LESSON 9

Sexual Reproduction in Flowering Plants

Inquiries 2
Periods 1–2

CONCEPTS

The flower is the sexual reproductive organ of a flowering plant.

Perfect flowers contain both male and female reproductive structures. Imperfect flowers contain either the male or the female reproductive structure.

Pollination is the transfer of pollen from anther to stigma. Pollen grains from different kinds of plants are very different in size and shape. Some plants self-pollinate; others require cross-pollination.

Pollen can be transported in many ways—by wind, water, gravity, insects, and humans, among others.

Fertilization occurs when a sperm nucleus from a pollen grain unites with the egg nucleus of an ovule in an ovary. A seed begins to form when fertilization occurs.

STUDENT OBJECTIVES

Examine two or more flowers and develop an understanding of their parts and functions.

Cross-pollinate the Wisconsin Fast Plants flowers in the growing system.

Explain several ways in which flowers are pollinated in nature.

Demonstrate an understanding of the difference between cell division and meiosis.

Update the Wisconsin Fast Plants organism photo card.

OVERVIEW

For this lesson, students focus on a large, perfect flower—that is, a flower with both male and female reproductive structures. They observe the flower, identify its male and female reproductive structures, sketch it, and dissect it. Then they cross-pollinate their Fast Plants flowers, taking on the role played in nature by animals, such as insects, birds, and bats.

BACKGROUND

In this lesson, you play an active role, asking probing questions to lead students in specific directions. During "Getting Started," students read "Methods of Reproduction," a selection that picks up where cell division left off in Lesson 8. You ask students to speculate on the function of a flower. Then you ask what must happen in a flower in order for a seed to be produced. Entertain answers, but do not draw conclusions at this point.

The ultimate goals of this lesson are for students to pollinate their Fast Plants flowers and to understand the purpose of pollination and fertilization. To facilitate this, during Inquiry 9.1, students observe and dissect the flower that you or they brought to class. Then, in Inquiry 9.2, they pollinate the Fast Plants flowers, which are probably smaller.

This lesson should be conducted approximately 13 days after the Fast Plants seeds are sown. By this time, many flowers should be in full bloom. In Inquiry 9.1, students identify the flower's male and female reproductive structures. They obtain pollen from an anther and an ovule from an ovary and observe both structures through a microscope. They observe pollen grains from two additional flowers and should

conclude that pollen grains from different species differ in size and shape. They discuss what must happen between the pollen and ovule for a seed to be produced. This should lead to further discussion of pollination and fertilization, which is highlighted in a reading selection called "The Wonder of Flowering Plants," to which students are encouraged to refer throughout the lesson.

In Inquiry 9.2, students cross-pollinate all of the flowers in their Fast Plants growing systems. They repeat this process each day through the 17th day after sowing. At that point, students pinch off any unopened flower buds, replenish the nutrient supply, and return the growing system to the light house.

Sexual Reproduction in Flowering Plants

Pollen grains are formed along the inner edge of the anther sacs. **Diploid** cells (those which contain the full chromosome content) undergo meiosis to form four **haploid** cells (those which contain only half the normal number of chromosomes). These four cells are called microspores. The outer wall of each microspore hardens to form a pollen grain. Mitotic divisions within each pollen grain produce a tube nucleus and two sperm cells, all of which remain haploid. The process is illustrated in Figure 9.1.

The ovary contains one or more eggs (ovules). A cell in each egg undergoes meiosis to form four haploid cells. Three of these cells die; the fourth becomes a large cell, called a megaspore. The nucleus within the megaspore divides by mitosis to form two haploid nuclei. Mitosis occurs twice more until eight haploid nuclei are formed within an enlarging embryo sac. Three of the nuclei migrate toward the opening, or **micropyle,** of the egg, through which the pollen tube may eventually enter. One of these three nuclei is the egg nucleus.

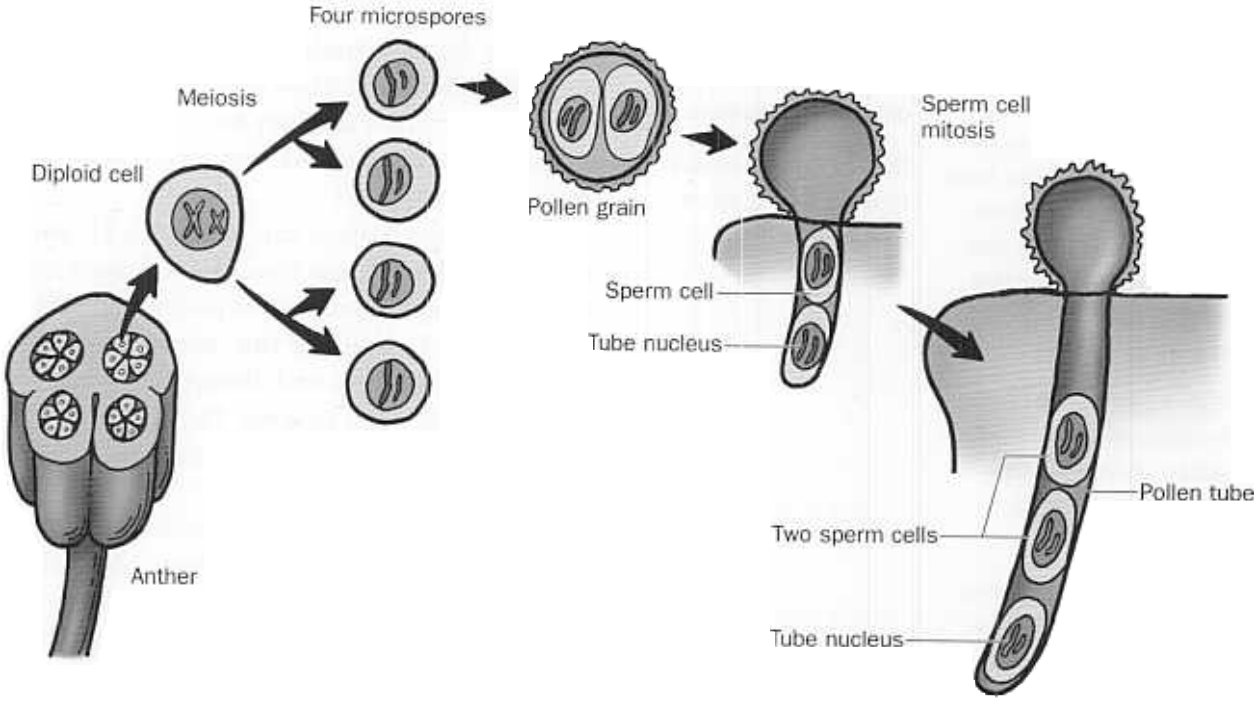


Figure 9.1 *The development of pollen grains*

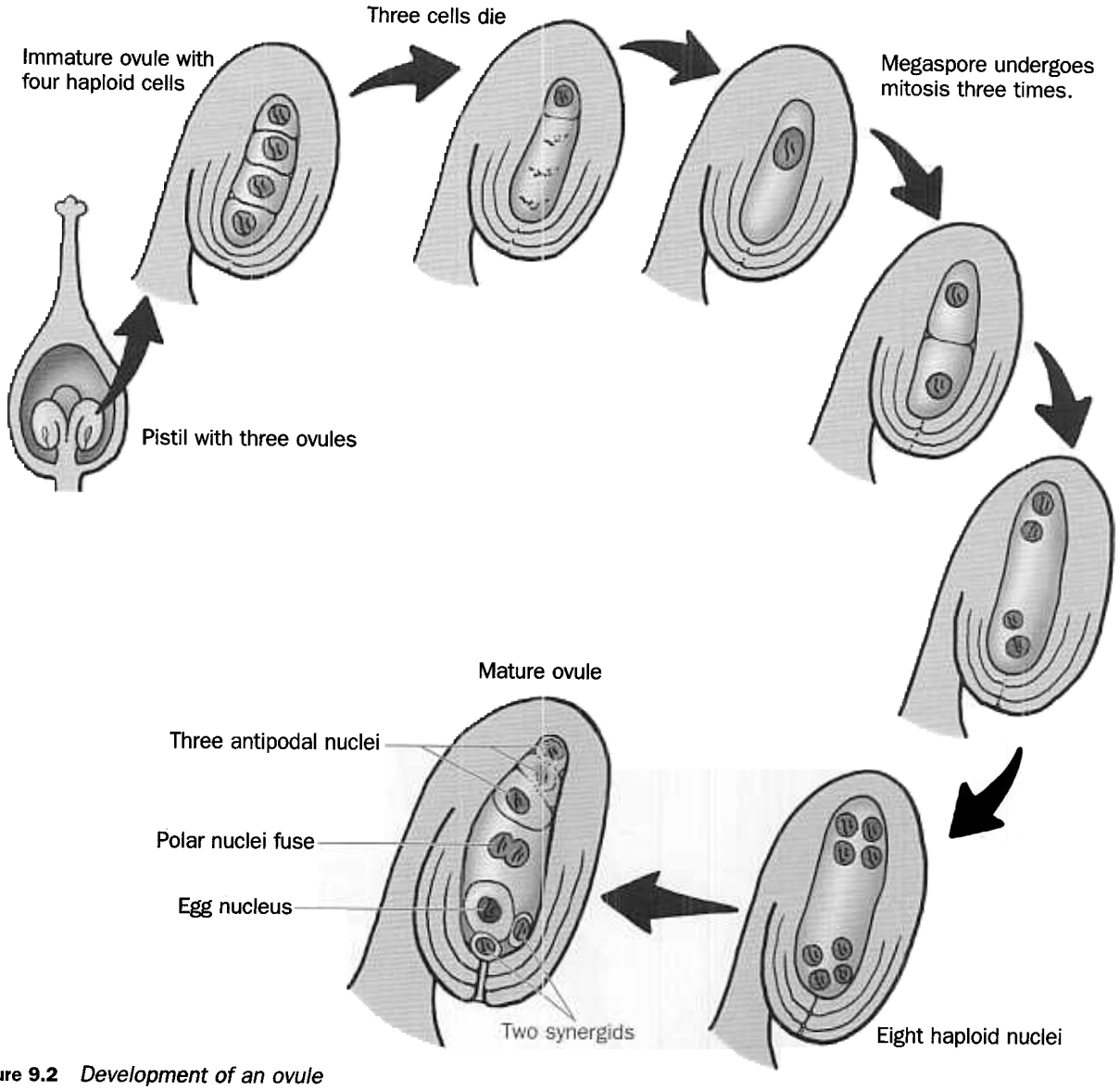


Figure 9.2 *Development of an ovule*

The other two are called **synergids.** Three of the nuclei, called **antipodal nuclei,** migrate to the opposite end of the embryo sac. The two remaining nuclei, the **polar nuclei,** move to the center of the egg and fuse. In the mature, unfertilized egg, membranes form around the antipodal, synergid, and egg nuclei to form cells. The fused polar nuclei remain free-floating in the center of the embryo sac. Therefore, the mature embryo sac contains six cells and seven nuclei. Figure 9.2 illustrates the development of an ovule.

When pollen grains are released by the anther, they usually are carried to the sticky stigma of the pistil by wind, water, insects, humans, and other animals. This transfer from anther to stigma is called **pollination.** Some plants can self-pollinate. This means that a pollen grain is compatible with a stigma from the same flower or that of another flower on the same plant. Other plants must cross-pollinate, which means that the pollen must be carried to a flower on a different plant of the same species. When a pollen grain comes in contact

with a compatible stigma, it begins to grow a tube down the style to the ovary, which contains the eggs. The tube nucleus then leads the way down the tube to an egg. The two sperm nuclei enter the embryo sac of the egg. One of them moves to the middle of the embryo sac and unites with the fused polar nuclei to form a triploid endosperm nucleus. The other sperm nucleus unites with the egg nucleus to form a diploid zygote. This process, unique to flowering plants, is called double fertilization and is illustrated in Figure 9.3.

The other nuclei remaining in the embryo sac degenerate. The zygote develops into the embryo, the beginning of a new plant. The triploid nucleus in the center of the embryo sac divides repeatedly, regulating the development of **endosperm,** a substance that provides food and energy for the growing embryo. In some seeds, such as those of *Brassica,* endosperm is entirely used up in the development of the large cotyledons, which store oil as the energy reserve for germination. In many other seeds, such as wheat, corn, and rice, endosperm is preserved as the primary food source used for germination and is a major source of nutrition for humans. The coat of the egg toughens and the whole structure becomes a seed. The ovary enlarges and develops into a **fruit,** which helps protect the seeds. Some fruits, such as peaches

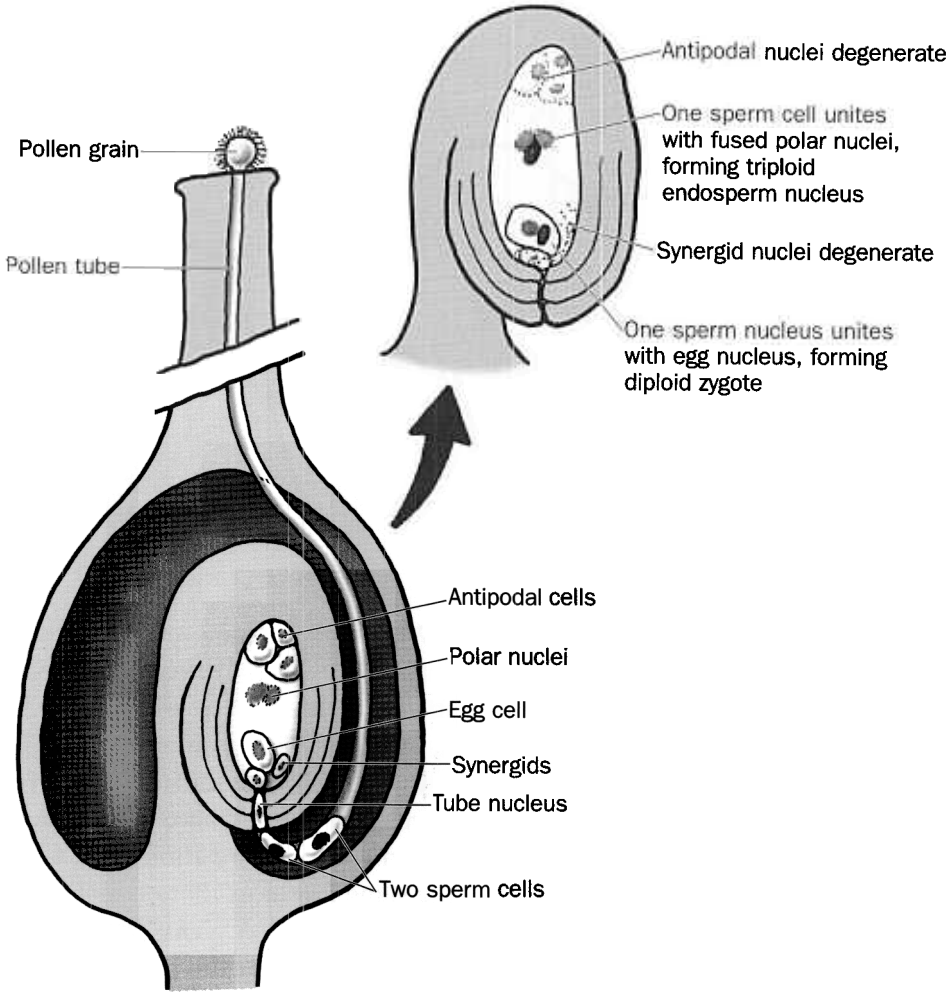


Figure 9.3 *Double fertilization*

and cherries, have just one seed; others, such as watermelons and tomatoes, have many.

As stated on the cabbage white maintenance calendar, Inquiry 6.2 will follow this lesson in the module. Preparation for Inquiry 6.2 can be found at the end of this lesson.

Visit the NSRC Web site (http://www.si.edu/nsrc) to find links to sites with more background information about plants, pollination, and fertilization.

READING SELECTIONS

The reading selection "The Wonder of Flowering Plants" in the Student Guide provides the fundamentals of sexual reproduction in flowering plants. There is sufficient detail in the selection for middle school students.

STUDENT MISCONCEPTIONS

Middle school students often are unaware that flowering plants undergo sexual reproduction. This lesson should clarify this issue.

MATERIALS FOR LESSON 9

For the teacher

1 transparency or piece of newsprint*
1 microvideo system*
1 black marker
Extra flowers (Options: Wisconsin Fast Plants, lily, tulip, amaryllis, gladiolus, astromeria)*
Containers with water to hold the flowers*

For each student

1 copy of Student Sheet 9.1: Template for Flower Drawings

For each group of 4 students

1 organism photo cards
2 perfect flowers (Options: Wisconsin Fast Plants, lily, tulip, amaryllis, gladiolus, astromeria)*
2 hand lenses
2 compound light microscopes*
2 plastic slides
2 coverslips
2 cotton swabs
2 scalpels
1 black marker

PREPARATION

1. Set up the microvideo system. This will be useful for displaying items you wish the entire class to see. For example, you many want to project a pollen grain through the system during Inquiry 9.1 if students are having difficulty identifying a pollen grain using their microscopes. Consider preparing a slide with several different pollen grains for this purpose before you teach the lesson. The microvideo system may also be used to display macroscopic objects.
2. Title a transparency or piece of newsprint "Function of the Flower." Keep it available for "Getting Started."
3. Ensure that the organism photo cards are in a location accessible to students. They will be updating their Fast Plants organism cards in Inquiry 9.2.

*Needed, but not supplied

Getting Started

1. Have the class follow along as student volunteers take turns reading aloud "Methods of Reproduction" at the end of this lesson in the Student Guide. Emphasize the transition from cell division, the primary mode of asexual reproduction of unicellular organisms, to the more complex processes necessary for sexual reproduction.

2. Have one student from each group pick up the group's growing system. Caution students to disentangle the stems and leaves of their Fast Plants from those in other growing systems in the light house as they remove them. Have each pair of students take a moment to observe a Fast Plants flower and the flower they brought to class.

3. Ask students to discuss and record on a fresh page in their science notebooks what they think is the function of a flower.

4. Discuss students' responses and record them on newsprint. At least a few students should realize that a flower's function is reproduction. Guide students toward the notion that seeds are produced within the flower. Ask what needs to happen to ensure that seeds are produced. Ask them whether seeds will be produced in the Fast Plants in their light boxes. Accept all responses at this point.

Inquiry 9.1
Dissecting a Perfect Flower

PROCEDURE

1. Go over Procedure Steps 1–9 with students. Inform students that in this inquiry, they work in pairs to dissect, observe, and sketch a flower and its parts. They dissect the flower they brought to class (or that you supplied), rather than one from their Fast Plants because the Fast Plants flowers are rather small and their internal structures are more difficult to see in detail.

2. Focus students' attention on the illustration in SG Figure 9.2. Go over the structures with them. Point to the caption, which states that this is an illustration of a "perfect" flower. Then elicit answers to the question in the caption, "What do you think an imperfect flower is?" This may lead to a discussion about how the pollen gets from one flower to another. Entertain students' remarks without coming to any conclusions.

3. As students work, move about the classroom to remind them to use SG Figure 9.2 as a reference for the various parts of their flowers. Encourage them to look at some of the other structures of their flowers, such as the petals, through the microscope.

SAFETY TIP

Always cut in a direction away from your fingers when using a scalpel.

4. Mention to students that in monocots, the petals are in multiples of three; in dicots, they are in multiples of four or five. Have them count the petals of a Fast Plants flower for evidence that their Fast Plants are dicots.

5. Students will notice that the ovules are much larger than the pollen grains. Explain that nuclei of the pollen and ovule unite to initiate the formation of a seed. The nuclei of the pollen grain and egg are much more similar in size than are the pollen grain and the egg themselves. Consider preparing a slide that contains both pollen grains and an egg and displaying it through the microvideo system, as shown in Figure 9.4.

6. When students complete this inquiry, revisit the similarities and differences between their larger flowers and the Fast Plants flowers.

7. Have students clean and dry their slides and move on to Inquiry 9.2.

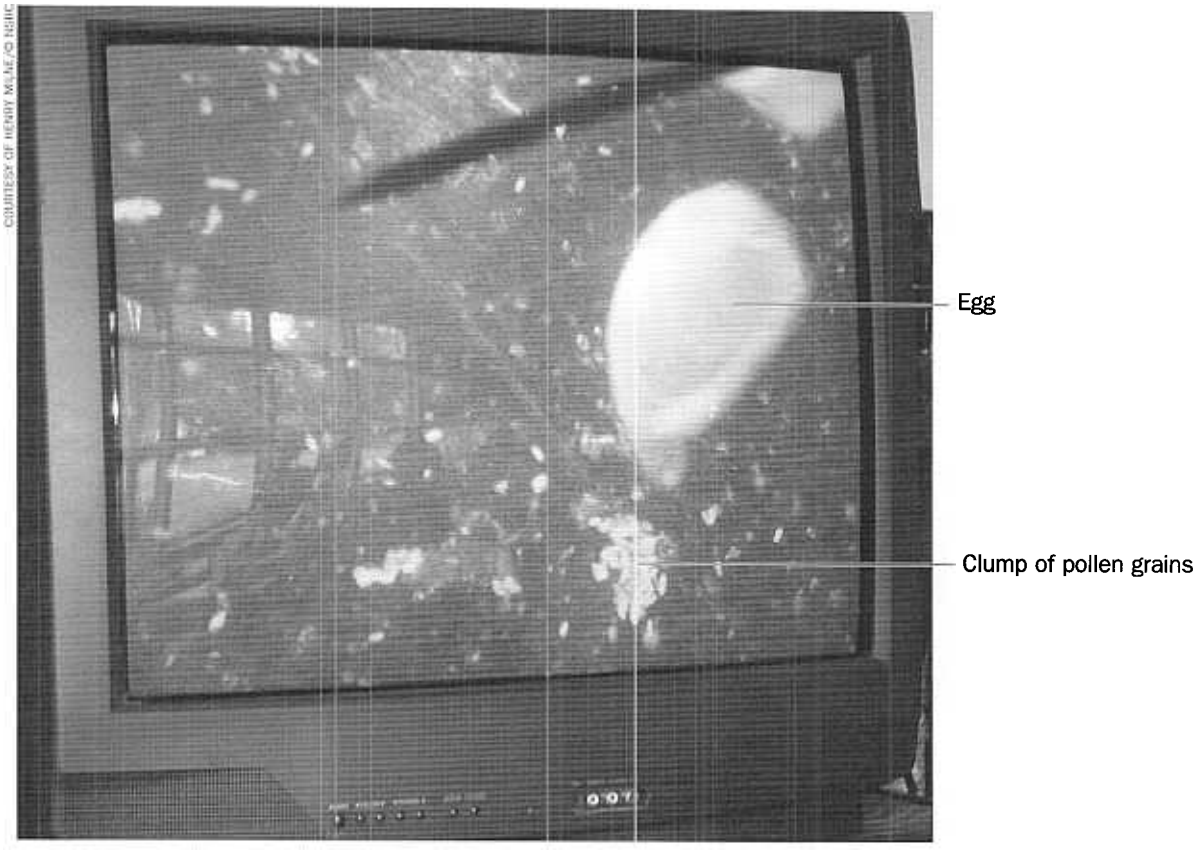


Figure 9.4 *Notice how large the egg is on the right side of the screen. The clump of pollen grains just below the egg is considerably smaller.*

Inquiry 9.2 Pollinating the Fast Plants Flowers

PROCEDURE

1. Go over Procedure Steps 1–4 with students. Emphasize the importance of pollination, and elicit from students how flowers are pollinated in nature. Discuss self- and cross-pollination and explain that Fast Plants require cross-pollination.

2. Take the following steps to demonstrate how students should work with their groups to pollinate the flowers without damaging them.

A. Gently roll the end of the cotton swab over the flower to pick up pollen, then carefully dab the swab onto the stigmas of flowers on different plants.

B. Use pollen from each plant to pollinate the flowers on the other five plants. Work in a circular pattern, as shown in Figure 9.5. Have students use a marker to number their plants from #1 through #6, beginning on the outside of the cup closest to them. Then ask students to proceed by obtaining pollen from plant #1 (the growing systems are labeled with numbers from a previous inquiry) to pollinate flowers on plants #2–#6. Next, have them obtain pollen from flowers on plant #2 to pollinate flowers on plants #3 and so on around to #1.

C. They can repeat this pattern until they have pollinated all of the flowers. Explain that it does not matter how many times the flowers are pollinated. In fact, the more times, the better. Numerous pollen tubes can grow down to the ovary from the stigma and, with Fast Plants, there are many ovules to be fertilized.

3. Explain that students will need to repeat this process for a few days for two reasons. First, new flowers will continue to open; second, each flower has a certain period of time in its development during which it is most receptive to pollination. Tell students that you will leave cotton swabs at the light boxes. A student from each group should pollinate the flowers as soon as he or she gets to class on the

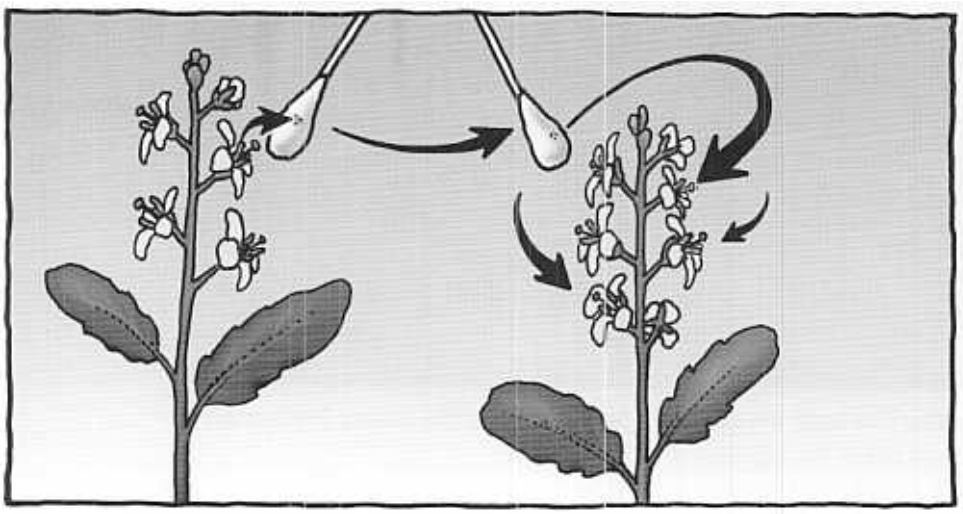


Figure 9.5 *Cross-pollinating Wisconsin Fast Plants flowers*

next few days. Students should agree on who will do this first and then should take turns so that each student has the experience. On the last day of pollination (usually 17 days after sowing) instruct students to pinch off any unopened flower buds.

4. To set the stage for learning about genetics, which begins in Lesson 18, have groups observe the stem and leaves of each of their Fast Plants for signs of purple pigment. Explain that even the tiniest tinge of purple means that the plant has produced that pigment. Have them record on a new page in their science notebooks how many of their Fast Plants contain the purple pigment.

NOTE As mentioned in Lesson 5, all of the Fast Plants seeds were of the F_1 generation for the purple pigment anthocyanin, having the genotype Pp. This means that the purple pigment, being dominant, should be expressed to some degree in all of the Fast Plants students have grown.

5. Give students a chance to update their Fast Plants organism photo cards. If they are unsure about what to write on the cards, elicit from them what they have learned about Fast Plants in this lesson. Ask them to list some of these things on their cards. You can expect responses such as: "have perfect flowers"; "cannot self-pollinate"; "flowers contain one pistil surrounded by several stamens"; and "Fast Plants are dicots." Help students identify which of the organisms they have encountered so far have cells that undergo meiosis to produce sex cells.

REFLECTIONS

Conduct a class discussion on the following questions, which students have answered on Student Sheet 9.1.

A. Using "The Wonder of Flowering Plants" as a reference, explain what happens inside the flower after pollination. (After pollination, a tube grows from the pollen grain down to the ovary. Sperm nuclei move down the tube and one unites with the egg nucleus of an ovule in a process called fertilization. This process begins the formation of a seed.)

B. What do you think will develop as the flowers wither? Hint: Think about the name of the structure that protects the seeds. (As the seed or seeds develop, the petals wither. A fruit develops which protects and helps in the dispersal of the seeds.)

C. Why do you think some flowers have so many pollen grains and ovules? (An abundance of pollen and ovules helps ensure that fertilization takes place and that a sufficient number of seeds is produced to ensure continuation of the species.)

HOMEWORK

Period 1

Have students read "The Wonder of Flowering Plants" at the end of this lesson in the Student Guide.

Period 2

Have students preview Lesson 6, Inquiry 6.2, which they will conduct during the next class period.

EXTENSIONS

■ **Language Arts**

1. Ask students to write a paragraph explaining how they think the expression "the birds and the bees" came about. Ask them to base their essays on what they read in "The Wonder of Flowering Plants."

■ **Science**

2. Have students research unique ways in which plants ensure that pollination takes place. Have them present their findings in poster form with illustrations and labels.

■ **Science** ■ **Careers**

3. Ask students to investigate the job of a horticulturist and submit their findings on one side of a page.

■ **Science** ■ **Technology**

4. Have students conduct research to see how scientists use biotechnology to cultivate more disease-resistant crops.

ASSESSMENT

Assessment for this lesson should be based on the student's ability to—

- Participate in the discussion and inquiries and adhere to directions.
- Contribute to the group discussion about the function of flowers.
- Explain the difference between perfect and imperfect flowers.
- Dissect a perfect flower, examine its structures, and identify the structures to you informally.
- Cross-pollinate all the Fast Plants flowers in the growing system.
- Offer responses that are consistent with your knowledge of his or her ability.

PREPARATION FOR INQUIRY 6.2

Purchase at a local grocery store a head of lettuce and enough spinach leaves to accommodate each group in all your classes. Each group of students will need pieces of spinach and lettuce that are about 5 cm × 5 cm. You will use them during Inquiry 6.2: Food Preferences of the Cabbage White Larva.

NOTE As you will read next, you will need lettuce for Lesson 10 as well. Consider buying lettuce for both lessons at the same time if there is no weekend or holiday between the lessons.

PREPARATION FOR LESSON 10 (ON COMPLETION OF INQUIRY 6.2)

Materials for Lesson 10

- 1 roll of 1″ dialysis membrane
- 1 roll of string
- 1 container of *Lemna* (duckweed)
- 1 head of lettuce*
- 1 clear plastic cup, 16 oz
- 1 kitchen knife*

1. Use a kitchen knife to cut a head of lettuce in half. Then cut one-half of the head of lettuce into pieces that are approximately 3 cm × 4 cm. Estimate the dimensions; exact measurements are not vital. Place the pieces into a plastic storage bag and refrigerate them until you bring them to school. Bring the other half-head of lettuce to school in case you run out of lettuce pieces.
2. Cut one 30-cm piece of dialysis membrane and one 12-cm piece of string for each group in each of your classes. Soak the membranes in a container of water until they are to be used by students.
3. Fill a 16-oz plastic cup with water. For each group in each of your classes, put in two *Lemna* leaves. For example, if you have eight groups in each of three classes, place 48 *Lemna* leaves in the cup of water.

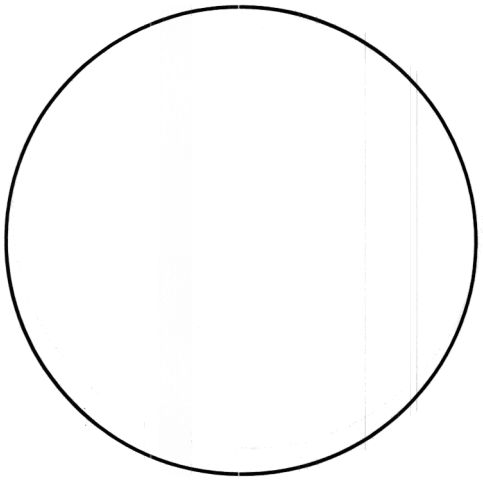
NOTE If you have not done so already, use the directions in Appendix E to prepare one growing system. Add the soil, but add neither seeds nor water. You will saturate the soil with water and fill the reservoir when your class does Lesson 10.

*Needed, but not supplied

Name:_____

Class:_____ Date:_____

Student Sheet 9.1
Template for Flower Drawings



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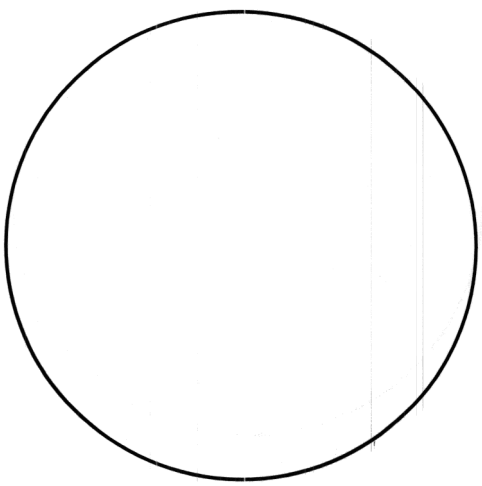

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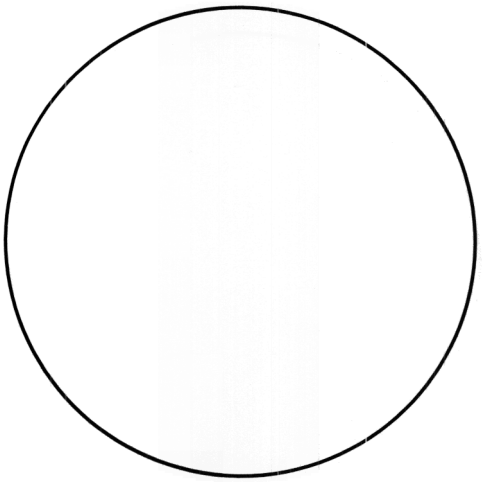
Student Sheet 9.1 (continued)



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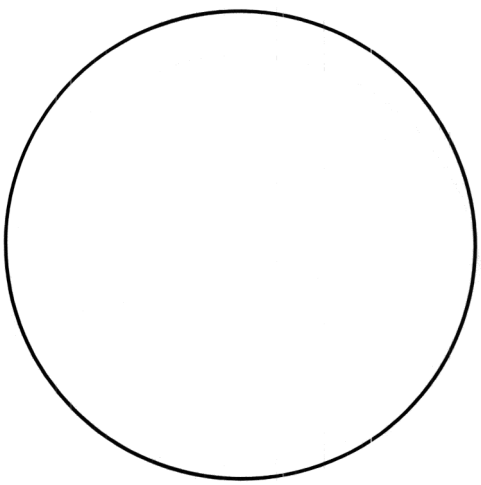

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Student Sheet 9.1 (continued)

Reflecting on What You've Done

A. Using "The Wonder of Flowering Plants" as a reference, explain what happens inside the flower after pollination.

B. What do you think will develop as the flowers wither? Hint: Think about the name of the structure that protects the seeds.

C. Why do you think some flowers have so many pollen grains and ovules?