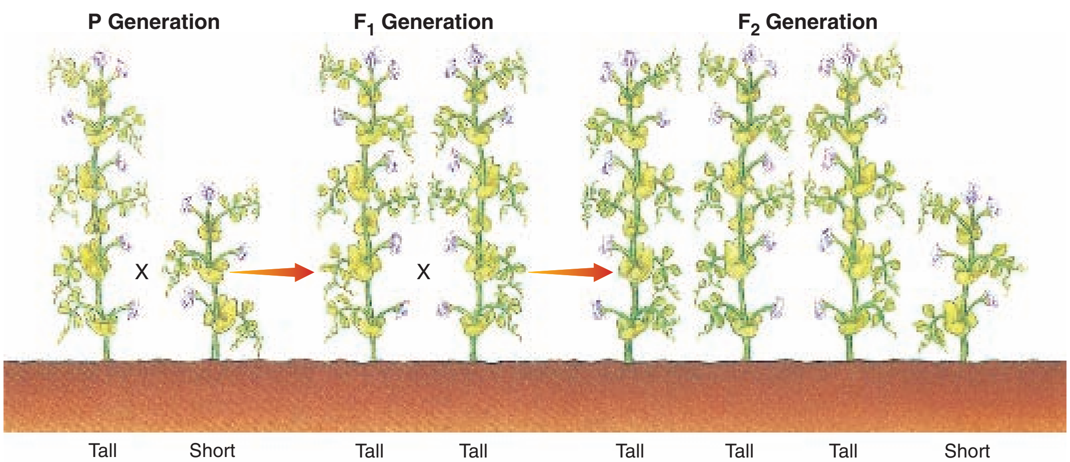
From this set of experiments, Mendel drew two conclusions. Mendel's first conclusion was that biological inheritance is determined by factors that are passed from one generation to the next. Today, scientists call the chemical factors that determine traits **genes.** Each of the traits Mendel studied was controlled by one gene that occurred in two contrasting forms. These contrasting forms produced the different characters of each trait. For example, the gene for plant height occurs in one form that produces tall plants and in another form that produces short plants. The different forms of a gene are called **alleles** (uh-LEELZ).

Mendel's second conclusion is called the principle of dominance. **The principle of dominance states that some alleles are dominant and others are recessive.** An organism with a dominant allele for a particular form of a trait will always 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. The allele for yellow seeds was dominant, while the allele for green seeds was recessive.

Segregation

Mendel wanted the answer to another question: Had the recessive alleles disappeared, or were they still present in the F_1 plants? To answer this question, he allowed all seven kinds of F_1 hybrid plants to produce an F_2 (second filial) generation by self-pollination. In effect, he crossed the F_1 generation with itself to produce the F_2 offspring, as shown in **Figure 11–4.**

▼ **Figure 11–4** When Mendel allowed the F_1 plants to reproduce by self-pollination, the traits controlled by recessive alleles reappeared in about one fourth of the F_2 plants in each cross. **Calculating** ***What proportion of the F_2 plants had a trait controlled by a dominant allele?***



Demonstration

Display the parental corn cobs and the F_1 corn cobs produced in a cross between purple *(PP)* corn and yellow *(pp)* corn, as well as those produced in a cross between starchy *(SS)* corn and sweet *(ss)* corn. Have students identify the traits associated with each allele for each cross and which allele is dominant and which is recessive. L2

Segregation

Use Visuals

Figure 11–4 Walk students through the crosses that Mendel set up as they are illustrated in the figure. Ask: **Did Mendel cross-pollinate F_1 plants to get F_2 plants?** *(No, he allowed them to self-pollinate.)* **Was the recessive allele for shortness lost in the F_1 generation?** *(No, it was masked by the dominant allele for tallness.)* **Are the F_1 plants true-breeding?** *(No, they did not produce offspring identical to themselves.)* Have student volunteers identify the gametes that each plant would produce in the P generation and in the F_1 generation. L2

Address Misconceptions

Some students might think it is impossible for two tall pea plants to produce short pea plants. For these students, review the cross as shown in Figure 11–4. Make sure they see that the tall pea plants came from a tall plant crossed to a short plant. Ask: **Why aren't any offspring short?** *(The allele for tallness is dominant and masks the allele for shortness.)* **Why do these plants have an allele for shortness?** *(One of their parents was short and could contribute only alleles for shortness to its offspring.)* L1 L2

BIO INSIGHTS

HISTORY OF SCIENCE

Methods of Mendel's success
Mendel was the first scientist of his time to obtain successful results from inheritance studies because of the methods he employed. In fact, his methods continue to be used today. Mendel studied only one trait at a time. He also took the time to verify that the parent plants were true-breeding for the particular trait he was studying. Mendel used a quantitative approach to analyze his results. He counted the number of offspring from every cross and used statistical analysis to interpret his numbers. Most important, Mendel formulated hypotheses to explain his results, and he developed experimental tests to confirm them.

Answers to . . .

CHECKPOINT *The process during sexual reproduction when male and female cells join*

Figure 11–2 *The flower no longer had its own source of pollen.*

Figure 11–4 *Three-fourths*

11–1 (continued)

Build Science Skills

Calculating Instruct students to plant F_2 corn seeds produced in a cross between two plants heterozygous for green and white color *(Gg)*. When the seeds sprout, students should get a mixture of green plants and white plants. Ask: **Which allele is dominant?** *(Green)* **Which is recessive?** *(White)* **How do you know?** *(More green plants)* Have students calculate the ratio of green plants to white plants. Discuss how their results compare with Mendel's. *(The class should have a ratio close to 3 green : 1 white.)* L1 L2

3 ASSESS

Evaluate Understanding

Assign students a trait in pea plants. Have them set up a cross as Mendel did to show the F_1 and F_2 offspring. Students should identify the dominant and recessive alleles.

Reteach

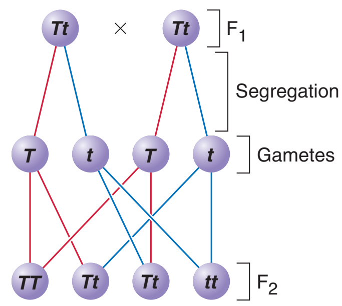
Help students devise a flowchart that outlines Mendel's method for his breeding experiments in pea plants. Encourage students to include as many Vocabulary words as possible.

Thinking Visually

Students' diagrams should be similar to Figures 11–3 and 11–5. Segregation of alleles ensures that each gamete carries only a single copy of each gene.

Interactive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 11–1.



▲ **Figure 11–5** **During gamete formation, alleles segregate from each other so that each gamete carries only a single copy of each gene. Each F_1 plant produces 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. The *TT* and *Tt* allele combinations produce tall pea plants; *tt* is the only allele combination that produces a short pea plant.

The F_1 Cross The results of the F_1 cross were remarkable. When Mendel compared the F_2 plants, he discovered that the traits controlled by the recessive alleles had reappeared! Roughly one fourth of the F_2 plants showed the trait controlled by the recessive allele. Why did the recessive alleles seem to disappear in the F_1 generation and then reappear in the F_2 generation? To answer this question, let's take a closer look at one of Mendel's crosses.

Explaining the F_1 Cross To begin with, Mendel assumed that a dominant allele had masked the corresponding recessive allele in the F_1 generation. However, the trait controlled by the recessive allele showed up in some of the F_2 plants. This reappearance indicated that at some point the allele for shortness had been 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 F_1 plants segregated from each other during the formation of the sex cells, or **gametes** (GAM-eetz). Did that suggestion make sense?

Let's assume, as perhaps Mendel did, that the F_1 plants inherited an allele for tallness from the tall parent and an allele for shortness from the short parent. Because the allele for tallness is dominant, all the F_1 plants are tall. **When each F_1 plant flowers and produces gametes, the two alleles segregate from each other so that each gamete carries only a single copy of each gene. Therefore, each F_1 plant produces two types of gametes—those with the allele for tallness and those with the allele for shortness.**

Look at **Figure 11–5** to see how alleles separated during gamete formation and then paired up again in the F_2 generation. A capital letter *T* represents a dominant allele. A lowercase letter *t* represents a recessive allele. The result of this process is an F_2 generation with new combinations of alleles.

11–1 Section Assessment

1. **Key Concept** What are dominant and recessive alleles?
2. **Key Concept** What is segregation? What happens to alleles during segregation?
3. What did Mendel conclude determines biological inheritance?
4. Describe how Mendel cross-pollinated pea plants.
5. Why did only about one fourth of Mendel's F_2 plants exhibit the recessive trait?
6. **Critical Thinking** **Applying Concepts** Why were true-breeding pea plants important for Mendel's experiments?

Thinking Visually

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

11–1 Section Assessment

1. Dominant: form of an allele whose trait always shows up if it is present; recessive: form of an allele whose trait shows up only when the dominant allele is not present
2. Separation of paired alleles; the alleles are separated during the formation of gametes, with the result that each gamete carries only a single allele from the original pair.
3. Factors that are passed from one generation to the next
4. Mendel cut away the male parts of one flower, then dusted it with pollen from another flower.
5. Only one-fourth of the possible gamete combinations did not have a dominant allele.
6. True-breeding pea plants have two identical alleles for a gene, so in a genetic cross each parent contributed only one form of a gene, making inheritance patterns more detectable.