Mendel and His Peas

Why don't you look like a rhinoceros? The answer to this question seems simple: Neither of your parents is a rhinoceros. But there is more to this answer than meets the eye.

Objectives

● Explain the relationship between traits and heredity.

● Describe the experiments of Gregor Mendel.

● Explain the difference between dominant and recessive traits.

Terms to Learn

heredity
dominant trait
recessive trait

READING STRATEGY

Brainstorming The key idea of this section is heredity. Brainstorm words and phrases related to heredity.

heredity the passing of genetic traits from parent to offspring

Figure 1 *Gregor Mendel discovered the principles of heredity while studying pea plants.*

As it turns out, **heredity,** or the passing of traits from parents to offspring, is more complicated than you might think. For example, you might have curly hair, while both of your parents have straight hair. You might have blue eyes even though both of your parents have brown eyes. How does this happen? People have investigated this question for a long time. About 150 years ago, Gregor Mendel performed important experiments. His discoveries helped scientists begin to find some answers to these questions.

✓ **Reading Check** What is heredity? (*See the Appendix for answers to Reading Checks.*)

Who Was Gregor Mendel?

Gregor Mendel, shown in **Figure 1,** was born in 1822 in Heinzendorf, Austria. Mendel grew up on a farm and learned a lot about flowers and fruit trees.

When he was 21 years old, Mendel entered a monastery. The monks taught science and performed many scientific experiments. From there, Mendel was sent to Vienna where he could receive training in teaching. However, Mendel had trouble taking tests. Although he did well in school, he was unable to pass the final exam. He returned to the monastery and put most of his energy into research. Mendel discovered the principles of heredity in the monastery garden.

Unraveling the Mystery

From working with plants, Mendel knew that the patterns of inheritance were not always clear. For example, sometimes a trait that appeared in one generation (parents) was not present in the next generation (offspring). In the generation after that, though, the trait showed up again. Mendel noticed these kinds of patterns in several other living things, too. Mendel wanted to learn more about what caused these patterns.

To keep his investigation simple, Mendel decided to study only one kind of organism. Because he had studied garden pea plants before, they seemed like a good choice.

Self-Pollinating Peas

In fact, garden peas were a good choice for several reasons. Pea plants grow quickly, and there are many different kinds available. They are also able to self-pollinate. A *self-pollinating plant* has both male and female reproductive structures. So, pollen from one flower can fertilize the ovule of the same flower or the ovule of another flower on the same plant. The flower on the right side of **Figure 2** is self-pollinating.

Why is it important that pea plants can self-pollinate? Because eggs (in an ovule) and sperm (in pollen) from the same plant combine to make a new plant, Mendel was able to grow true-breeding plants. When a *true-breeding plant* self-pollinates, all of its offspring will have the same trait as the parent. For example, a true-breeding plant with purple flowers will always have offspring with purple flowers.

Pea plants can also cross-pollinate. In *cross-pollination*, pollen from one plant fertilizes the ovule of a flower on a different plant. There are several ways that this can happen. Pollen may be carried by insects to a flower on a different plant. Pollen can also be carried by the wind from one flower to another. The left side of **Figure 2** shows these kinds of cross-pollination.
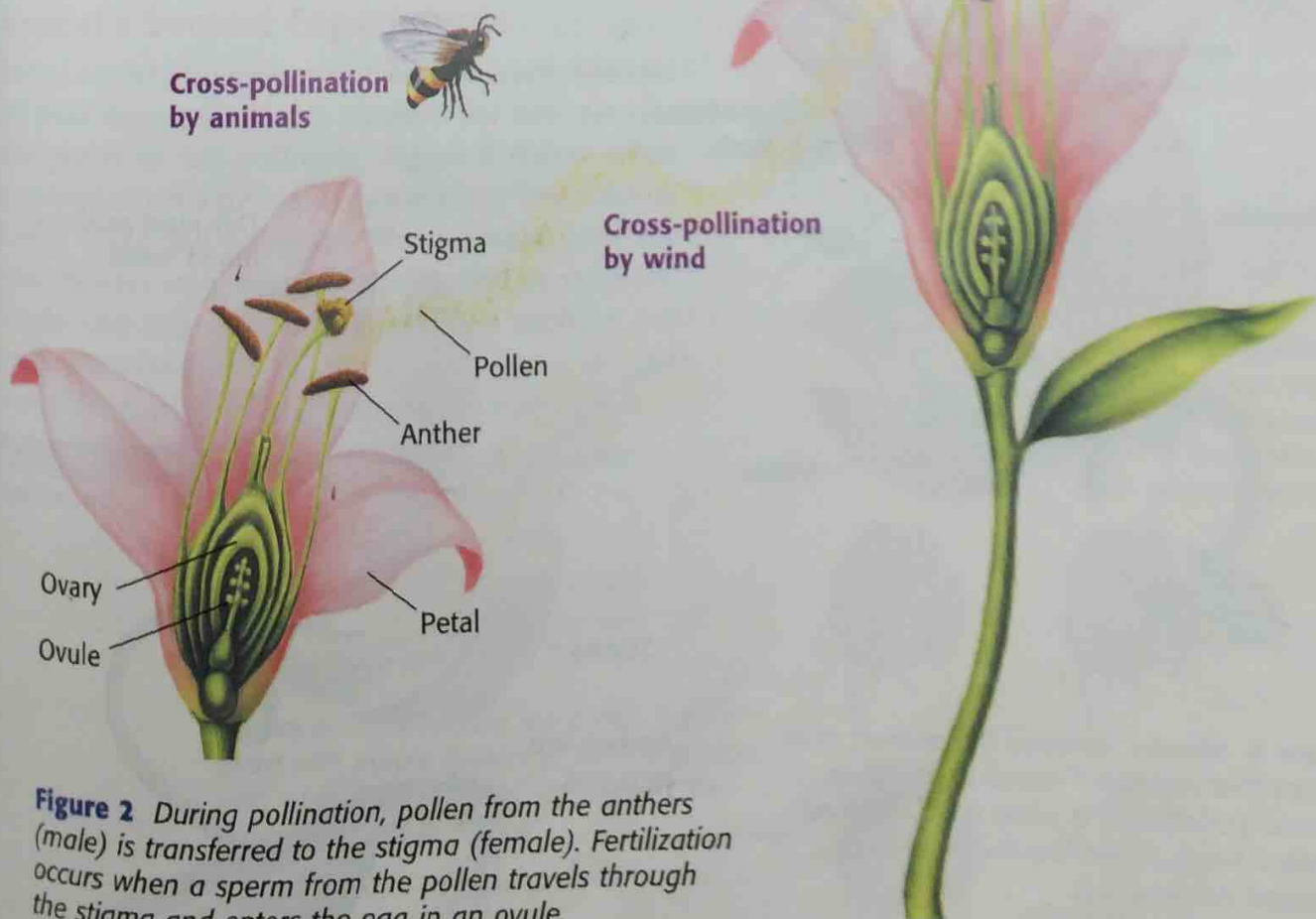
Self-pollination

Cross-pollination by animals

Cross-pollination by wind

Stigma

Pollen

Anther

Ovary

Ovule

Petal

Figure 2 During pollination, pollen from the anthers (male) is transferred to the stigma (female). Fertilization occurs when a sperm from the pollen travels through the stigma and enters the egg in an ovule.

Seed Shape

Round   Wrinkled

Plant Height

Tall   Short
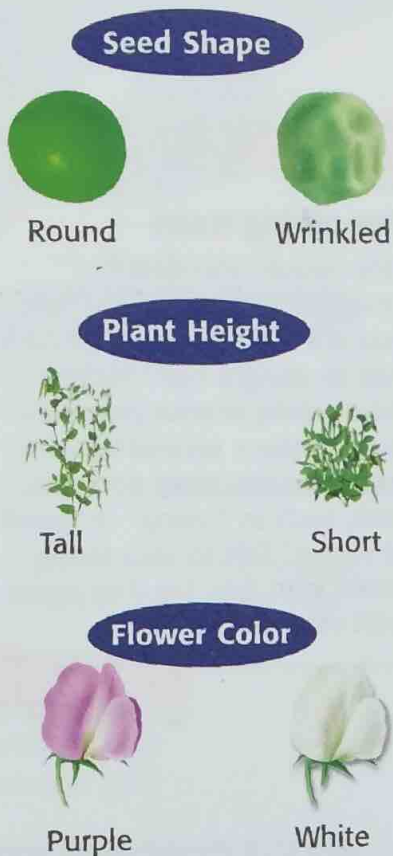
Flower Color

Purple   White

Figure 3 These are some of the plant characteristics that Mendel studied.

Characteristics

Mendel studied only one characteristic at a time. A characteristic is a feature that has different forms in a population. For example, hair color is a characteristic in humans. The different forms, such as brown or red hair, are called *traits*. Mendel used plants that had different traits for each of the characteristics he studied. For instance, for the characteristic of flower color, he chose plants that had purple flowers and plants that had white flowers. Three of the characteristics Mendel studied are shown in **Figure 3.**

Mix and Match

Mendel was careful to use plants that were true breeding for each of the traits he was studying. By doing so, he would know what to expect if his plants were to self-pollinate. He decided to find out what would happen if he bred, or crossed, two plants that had different traits of a single characteristic. To be sure the plants cross-pollinated, he removed the anthers of one plant so that the plant could not self-pollinate. Then, he used pollen from another plant to fertilize the plant, as shown in **Figure 4.** This step allowed Mendel to select which plants would be crossed to produce offspring.
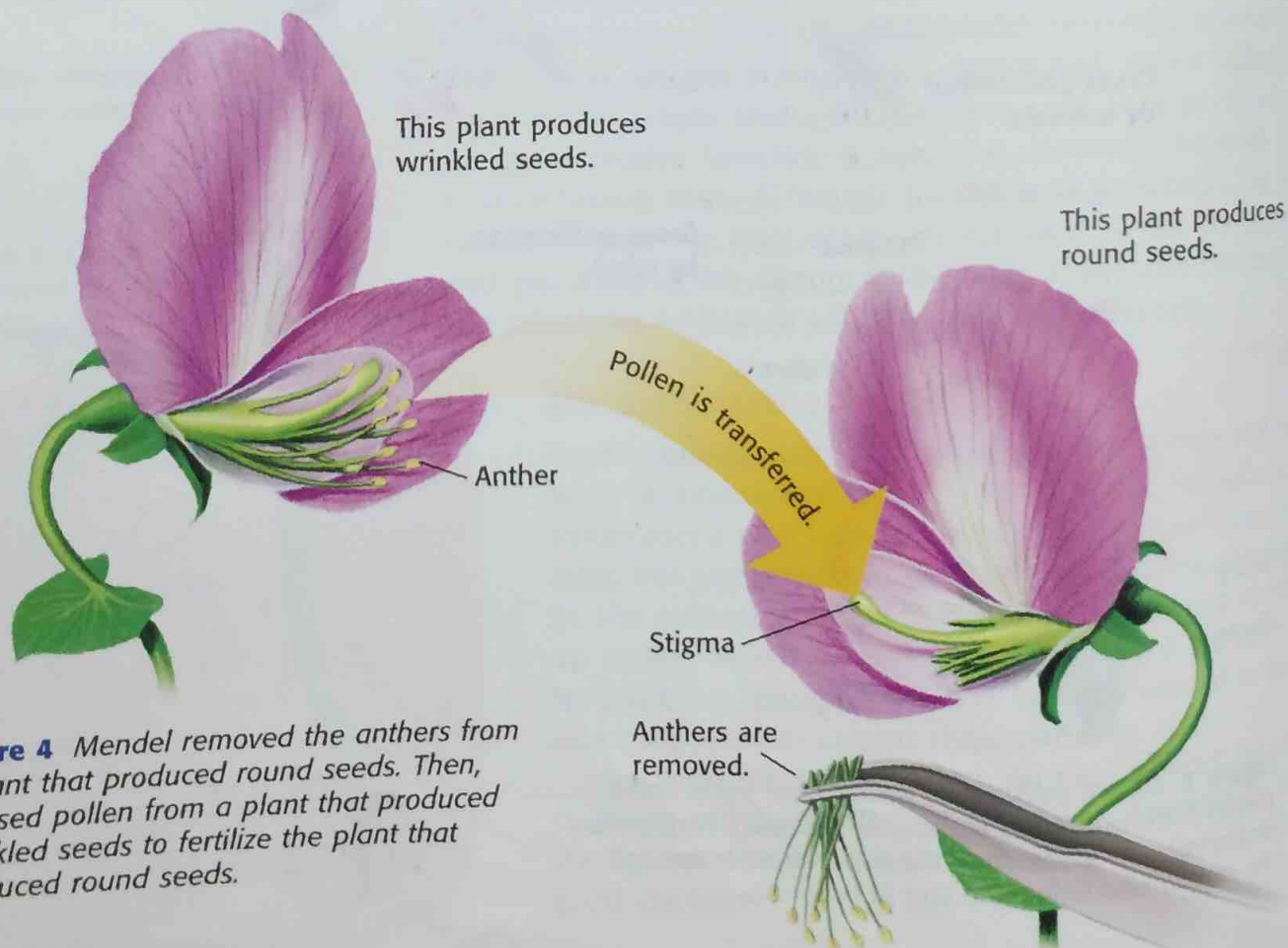
This plant produces wrinkled seeds.

This plant produces round seeds.

Pollen is transferred.

Anther

Stigma

Anthers are removed.

Figure 4 Mendel removed the anthers from a plant that produced round seeds. Then, he used pollen from a plant that produced wrinkled seeds to fertilize the plant that produced round seeds.

Mendel's First Experiments

In his first experiments, Mendel crossed pea plants to study seven different characteristics. In each cross, Mendel used plants that were true breeding for different traits for each characteristic. For example, he crossed plants that had purple flowers with plants that had white flowers. This cross is shown in the first part of **Figure 5.** The offspring from such a cross are called *first-generation plants.* All of the first-generation plants in this cross had purple flowers. Are you surprised by the results? What happened to the trait for white flowers?

Mendel got similar results for each cross. One trait was always present in the first generation, and the other trait seemed to disappear. Mendel chose to call the trait that appeared the **dominant trait.** Because the other trait seemed to fade into the background, Mendel called it the **recessive trait.** (To *recede* means "to go away or back off.") Dominant and recessive traits appear in all organisms, including humans. For example, dark hair is a dominant trait and light hair is a recessive trait.

Mendel's Second Experiments

To find out what happens to recessive traits, Mendel did more experiments. He allowed the first-generation plants to self-pollinate. **Figure 5** shows what happened when a first-generation plant with purple flowers could self-pollinate. The recessive trait for white flowers reappeared in the second generation. Mendel did this same experiment on each of the seven characteristics. In each case, some of the second-generation plants had the recessive trait.

✓ **Reading Check** Describe Mendel's second set of experiments.

dominant trait the trait observed in the first generation when parents that have different traits are bred

recessive trait a trait that reappears in the second generation after disappearing in the first generation when parents with different traits are bred
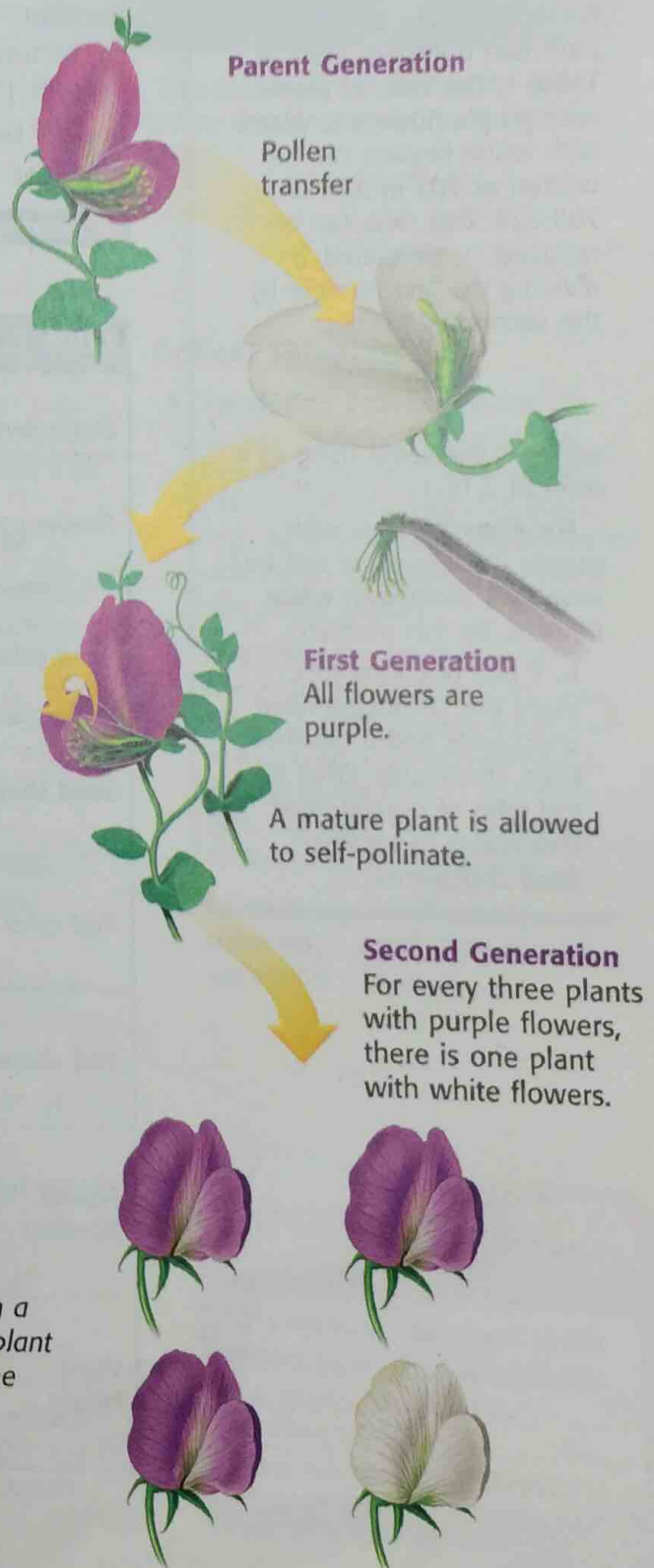

Parent Generation

Pollen transfer

First Generation
All flowers are purple.

A mature plant is allowed to self-pollinate.

Second Generation
For every three plants with purple flowers, there is one plant with white flowers.

Figure 5 *Mendel used the pollen from a plant with purple flowers to fertilize a plant with white flowers. Then, he allowed the offspring to self-pollinate.*

Understanding Ratios

A ratio is a way to compare two numbers. Look at **Table 1.** The ratio of plants with purple flowers to plants with white flowers can be written as 705 to 224 or 705:224. This ratio can be reduced, or simplified, by dividing the first number by the second as follows:

$$\frac{705}{224} = \frac{3.15}{1}$$

which is the same thing as a ratio of 3.15:1.

For every 3 plants with purple flowers, there will be roughly 1 plant with white flowers. Try this problem:

In a box of chocolates, there are 18 nougat-filled chocolates and 6 caramel-filled chocolates. What is the ratio of nougat-filled chocolates to caramel-filled chocolates?

Ratios in Mendel's Experiments

Mendel then decided to count the number of plants with each trait that turned up in the second generation. He hoped that this might help him explain his results. Take a look at Mendel's results, shown in **Table 1.**

As you can see, the recessive trait did not show up as often as the dominant trait. Mendel decided to figure out the ratio of dominant traits to recessive traits. A *ratio* is a relationship between two different numbers that is often expressed as a fraction. Calculate the dominant-to-recessive ratio for each characteristic. (If you need help, look at the Math Practice at left.) Do you notice anything interesting about the ratios? Round to the nearest whole number. Are the ratios all the same, or are they different?

✔ **Reading Check** What is a ratio?

Table 1 Mendel's Results

Characteristic	Dominant traits	Recessive traits	Ratio
Flower color	705 purple	224 white	3.15:1
Seed color	6,002 yellow	2,001 green	?
Seed shape	5,474 round	1,850 wrinkled	?
Pod color	428 green	152 yellow	?
Pod shape	882 smooth	299 bumpy	?
Flower position	651 along stem	207 at tip	?
Plant height	787 tall	277 short	?

Gregor Mendel—Gone but Not Forgotten

Mendel realized that his results could be explained only if each plant had two sets of instructions for each characteristic. Each parent would then donate one set of instructions. In 1865, Mendel published his findings. But good ideas are sometimes overlooked or misunderstood at first. It wasn't until after his death, more than 30 years later, that Mendel's work was widely recognized. Once Mendel's ideas were rediscovered and understood, the door was opened to modern genetics. Genetic research, as shown in **Figure 6,** is one of the fastest changing fields in science today.
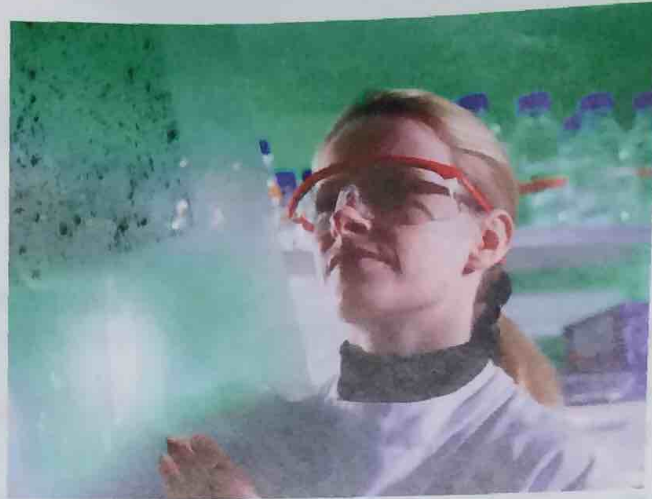

Figure 6 *This researcher is continuing the work started by Gregor Mendel more than 100 years ago.*

SECTION Review

Summary

- Heredity is the passing of traits from parents to offspring.
- Gregor Mendel made carefully planned experiments using pea plants that could self-pollinate.
- When parents with different traits are bred, dominant traits are always present in the first generation. Recessive traits are not visible in the first generation but reappear in the second generation.
- Mendel found a 3:1 ratio of dominant-to-recessive traits in the second generation.

Using Key Terms

1. Use each of the following terms in a separate sentence: *heredity, dominant trait,* and *recessive trait.*

Understanding Key Ideas

2. A plant that has both male and female reproductive structures is able to

   a. self-replicate.
   b. self-pollinate.
   c. change colors.
   d. None of the above

3. Explain the difference between self-pollination and cross-pollination.

4. What is the difference between a trait and a characteristic? Give one example of each.

5. Describe Mendel's first set of experiments.

6. Describe Mendel's second set of experiments.

Math Skills

7. In a bag of chocolate candies, there are 21 brown candies and 6 green candies. What is the ratio of brown to green? What is the ratio of green to brown?

Critical Thinking

8. **Predicting Consequences** Gregor Mendel used only true-breeding plants. If he had used plants that were not true breeding, do you think he would have discovered dominant and recessive traits? Explain.

9. **Applying Concepts** In cats, there are two types of ears: normal and curly. A curly-eared cat mated with a normal-eared cat, and all of the kittens had curly ears. Are curly ears a dominant or recessive trait? Explain.

10. **Identifying Relationships** List three other fields of study that use ratios.