Experiments With Plants: Student Activity Book (0)

National Science Resources Center

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Experiments with Plants

STUDENT ACITVITY BOOK

SCIENCE AND TECHNOLOGY FOR CHILDREN

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LESSON 1

What Do You Know about Experiments?

Think and Wonder

How do scientists find out about the world? For one thing, they perform experiments especially designed to answer a question or gather information. In this unit, you will be working as scientists to learn about Wisconsin Fast Plants™. But, before you begin, it is important for you to understand what makes a good experiment. You will be learning that it is a lot like a fair test. In the next lesson, when you begin designing your own experiment, you will want to make sure that it is a fair test.

Materials

For you

1 student notebook

Find Out for Yourself

1. For the next 6 weeks, you and your team will plan and carry out experiments using Wisconsin Fast Plants. Before beginning the experiments, you need to plan, read, and research. You also will need a notebook so that you can keep careful records of your experiments. Remember to date each entry that you make in your notebook.
2. How do scientists do experiments? What makes something a good experiment? Brainstorm about these ideas with your class.
3. To do a real experiment, you need to start thinking about it as a fair test. For example, if you wanted to plan an experiment to find out who the fastest runner in your class is, how would you set up the race fairly? What would have to stay the same for each runner in order to make it a fair test? What things could be different about each runner?
4. Next, show what you know about flowering plants by drawing and labeling the parts. Be sure to put today's date on the drawing. Keep it with your science materials and do not add to it later. It will be useful for you to look at it when you have completed this unit.

5. Now, share what you know about flowering plants with the class. Your teacher will record your ideas.

6. If you still have questions about what a fair test is, think about the following familiar situations:

   - What is the best way to study for a spelling quiz—with the television on or off? How could you find out? Design a fair test.
   - You spilled spaghetti on your shirt again. Mom says that the stain will come out, but only if you rinse it off with cold water immediately. There are a number of ways to find out if mother knows best. What kinds of experiments would you suggest?
   - You have noticed that your dog seems to like the free sample of a new dog food, which came in the mail. Design an experiment to find out if he really prefers the new brand to his old one.

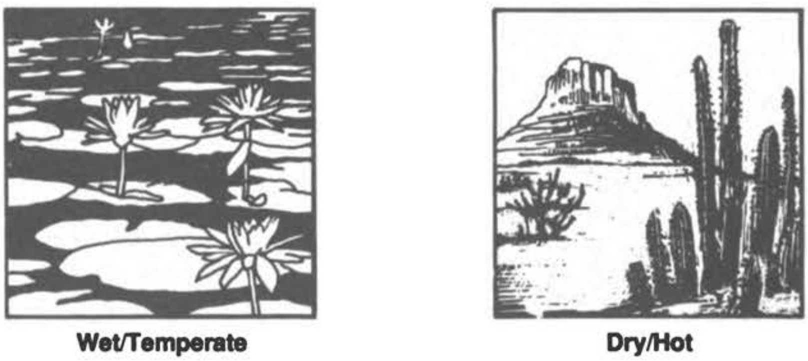
7. Keep these ideas in mind as you read about the *Brassica* plants, which you will be using to design experiments. (See pgs. 4 and 5.) What do these plants need to grow best? What kind of experiment might you do? How would you make that experiment a fair test?

Ideas to Explore

1. There are many different kinds of plants in the world. Each plant needs special conditions to grow well. Keeping this in mind, think about the following question: What would happen if you did an experiment in which you put a cactus in a pool and a water lily in the desert? What changes would you observe in each plant?

Figure 1-1

Where do water lilies and cacti grow?



2. The plant world is full of interesting curiosities that all have their own special requirements. Do some research in the library to find out more about these strange but wonderful things:

   - Giant saguaro cactus
   - Rafflesia
   - Foxglove

- Coconut
- Venus flytrap
- Popcorn
- Horsetails

Reading Selection

Fast Plants for Fast Times

The Wisconsin Fast Plant™ is the plant you will be using for your experiments in this unit. It took Dr. Paul Williams, who is a professor and researcher at the University of Wisconsin, about 15 years to develop it. Fifteen years may seem like a very long time to spend breeding a plant, but think of all that he accomplished. Through selective breeding, Dr. Williams was able to speed up the plant's life cycle, making it ten times faster than that of its ancestors. Today, this small yellow-flowered plant whizzes through its entire life cycle, from seed to seed, in just 6 weeks.

Dr. Williams had an interesting reason for wanting to develop a fast plant. He is a plant pathologist, and his job is to study plant diseases and to find out if some plants inherit the ability to fight off diseases. In order to speed up his work, he needed a fast-growing plant to use in his studies.

Dr. Williams started with a world collection of more than 2,000 *Brassica* seeds and planted them in his laboratory using planting, lighting, and watering equipment almost exactly like what you will use. He observed that, out of the 2,000, only a few plants flowered much sooner than others. He took advantage of these exceptional plants by cross-breeding them. These few would be the parents of his next generation of plants. Dr. Williams wondered what kind of offspring these faster flowering parents would produce. Would the offspring inherit the ability to flower earlier than the average *Brassica* plant?

Yes! In fact, a few of the new plants even flowered a little faster than the parent plants. These slightly faster offspring were then cross-pollinated, becoming the parents of the next generation.

Dr. Williams continued to use this method of selective breeding for years. He grew populations of 288 or more plants in each generation. He cross-bred the earliest flowering plants of this population and used their seeds to grow the next generation. In each new generation, he found that about 10 percent of the plants flowered slightly earlier than their parent generation had.

The selective breeding project was a grand success. The result is what is now known as Wisconsin Fast Plants™. Besides developing a 6-week growth cycle, Dr. Williams was able to breed in other desirable qualities that make the plant a nearly ideal laboratory tool. Some outstanding traits of these plants are:

- They produce lots of pollen and eggs, resulting in many fertile seeds.
- Their seeds do not need a dormancy (or rest) period, so they can be replanted immediately.
- The plants are small and compact.

- They thrive in a crowd.
- They grow well under constant light.

Wisconsin Fast Plants have become important laboratory research tools all over the world. Soon they will be part of National Aeronautics and Space Administration's space biology program. But most exciting of all, these special plants are becoming part of school science programs across the country, from the elementary to the university level.

Reading Selection

What Do Wisconsin Fast Plants Need to Grow Best?

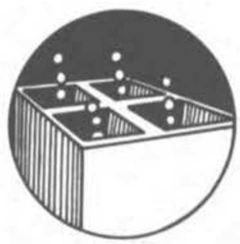
You are about to meet a unique member of the plant world, Wisconsin Fast Plants™. *Brassica rapa* is the scientific name. For the next 6 weeks or so, you will be working very closely with these plants, observing and measuring them through all the stages of their life.

These remarkable little plants will sprout, or germinate, develop leaves and buds, flower, produce pods filled with seeds, and die—all within about 6 weeks. They are not called "fast" for nothing! To fully appreciate how quickly all of this happens, look at the calendar on pg. 8.

Because Wisconsin Fast Plants are unique, it is not surprising that they have some unusual requirements for growth and development. Let's look at each one of them in detail.

- **Light**
  The *Brassica* needs 24 hours of continuous light. Not only that, the light must come from cool, white, fluorescent bulbs.

- **Fertilizer**
  The regular dose is three fertilizer pellets per planter quad cell.



- **Space**
  One plant per planter cell is the spacing recommendation to achieve the best growth.

- **Pollination**
  In order for the plants to produce seeds, pollen must be transferred from one plant to another. This is known as cross-pollination.

- **Temperature**
  The plants do best when the temperature stays between 70°F and 80°F (21°C to 27°C).

- **Water**
  The plants require a continuous supply of water. They must not be allowed to dry out for more than a few hours.

These six factors—light, fertilizer, space, pollination, temperature, and water—are very important to the health and productivity of the plant. Scientists call them **variables**—conditions the plants need for growth.

Are some variables more important than others? Exactly how does each of the variables affect the plants? What will happen if you change one of the variables?

During this unit, you will be designing an experiment by changing one of these variables. Which one would you like to work with? Remember, the first step in planning a good science project is asking a good question that you can answer yourself by experimenting.

Life Cycle of a Normal *Brassica* Plant

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	0 DAY 0... PLANTING DAY	1	2 DAY 2 –COTYLEDONS	3 OR 3... EMERGE –	4 DAYS 4, 5, –FIRST TRUE LEAVES	5 OR 6... EMERGE –
6	7 ...DAYS —FLOWER	8 7, 8, OR BUDS	9 9.... APPEAR—	10 ...DAYS —GROWTH	11 10, 11, OR 12.... SPURT	12
13	14 DAYS	15 14	16 ....TO.. POLLINATION	17	18 ......18...	19 DAYS 19.....
20	21	22 DAYS 19 TO 35	23 .... SEED PODS	24 .... DEVELOP	25	26 ....
27	28	29 .... SEED	30 .... PODS DEVELOP	31 DAYS 19 TO 35	32	33 ....
34 .... SEED PODS	35 ... TO 35 DEVELOP–					

LESSON 2

Identifying Variables and Planning a Fair Test

Think and Wonder

A worthwhile experiment requires planning. In fact, planning is the most important stage in experimentation. Today, you will take the first steps toward planning a good experiment.

Two major ideas will have to come together in order for you to design the experiment well. These ideas are:

- Several different variables determine how well Wisconsin Fast Plants™ grow.
- A successful experiment is a fair test.

By the end of this lesson, you will be well on your way to planning an experiment that is a fair test of how one of the variables affects the life of Wisconsin Fast Plants.

Materials

For you

1 student notebook
1 **Activity Sheet 1A, Planning Work Sheet**

For your four-member team

1 **Activity Sheet 1B, Directions for Using the Planning Work Sheet**
1 piece of paper
1 pair of scissors

Find Out for Yourself

1. What are all of the things that Wisconsin Fast Plants need to grow? Discuss your ideas with your class. Your teacher will make a list of your ideas.
2. Now, let's think about each idea. What are all of the things that Wisconsin Fast Plants need to grow **best**? Discuss these conditions, or variables, with the class. Refer to the **Reading**

Selection on pg. 6 in Lesson 1 for more information about each of these variables. Each of them will play a part in your experiment, so it is important to understand each one.

Today you will become part of a four-member team that will have four complete quads (or sixteen plants) to work with. Two quads should be labeled control plants, and two should be labeled experimental plants. The control plants will be grown under the ideal conditions and will develop normally. The experimental plants will be grown according to the experimental plan your team designs. Today your team will begin designing an experimental plan to test one variable.

3. Pay close attention while your teacher shows you how to use the planning board to come up with your plan.
4. Now, join your team to work together on **Activity Sheets 1A** and **1B**. Follow the directions carefully. Discuss as many variables as possible in the time that your teacher gives you. These discussions should help your team decide which variable to focus on during the experiment.
5. Be ready to share with the class your ideas about which variable might be changed to make a good experiment. In all of your discussions about variables, try to remember that you are trying to plan an experiment that will be a "fair test" of one variable. The way to do that is to change only one variable in your experiment and to keep all of the other variables unchanged.
6. For the next day or two, you need to think about the project. Give yourself time to reflect on different ideas before you select the one that will become the topic for your major experiment. Discuss your ideas with various people: your parents, classmates, teammates, and teacher. Ideas that are shared have a way of growing and blossoming!
7. You also need more information. Read about the life cycle of Wisconsin Fast Plants on pgs. 12 to 15. It will help you learn what to expect of a normal, nonexperimental plant. You should think about why this is important if you are going to conduct an experiment.

Ideas to Explore

1. Do more research on the life cycles of plants and the effects that their environmental conditions have on them. Topics to investigate include:
   - How acid rain is damaging trees
   - How the salt put on roads in winter in some parts of the country affects grasses and other plants
   - How pollutants in the air affect lichens growing on trees
   - How long it takes plants to recover after a forest fire

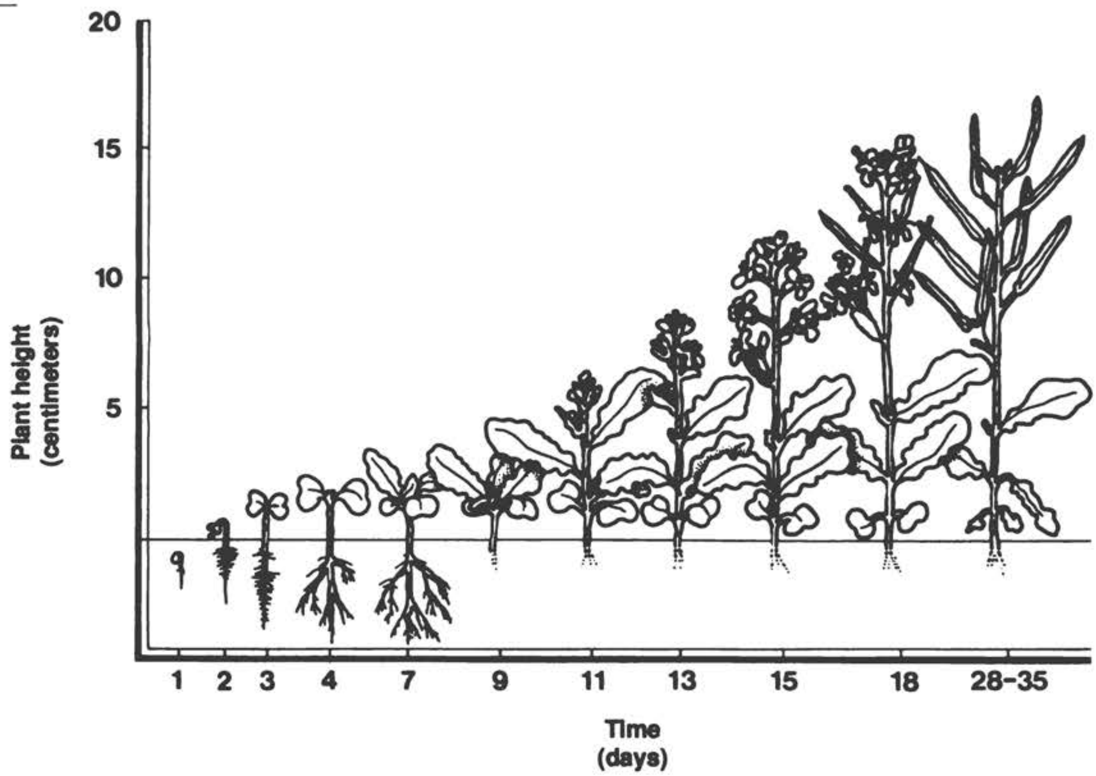
2. Read to find out more about the way in which the scientific method works. A good book on the subject is *How to Think Like a Scientist: Answering Questions by the Scientific Method* by Stephen P. Kramer.

Reading Selection

Figure 2-1

Growth chart of Wisconsin Fast Plants

The Life Cycle of Wisconsin Fast Plants



In Lesson 1, you read about what Wisconsin Fast Plants™ need to grow. Now, read about how they grow under ideal conditions. In a remarkably short time, the plants speed through all of the stages in their life cycle.

The tiny root is the first part to emerge from the seed, usually within 24 hours of planting. About 4 hours later, the two **seed leaves** (also known as **cotyledons**) appear above ground. At first, the heart-shaped seed leaves are white, but soon they become green and take on the job of making food for the seedling until the **true leaves** develop fully (at about Day 7).

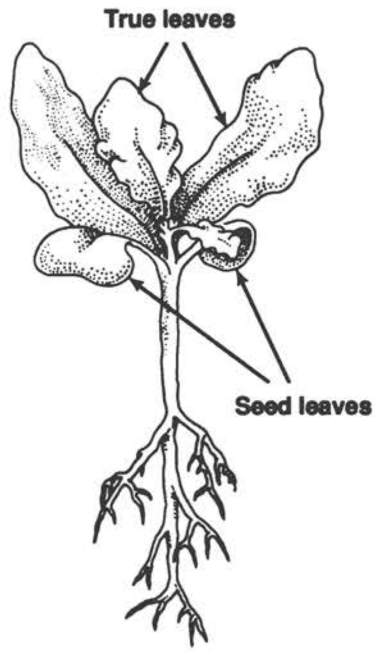
On Day 4 or 5, the true leaves look like tiny lumps at the growing tip of the plant, between the seed leaves. As they grow, they look quite different from the seed leaves but have the same job: food production. The true leaves continue to emerge over the next several days and grow very rapidly in size.

Soon after the first true leaves have developed fully, the **flower buds** appear (Day 8 or 9). Look for them clustered at the growing tip of the stem. The buds are closed tightly and are greenish-yellow, sometimes tinged with purple. In another day or two, the buds will open to reveal bright yellow, four-petaled *Brassica* flowers.

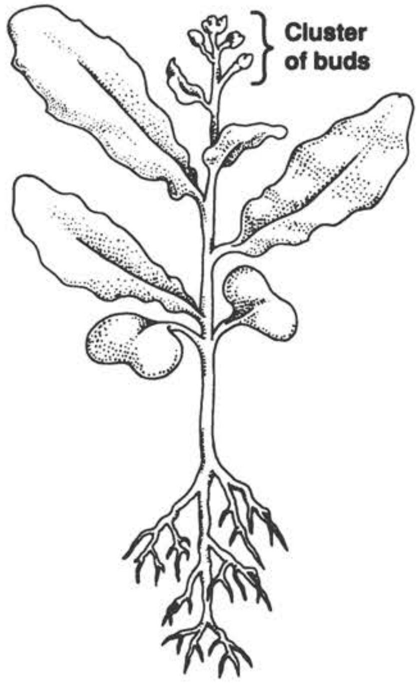
The second week of life is a time of enormous activity for the plant. Besides growing buds and enlarging leaves, the plant also is going through an upward growth spurt, much as humans do during

Figure 2-2

The growth of leaves and flower buds



From Days 4 through 7, the true leaves continue to emerge and grow at a remarkable fast pace



By Day 8 or 9, the yellow-green flower buds appear in a tight cluster

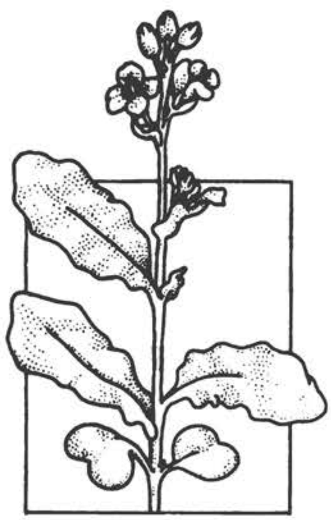
adolescence. Sometime between Day 9 and Day 13, the plant's stem will grow longer between the places where the leaves are attached.

From Day 13 to Day 18, the flowers are fully open, ready for pollination to take place. In nature, this is best done by a bee. For Wisconsin Fast Plants, **cross-pollination** is necessary in order for the plant to produce fertile seeds. This means that pollen from the male part of one plant must be moved to the female part of another plant. You will read more about pollination in Lessons 6 and 7.

Figure 2-3

The plant's growth spurt

Before growth spurt



After growth spurt

After the transfer of pollen from one plant to another, the flowers begin to change. The petals fade, wither, and fall. The eggs inside the **pistil** are developing into seeds. The pistil, now called the **seed pod**, grows longer and swells as the seeds continue to grow over the next 20 days. During this time, there is very little upward growth because the plant is putting its energy into seed production.

Figure 2-4

A plant with mature pods

At about Day 35, the plant is removed from the watering system and allowed to dry out so that the seeds may ripen. After about a week, the pods can be snapped off and the seeds removed. The life cycle is complete: the plant has grown from seed to produce its own seed, and now the new seed can be planted to begin the life cycle, once again.

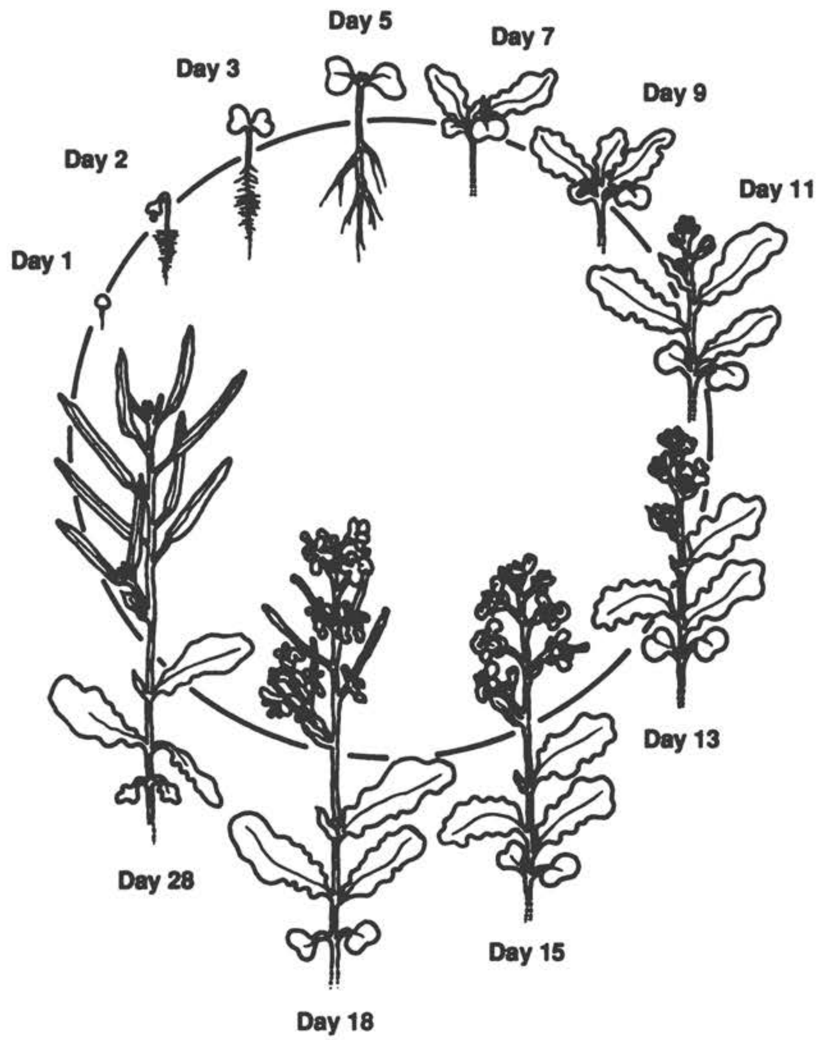
The *Brassica* plants will grow in this way if they have ideal conditions. Keeping this in mind, what do you think would happen if:

- the plants were shielded from the light for 3 hours a day?
- the plants got no fertilizer?
- the plants got twice as much fertilizer as required?
- the temperature went down to 45°F (7°C) for 6 hours every night?
- the temperature were kept at 90°F (32°C)?
- the plants were overcrowded?
- the blossoms were not pollinated?

Do you think that changing one variable would make a difference in the life cycle of the plant? How might the plants be different? How might their life cycle be slowed down or speeded up? Would they still produce flowers? Would they still produce seeds? What do you think?

Figure 2-5

The life cycle of the Brassica *plant*



LESSON 3

Outlining the Experimental Plan

Think and Wonder

In Lesson 2, you learned to identify the variables in an experiment and realized that only one variable may be changed at a time. All of the other variables must be kept unchanged for the experiment to be a fair test.

In this lesson, you and your teammates will plan your experiment in more detail. You will decide on a specific question to investigate and on who will grow control plants and who will grow experimental plants.

Also, you will discuss with your class the importance of keeping records throughout a scientific experiment.

Materials

For you

1 student notebook
1 **Activity Sheet 1A, Planning Work Sheet** (from Lesson 2)
1 **Activity Sheet 1B, Directions for Using the Planning Work Sheet** (from Lesson 2)
1 **Daily Data Record** (optional)

For your four-member team

1 **Activity Sheet 2, Outlining the Team's Experiment**
Glue

Find Out for Yourself

1. Take out **Activity Sheets 1A** and **1B** and join your teammates for this next set of activities. Pick one person from your team to record the plan for your team's experiment.
   - Decide on the one variable your team will test in its experiment. Then glue that variable in place under the heading on your **Activity Sheet 1A**, "Variable we will test."
   - Where should the rest of the variables go? Under the heading on your **Activity Sheet 1A**, "Variables we will not change." The team's recorder should glue those in place, too.

2. Your team must make another important decision today about how to manage the four quads (containers) of plants you will use in your experiments. You have several choices:

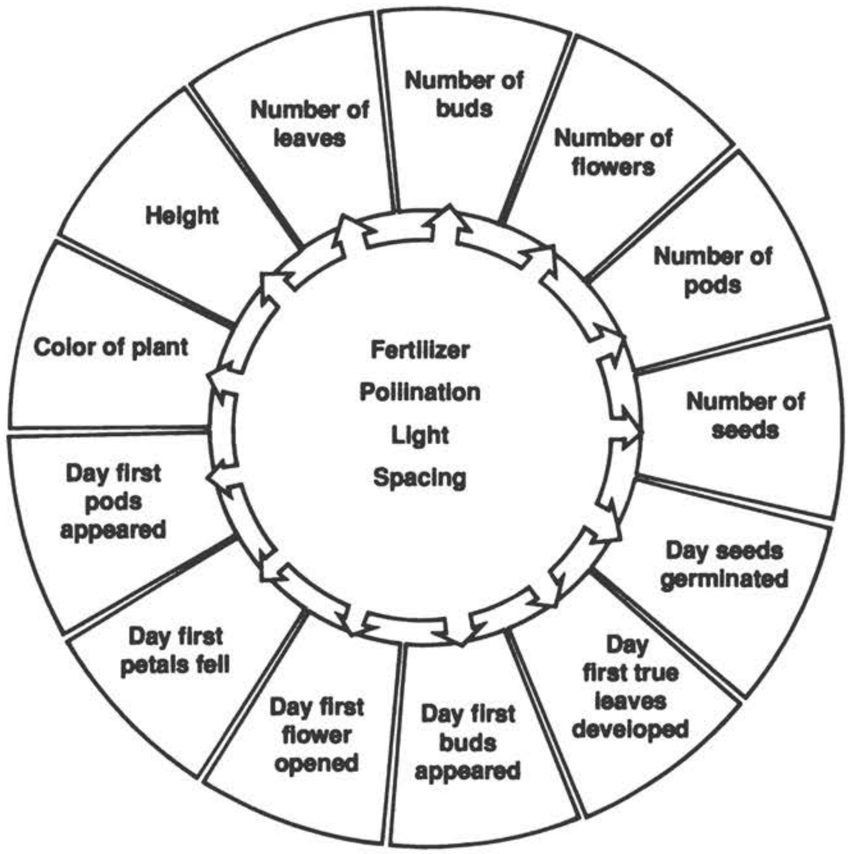
   - Each person on the team could be exclusively responsible for taking care of and keeping records for one set of four plants (a quad). This means that your team would divide itself into two researchers who will be responsible for the two sets of experimental plants for the team and two researchers who will be responsible for the control plants. All members of the team would share information with each other and fill in for each other in case someone is absent.
   - Your team could divide the caretaking and recordkeeping responsibilities as outlined above, but then switch places halfway through the project.
   - Your team could work out its own rotating schedule for taking care of keeping records on the plants.

   How will your team do it?

3. Next, your class will discuss how to come up with a good question or problem to investigate. It is important to come up with a question that is well focused. Use the chart in Figure 3-1 to help guide your discussion.

Figure 3-1

How could each of the variables affect the plants?



4. Return to your team and discuss the specific questions related to the experimental variable that you might investigate. Take your time and focus on a good, solid, interesting topic. Remember, you are going to have to live with it for about 6 weeks. Once you have decided on a specific question to investigate, record it on **Activity Sheet 2, Outlining the Team's Experiment**.

5. Follow the directions to complete the rest of this activity sheet. It will help you think more clearly about the question your team will investigate. When you have finished, turn in your outline to your teacher for review.

6. Before the end of the class, your teacher will distribute copies of the **Daily Data Record** or show you how to set up your student notebook to keep daily records. Do not forget to date each entry in your notebook.

7. Think ahead:

   - Why is it important for you to keep careful daily records of your experiment?
   - What are some of the important things to observe every day?
   - What are some of the parts of your plants that you might count or measure each day?
   - What are some of the "firsts" you could record? (Hint: Such as the first true leaf.)

8. The next time you work with this unit, it will be planting day. To help you get ready, read the following directions for planting. The same directions are on **Activity Sheet 3**, which you will be using on planting day.

How to Plant *Brassica* Seeds

1. Pick up all of your **supplies** from the distribution station. Be sure that you and your partner have these items before you begin planting:

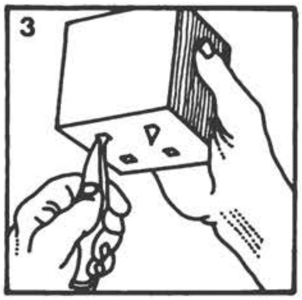
1	tray	8	seeds*
1	planter quad	1	toothpick
1	spoon	1	planter label
1	cup of potting mix	1	paper towel
4	wicks	1	pair of forceps
12	fertilizer pellets*	1	dropper

*If you are experimenting with **fertilizing** or **overcrowding**, fill in below the number of fertilizer pellets or seeds you are using:

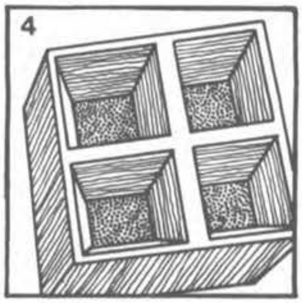
☐ fertilizer pellets

☐ seeds

2. Number each **cell** of the planter quad from 1 to 4.
3. Place one **wick** in each cell of the planter quad. Use your forceps to pull the wick through the hole until the tip sticks out about 1 centimeter (¼").

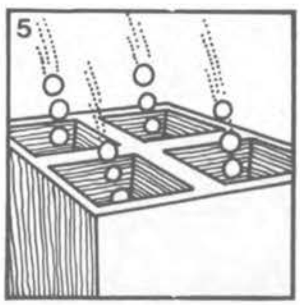


4. Using the spoon, fill each section of the planter quad halfway with **potting mix**.

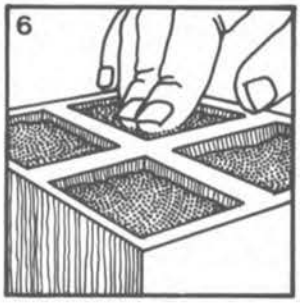


5. If you are not experimenting with fertilizer, add three **fertilizer pellets** to each cell. Look closely. The fertilizer pellets are much larger than the seeds.

*If you are experimenting with fertilizer, add to each cell the number of pellets called for in your experimental plan.



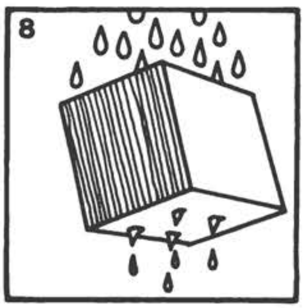
6. Fill each cell to the top with **potting mix**. Press it down a little with your fingers.



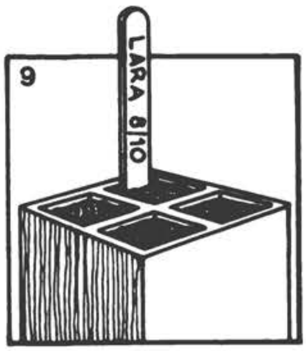
7. Put a drop of water on your tray and dip your toothpick in it. Use the wet toothpick to pick up one **seed**. Place the seed just below the top of the soil in one cell and cover it. Plant a second seed in this cell in the same way. Repeat until there are two seeds in each cell of the planter.

   *If you are experimenting with overcrowding, plant in each cell the number of seeds called for in your experimental plan.

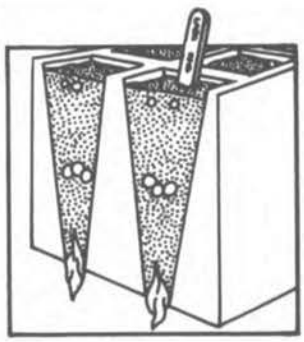
8. Using the dropper, **water** very gently, a drop or two at a time, until water drips from the bottom of each wick.



9. Write your name, today's date, and either E (for experimental) or C (for control) on the **label** and place it in the planter.



10. Place your quad under the lighting system with the label facing out. Double-check to ensure that your planter is completely on the **water mat**.



LESSON 4

Planting the Seeds

Think and Wonder

During this lesson, each of you will plant one set of seeds in a four-celled container called a quad. The success of the rest of your project depends on planting correctly today. Be sure that you and your teammates all understand the plan for your team's experiment.

Some of you will plant according to the standard directions. But if you are testing the effects of over- or underfertilizing your plants, or if you are experimenting with overcrowding, some members of your team will plant in a different way, depending on your team's plan.

Materials

For you

1 student notebook

For you and your partner

1 pair of forceps
1 cup of water
1 dropper

For each student planting according to the standard instructions

1 **Activity Sheet 3, How to Plant Wisconsin Fast Plants™ Seeds: Instructions and Checklist**
1 tray for carrying supplies
1 planter quad
1 5-ounce cup of potting mix
12 fertilizer pellets
1 toothpick
1 paper towel
1 spoon
4 wicks
8 seeds (2 per quad cell)
1 planter label

For each student experimenting with fertilizer

You will need all the standard material and should follow the standard instructions **EXCEPT** that you should use only the amount of fertilizer called for by your team's experimental plan. The amount will be either more or less than the standard amount, which is twelve pellets.

For each student experimenting with overcrowding

You will need all the standard material and should follow the standard instructions **EXCEPT** that you should use only the number of seeds called for by your team's experimental plan. This amount could be eight seeds (the standard amount), in which case the team will not thin out the plants in Lesson 5, and will leave them overcrowded. Or the amount to be planted could be more than eight seeds in a quad.

Find Out for Yourself

1. Before planting, read all of the instructions on **Activity Sheet 3, How to Plant Wisconsin Fast Plants™ Seeds**. Ask questions about anything that is not clear.
2. Now fill in the blank boxes on the instruction sheet with the numbers of fertilizer pellets and seeds you are using if you are experimenting with fertilizing or overcrowding.
3. A team experimenting with the fertilizer variable will give a very brief explanation of its project. Make a prediction about what **you** think will happen to plants that are underfertilized. How will they differ from the plants that are given the standard amount? How will they differ from the plants that are given more than the standard amount?
4. The team experimenting with the overcrowding variable also will give a very brief explanation of its project. Make a prediction about what you think will happen to the plants that live in overcrowded conditions. What will those plants have to share?
5. Pick up your supplies following your teacher's example. Now, follow the directions for planting very carefully. They are found on **Activity Sheet 3**. Be sure that the fertilizer goes in first, not the seed. If you do not understand something, stop! Ask your teacher or a teammate for help.
6. When you have finished planting, return all of the leftover supplies to the distribution station. Then clean up your work space. Do your fair share.
7. Record today's activity in your student notebook. Remember to include the date you planted the seed.

8. Another experiment will start tomorrow to determine the effects of reducing the hours of light that the plants get. This experiment will bring up some interesting questions. For example:

    - How many hours of light will the experimental plants get each day?
    - How would you prevent light from shining on the experimental plants?
    - What will you do with the control plants?
    - What would you do about weekends?
    - How many hours of darkness do you think will make a difference?

Listen while the team experimenting with the effects of reduced light tells you about their project. Maybe you can offer some suggestions.

Predict what you think will happen to these plants.

LESSON 5

Thinning and Transplanting (Day 4 or 5)

Think and Wonder

Today, most of the class will thin their plants to one per cell. This is the ideal growing condition. Other students—those who chose to experiment with overcrowding—will not thin and will leave their quads overcrowded according to their experimental plan.

Materials

For you

1 student notebook
1 toothpick
1 sheet of graph paper

For you and your partner

1 hand lens
1 pair of forceps

Find Out for Yourself

1. Why does a gardener thin out a row of seedling carrots? Why would you transplant a sun-loving rose bush to a new location? Be ready to discuss these questions.
2. Know what you are supposed to do today. Different teams will be following different plans. Be sure you know your team's plan before you do anything.

Overcrowders

If your team is trying to find out what happens to the plants in overcrowded conditions, be ready to explain your plan to the rest of the class very briefly. For example:

- Tell the class how many seedlings you will be keeping in each cell.
- Mention your control plants and how they will be grown.
- Invite your classmates to predict what they think will happen to the overcrowded plants.

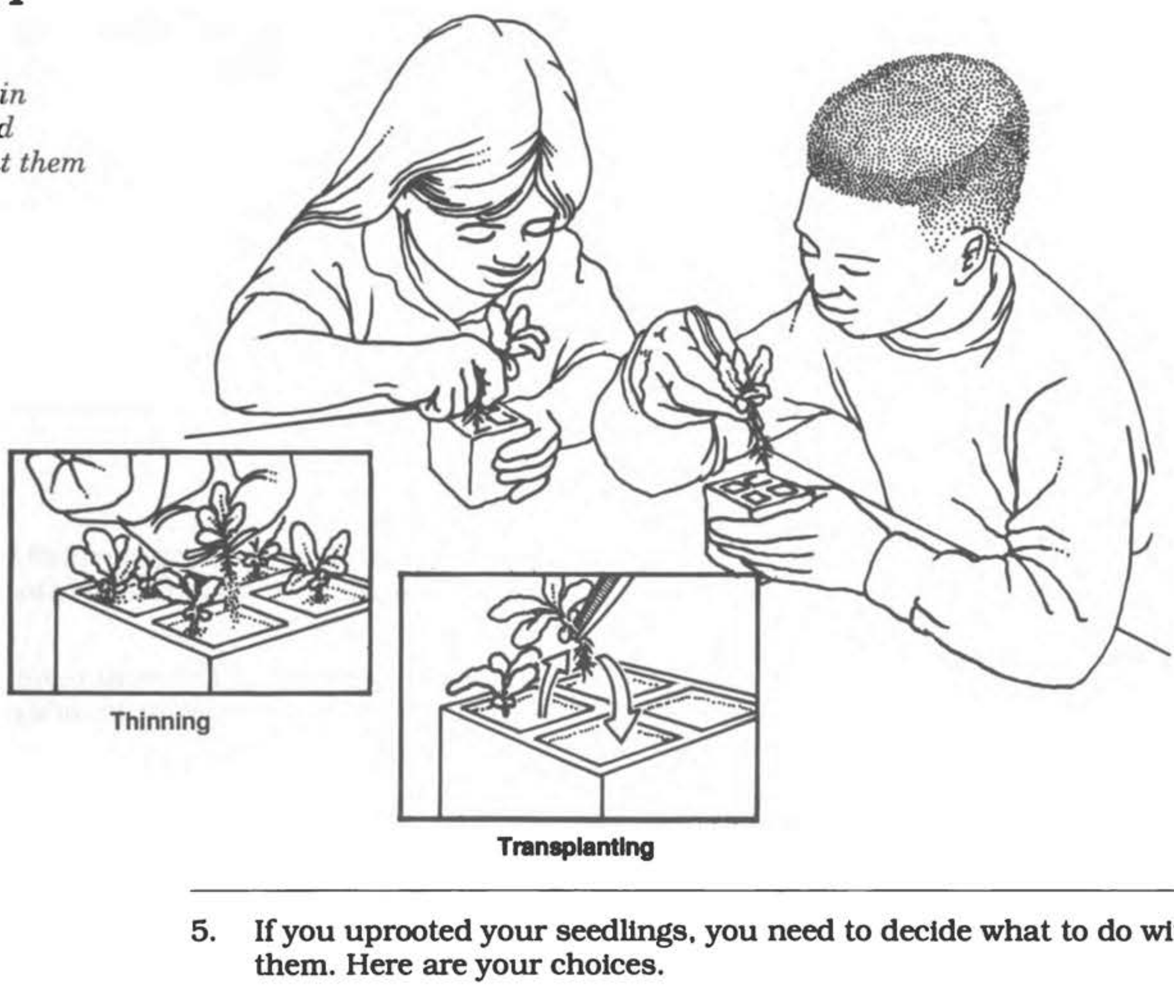
3. Next, everyone should pick up their plants and spend a few minutes observing them with the hand lens. Notice that, even at this very early stage, there are differences among plants.

4. If your team is not an **Overcrowder**, decide which one plant from each cell you will keep and which plants you will thin out. At the end of the activity, you should have one plant in each cell, for a total of four plants in your planter.

   Working carefully to avoid injuring the seedlings, use the toothpick to loosen the soil around the seedling you intend to take out. Poke a hole about 2 cm deep (your pencil point up to the paint) in the soil of the container where the seedling will go. Use the forceps or your fingers to lift out the seedling very gently with its roots attached, and place it in the hole you have prepared. Pat the soil down a little around the roots of the newly transplanted seedling.

Figure 5-1

How to thin plants and transplant them



5. If you uprooted your seedlings, you need to decide what to do with them. Here are your choices.
   - Transplant them into one of your cells where no seeds germinated.
   - Donate them to a classmate, or place them in extra quads that your teacher prepared.

- Set one aside, to observe its root system later.

6. Clean up. Discard any plants that cannot be used, or, with your teacher's permission, wash them off and take a bite! Put the equipment back. Throw away trash.

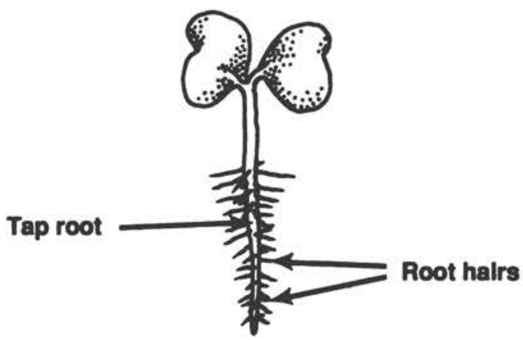
7. Record today's activities and observations in your student notebook. Make your entry as complete as possible and date it. Here are some hints about what to include: descriptions, drawings, leaf counts, and measurements of height. This is a good time to begin recording the plant's growth on graph paper.

Ideas to Explore

Today is your only opportunity to look at the root system of the *Brassica*. Use your hand lens to observe closely. Find the tap root, the main root from which smaller roots grow, and the root hairs.

Figure 5-2

Tap root of the Brassica *plant and root hairs*



LESSON 6

Getting a Handle on Your Bee

Think and Wonder

Have you ever looked at a bee very closely? Today, you will do exactly that. Then you will glue the bee to a toothpick to make a bee stick for pollinating your plants as soon as the blossoms open.

Those of you who are not pollinating will be able to observe the bee, even though you will not make a bee stick. In addition, you will need to get ready to prevent pollination of your experimental plants when the flowers open.

Materials

For each student pollinating

- 1 student notebook
- 1 dried bee
- 1 toothpick
- 1 tray
- 1 **Activity Sheet 4, How to Make a Bee Stick**
- 1 hand lens

For each four-member team pollinating

- 1 small cup of white glue
- 1 paper cup

For each four-member team not pollinating

- 1 dried bee
- 1 hand lens
- Recycled materials for constructing the pollination prevention barriers
- Reading materials on pollination, if available

Find Out for Yourself

1. Are you a pollinator or a nonpollinator? Look for the set of directions you should follow.

Pollinators

- Your teacher will give you copies of **Activity Sheet 4**.
- Pick up your supplies. Follow the directions on **Activity Sheet 4** to make a bee stick. When you have finished, your bee will have a "handle."
- Take the time to examine the bee closely with a hand lens. How many of its body parts can you find? Which body parts do you think are involved in pollination?

  Note: Some bees may be damaged and may not have all of their parts. Ask a classmate to share if your bee is not complete.
- Push the bee stick into the top of the upside-down paper cup that your teacher put at your work space. Your teacher will store the bee sticks in a safe place.

Nonpollinators

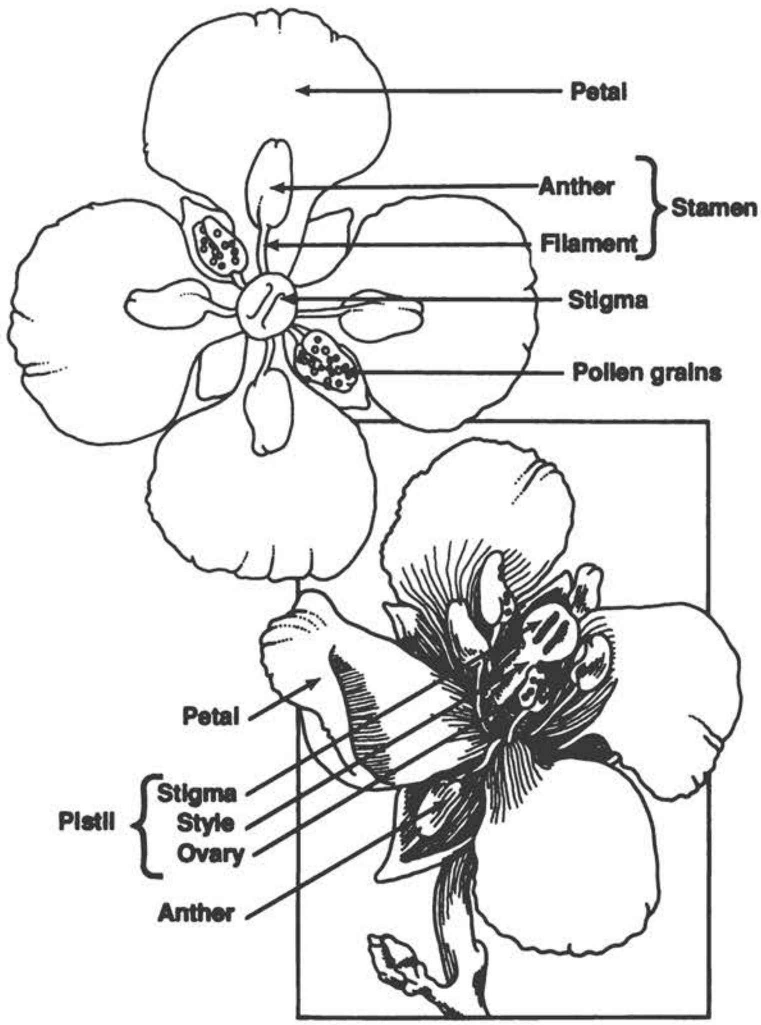
- You have three different tasks today: to observe the bee, to do more research on pollination, and to build a pollen barrier. You and your teammates should have a plan for how you will prevent pollen from traveling from plant to plant. Be sure that you understand all of your tasks for today before picking up your supplies.
- Pick up your supplies for observing the bee and building a pollen barrier.
- Take the time to examine the bee with a hand lens closely. How many of its body parts can you find? Which parts do you think are involved in pollination?

  Note: Some bees may be damaged and may not have all of their parts. Ask a classmate to share if your bee is not complete.
- Become the class experts on pollination. Read the **Reading Selection** on pg. 40 in Lesson 7, as well as anything else you can find on pollination.
- Following your team's plan, construct barriers between your plants to prevent pollen from moving accidentally from one plant to another. Remember to put the barriers in place before the buds open into flowers.
- Be prepared to give the class a brief summary of your experimental plan during the next class.

2. Clean up. Do your fair share.
3. Be ready to report some of your observations about bees when your teacher projects the overhead transparency of the bee's body.
4. If you haven't already done so, read more about bees on pg. 35.
5. Very soon, the buds on your plants will be opening into bright yellow blossoms. Use a hand lens to examine closely the parts of the flowers. Are you interested in learning the names of these parts? Figure 6-1 illustrates the *Brassica* flower with its parts labeled.

Figure 6-1

The Brassica *flower*



6. Remember, those students experimenting with the pollination variable should be ready to give a brief description of their experimental plan to their classmates during the next lesson.
7. Remember to continue keeping daily dated records of your observations. Include information on the size, number, and color of leaves, on your plant buds, and on the height of the plant.

Ideas to Explore

1. Bees are fascinating! There are many excellent books about them. Here are some ideas for research in the library.
   - Find out more about the three types of honeybees: the queen, the drone, and the worker.
   - Each type of bee has a body especially suited for its job in the hive. Compare the three types of bodies.
   - The bee goes through four distinct stages in its life cycle: egg, larva, pupa, and adult. Read more about each stage.
   - How does a bee see, hear, taste, smell, and touch?
   - How does a bee make honey?
   - How does a bee communicate by dancing?
   - Why is the bee important to people?
2. Use junk and recycled materials to make models of honeybees and *Brassica* flowers based on your research and your own observations.
3. This is a challenge! Can you think of any "bee-related" music? Bring it in to play while the class pollinates.
4. Go on a field trip to the playground. Collect, examine, then release any insects you find there.

Reading Selection

Bees

What do you already know about bees, besides the fact that they make delicious honey and have a painful sting? There is a lot to know about bees, and there are many excellent books about them. Here's a bit of information about them.

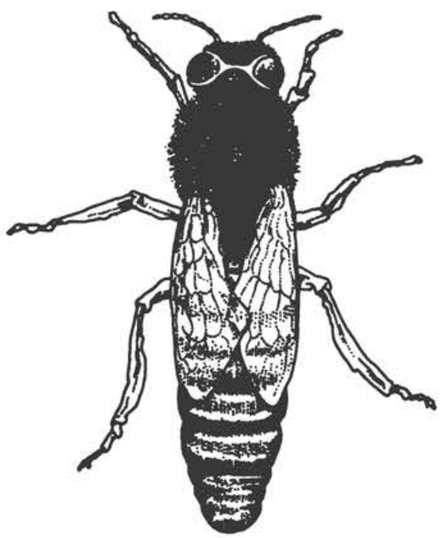
The bee is an important contributor to life on earth. Bees produce honey and wax and play a major role in the pollination of flowering plants. Pollination is the process by which pollen is transferred from the male part of one plant to the female part of another plant, allowing fertilization and seed production to take place. (More about pollination is coming up in Lesson 9.)

The honeybee is a social insect: it lives in a remarkably well-organized colony where every bee has a particular type of work to do. The colony, or hive, consists of three types of bees: the queen, the drones, and the workers (the kind used in this unit). Each type of bee has the same three-part body plan—the head, the thorax, and the abdomen. But because each bee has a different job to do, parts of their bodies have become highly specialized. Below are brief descriptions and illustrations of the bees in a colony and some of the jobs they each do.

The Queen   Life span: 3 to 5 years

The queen bee is the largest bee in the hive and the only one of her kind. She is an egg factory, capable of laying about 1,500 eggs in a single day. She takes one "mating flight" during which she is fertilized for life by a male bee or drone. She is pampered, fed, and cleaned all day long by the worker bees.

Figure 6-2



Queen

The Drone   Life span: 1 or 2 seasons (usually spring and/or summer)

The male bee, or drone, is stockier than the queen and a strong flier. Drones make up about 10 percent of the hive population. The drone's only purpose in life is to catch the queen during the mating flight and fertilize her with his sperm. Then he dies. The rest of the drones return to the hive to be fed and cared for until times get tough in the fall. Then the worker bees bite off their wings and throw them out into the cold.

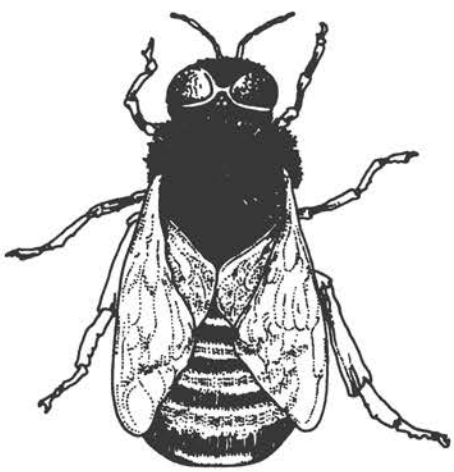
The Worker   Life span: 3 to 6 weeks

The worker bee is a female and the smallest in size of the three. Workers make up about 90 percent of the hive population. This bee literally works herself to death. Here is a list of some of the jobs the worker does at different stages in its life:

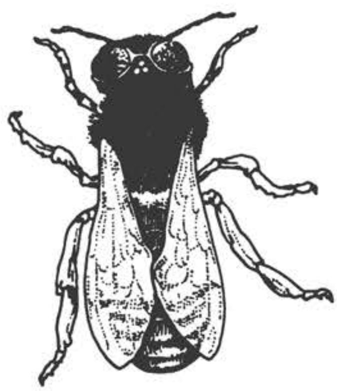
- feeding the larvae
- building, cleaning, and guarding the hive
- making wax
- controlling the temperature in the hive
- collecting nectar and pollen

The body of the worker bee is specially adapted for collecting food. Her long, straw-like tongue sucks nectar from deep inside the flowers. The nectar is then stored in a "honey stomach" for transport back to the hive. The worker's body is very hairy and traps pollen as the bee travels from travel to flower to flower. The bee packs this pollen into a "basket" on its hind leg and carries it back to the hive.

Figure 6-3



A. Drone



B. Worker

LESSON 7

Pollination and Interdependence

Think and Wonder

Under ideal conditions, from Day 12 through Day 18, the blossoms will open, making pollination possible. In nature, this would be done by the bee. For those of you who are pollinating, use the bee sticks you made in Lesson 6 to cross-pollinate your plant. Continue for five days.

For those of you who are not pollinating, be prepared to put up your "pollination barriers" as soon as the first bud opens (or even before).

The Reading Selection on pg. 40 discusses this interdependent relationship between the bee and the *Brassica*.

Materials

For you

1 student notebook

For every two students

1 hand lens

For each student pollinating

1 bee stick (made in Lesson 6)
Plants with open flowers

For each four-member team not pollinating

Pollination prevention barriers (made in Lesson 6)

Find Out for Yourself

1. Follow the set of instructions that apply to you.

   Nonpollinators

   - Explain your experimental plan briefly to the class. Tell how you have kept all of the variables under control. Demonstrate how you will prevent accidental pollination, and show the barriers you have constructed. Ask your classmates for comments or suggestions. Also, invite your classmates to predict the results of your experiment.

- Set up your experiment.
- Then, join a teammate who is pollinating so that you can observe the process and be ready to discuss it later.

Pollinators

- Listen while the nonpollinating team explains its plan. Offer any suggestions that might help to make the experiment a success. What do you think the outcome of this experiment will be?
- Pick up your supplies from the distribution station.
- Pollinate every blossom that is open. Follow these directions:
  - Place your bee against a blossom and rotate the stick gently.
  - Move the bee to the blossom of another plant. Rotate the bee gently.
  - Continue to "buzz" back and forth between the plants until all of the open blossoms have been pollinated.
  - Stop! Observe! Use your hand lens to look for yellow pollen grains on different parts of the flower. Then look for pollen on the bee.
- Clean up.
- Be sure to pollinate every day for the next 5 school days.

2. Everyone now needs to be ready to share some of their observations about the bee and the flower when the teacher projects the overhead transparency called "How Cross-pollination Takes Place." Why is the bee attracted to the flower? What does the flower have that the bee needs? And what does the bee do for the flower?
3. Read *The Bee and the* Brassica: *Interdependence* on pg. 40.
4. Make a prediction. What do you think will happen to the flowers after pollination?
5. Your plants will be going through many changes during the coming weeks and it will be very important for you to observe and record them every day. Remember to continue to count, measure, sketch, and write about your plant every school day. Your teacher may assign you a special time to do this important job.

   What are some of the changes that you might record? You might notice differences in height or in the numbers of leaves, buds, flowers, and seed pods. Perhaps colors or textures will change. Or maybe only some of these things will change and some will remain the same. A "no change" note in your records might turn out to be just as important later as one that does show change.

Ideas to Explore

1. Do some research in the library to find out more about:
   - other agents of pollination
   - other interdependent relationships. Here are a few to get you started:
     - the clown fish and the sea anemone
     - the horse mackerel and the Portuguese man-of-war jellyfish
     - the aphid and the ant
     - the plover bird and the crocodile
     - the shark and the remora fish
2. Do you have an insect collection? Perhaps you could bring it in to share with the class.

Reading Selection

The Bee and the *Brassica*: Interdependence

The bee and the *Brassica* plant depend on each other to survive. Each takes something from the other, and each provides something to the other. You might say that they have a real partnership.

What is the relationship between the bee and the *Brassica* plant? The bee helps the plant produce seeds so that a whole new generation of plants can grow, and the plant provides the bee with food. It all starts with the fact that a *Brassica* flower has both male and female parts. One of the male parts, the anthers, produces pollen, which looks like fine yellow powder. This pollen must travel to one of the female parts, the stigma, in order for pollination, fertilization, and the production of new seeds to take place.

For the *Brassica* plants, it is very important that the pollen from one flower be transferred to the stigma of another flower on another plant. Cross-pollination is what you call the transfer of pollen from one flower on one plant to the stigma of another flower on another plant. The pollen then helps fertilize another female part—the ovules—and they become seeds.

But how does the pollen reach the other flower so that seeds can be produced? This is where the bee comes in. The bee is attracted to the flower's bright color and sweet perfume. And the flower has much to give to the bee: two kinds of food—nectar and pollen.

Picture this: the bee is dipping her head deeply into the blossom to reach the nectar deep inside. She sucks the nectar up with her strawlike tongue. As she does, her body, covered with feathery hairs, rubs up against the anthers. The hairs trap some of the pollen. When the bee flies to the next plant, some of the pollen brushes off onto the next flower's stigma.

Now the worker bee has done several jobs at once. She has collected two kinds of food from the flower, and she has carried pollen from one plant to another so that new seeds can form. Soon these seeds will grow into new plants with flowers, completing the life cycle of the *Brassica*.

Figure 7-1

How cross-pollination takes place

LESSON 8

Harvesting and Threshing the Seeds

Think and Wonder

The *Brassica* plants are nearing the end of their life cycle, going from seed to seed. Today is your last opportunity to collect new data. Has your experiment affected the life cycle of the *Brassica* plant?

Materials

For you

- 1 student notebook
- 1 tray
- 1 envelope for storing seeds
- 1 quad of dried plants
- 1 **Activity Sheet 5, Data Record: Seeds and Pods** (optional)

Find Out for Yourself

1. Join your teammates. Retrieve your plants and pick up the materials you need for today's class. Observe both the experimental and the control plants. How has each changed in color and texture? Compare your plants with those of your teammates. Notice how the control plants differ from the experimental plants in your group.
2. Today, you will be able to gather some new and very important data about seeds and pods. What is this new data? See below for some hints.
3. Preview **Activity Sheet 5** with your team or listen while your teacher explains how to set up a similar recordkeeping page in your notebook. Then plan how to complete the task. Here are some suggestions to help you in your planning:
   - Decide on what kind of data the team will collect.

     Will you count the pods on each plant, measure the size of the pods, count the seeds in each pod, or do all of these?
   - How will you collect data?

There are many ways to divide the job. For example, one person could count and the other person could double-check the count. Think of other good ways to record the results.

4. Now, you are ready to harvest your crop by removing the pods gently from the plants either with your fingers or by using scissors. To thresh the seeds, roll the pods between your hands over the tray. Be careful not to lose any of the seeds.
5. Record your new data either on the activity sheet or in your notebook. Have you double-checked your counts?
6. Label an envelope with your name, the harvest date, and the total number of seeds collected. You also may add the question you were trying to answer by your experiment and state whether your plant was a control or an experimental plant. Put your seeds in the envelope for storage. These seeds will be useful in the germination experiments in Lessons 12 and 13.
7. Discuss this topic, "Did today's new data help answer our experimental question? How? Is the evidence convincing? Why or why not?"
8. Get an early start. Before the next lesson, spend some time reviewing all of the data you have accumulated. It is an impressive collection. Start thinking about how to organize this pile of information and to interpret what it means

Ideas to Explore

1. Wisconsin Fast Plants™ seeds do not need a dormancy (or rest) period before being planted. This means that you could harvest the seeds and plant them on the same day.

   How could you take advantage of this opportunity to begin a second round of experiments? What new questions would you try too answer?
2. Lessons 12 and 13 involve experiments in germination. Do some reading to find out more about this interesting process.

LESSON 9

Organizing and Analyzing the Data from the Experiment: Part 1

Think and Wonder

What did you and your team find out from your experiment? Did you find the answer to your question? Did you find out anything else?

You cannot answer these questions accurately until you take a close look at the data. Look at the data in three different ways:

- By yourself, for an overview of your own data.
- With the teammate who grew plants in the same way as you did, so that you can compare how your two sets of plants performed.
- With all of your teammates, so that you can compare and contrast what happened to the control plants with what happened to the experimental plants.

Materials

For you

1 student notebook
1 **Activity Sheet 6, Data Record: How Did Each of the Variables Affect the Plants?**

Find Out for Yourself

1. Spend some time with your own data. You probably have collected a large amount of information. Let us begin to determine what it all means.
   - First, be clear about the question that your team was trying to answer.
   - Then, reread your own observations in your notebook. Keep the question in mind.
   - Look for observations that might give clues to the answer.
   - Reread your data sheets and look for patterns or trends. You may use **Activity Sheet 6** to organize your data.

2. Once you have become reacquainted with your own records, meet with the teammate who grew plants under the same conditions as you did. If you grew control plants, meet with the other person on your team who grew controls. If you grew experimental plants, meet with the other person on your team who did the same. What you are going to do is make comparisons of your two sets of plants and jot down what you discover. You are looking for likenesses in the life cycle, trends that are similar, or growth curves that are alike in places. Look at the guidelines below. Then consider two key topics: a) the timing of events in the life cycle and b) measurements or quantities.

   Timing

   - When did the cotyledons (seed leaves) emerge?
   - When did the true leaves emerge?
   - When did the buds appear?
   - When did the flowers open?

   Measurements and quantities

   - How many of the original seeds germinated?
   - How many leaves did each plant have?
   - How many flowers did each plant have?
   - How many seed pods did each plant produce?
   - How many seeds did each plant produce?
   - How tall was each plant at different stages in its life?

3. Some helpful things to do include looking for trends—something that appears often in the data. Also, try averaging your data and your partner's data.

4. Next, meet with your team to contrast the data on the control plants with the data on the experimental plants. Try to discover what difference it made, if any, to change one variable. Use the guidelines above to analyze your data. Jot down your findings.

   Remember, finding out that changing a variable has no effect is just as important as finding out that it does have an effect.

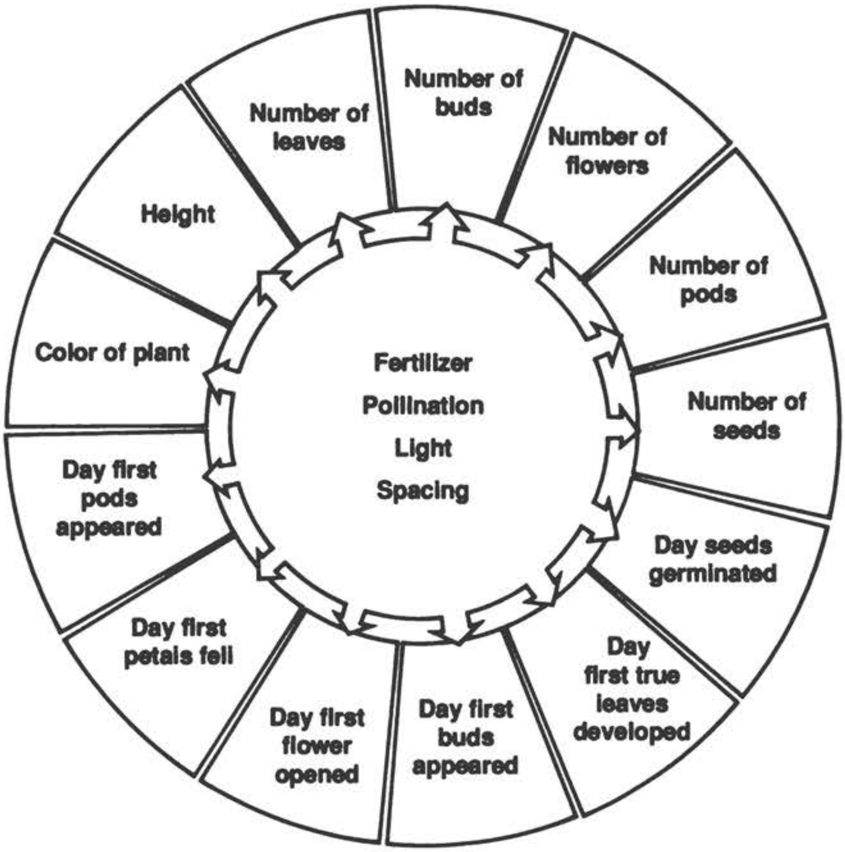
5. The final task for your team today is to think about how to organize your combined data. The way you organize and display your data should make clear to others what effect, if any, changing the variable had on the experimental plants.

   To help you organize your data, your teacher will lead a discussion on your team's conclusions so far and will explore with you how you reached these conclusions. You will begin to see more clearly the relationship between the experimental variables and how changing those variables affects the plants.

6. In the next class, your team will organize and display the combined data you collected in the experiment. To prepare, think about the best way to do this.

Figure 9-1

How did each of the variables affect the plants?



Ideas to Explore

Where have you seen data displayed today? It may have been a graph in a magazine, a table in a newspaper, or a diagram in an advertisement. Bring in what you saw to share with the class.

LESSON 10

Organizing and Analyzing the Data from the Experiment: Part 2

Think and Wonder

Now is your opportunity to tell everyone what you have learned. Show off your results. Display your data on a graph, table, chart, or diagram. Then use your data to draw a conclusion.

Materials

For you

1 student notebook

For your four-member team

Paper for graphs, charts, diagrams, and tables

Find Out for Yourself

1. With the class, review different ways to organize and display data from your team's experiment. Graphs, charts, tables, and diagrams are all useful ways. Feel free to use the one that suits your data best.
2. Your teacher will give your team the supplies needed to make the data display. While you are working on the display, keep these questions in mind:
   - Has our team done a good job of sharing the work for this task? Does everyone have a part to play?
   - Is the team being very careful to transfer data accurately from the notebooks to the new graphs and tables?
   - When the team has finished, will its display show a comparison of the control group of plants with the experimental group of plants?
3. Now comes a big step in the project: drawing a conclusion from the data. Your team needs to write down the answer to the question that formed the basis of your experiment. Try it. Use a few sentences. Remember, you should be able to point to the data that support your conclusion.

Some teams may find that they cannot answer their question, or that they are not sure of their answer. Were their projects failures? No! Those teams learned a lot. What did they learn?

4. How do scientists communicate the results of their research to other scientists? How do they share information about their discoveries with the rest of the world? Sometimes, they hold a scientific conference, where they share the findings from their experiments and hear about what other scientists have discovered.

   You will be participating in a scientific miniconference. There are only a few simple rules:

   - You must explain the team's plan for its experiment.
   - You must have the "raw data" (notebooks, observations, sketches, data sheets) from the whole team available as evidence.
   - You must display your team's combined data.
   - You must state your conclusion(s) in one or two sentences.

   As long as you keep to the rules, you can add anything else you think will make your conference more interesting. Perhaps you would like to dress up, add props, or have someone videotape the event. Or perhaps a classmate could play the part of a reporter and interview the scientists about their work. These interviews could be published later in a school newspaper. Some teams might organize a panel discussion or a debate and invite an audience of parents or another class.

No matter how you do it, the point is for you to share what you have learned through your experiments with plants. And you may even have fun doing it!

LESSON 11

The Scientific Conference: Communicating the Experiment and Its Results

Think and Wonder

Like scientists the world over, you will be holding a scientific miniconference to communicate the results of your first experiments with Wisconsin Fast Plants™. Each team will have an opportunity to describe its experiment and to share its findings with the group in presentations that could resemble those made at scientific conferences—exhibits, debates, panel discussions, and even interviews! You also will have an opportunity to learn from the experiments that the other teams carried out.

Materials

For you

1 student notebook

Materials as needed for your presentation

Find Out for Yourself

1. As you discovered in Lesson 10, there are four important items to include in your presentation. Your presentation must contain these items; if it contained nothing else, that would be acceptable. But why stop there? You probably have lots of ideas of how to make your presentation outstanding. First, let us look at the four basic elements:

   - *The presentation must include an explanation of the team's plan for its experiment.* Take out your Planning Boards from Lesson 2 and make them a part of your exhibit. You can use the board (enlarged perhaps) to describe the plan, to explain how you decided what variable to test, and to evaluate how the plan worked.

- *All of the "raw data" from the whole team must be available as evidence.* Team members should organize their own notebooks, sketches, and data sheets so that each person can point easily to the evidence supporting his or her conclusion(s). This does not mean that you should recopy or in any way change the original data because, after all, it is your personal record of the experiment. You need only to have it all there and be familiar enough with it to use it to prove your conclusion.
- *The team's selected, combined data must be displayed graphically.* These are the graphs, tables, charts, or diagrams that your team has made by combining your data in Lesson 10. The display should show how the experimental group of plants compared with the control group of plants.
- *The conclusion(s) should be stated very briefly.* Express your conclusion(s) in one or two sentences. Of course, you should be able to point to the evidence in your data that supports the conclusion.

Those are the only requirements. Anything else you want to do to make the presentation more interesting and more fun is up to you.

2. Do you need a few ideas to get started? Try inventing a board game, writing a computer program, making a crossword puzzle or a find-a-word game using plant vocabulary, thinking up riddles about parts of flowers, writing poems about bees, dramatizing pollination using a model of a bee and a flower, or illustrating a timeline of the life of a plant.

Below are models you can choose from for your presentations.

MODELS OF PRESENTATION OPTIONS

The Science Fair type of presentation

Perhaps your team would like to give a presentation in the style of a science fair project. One way to do this is illustrated below.

The Debate

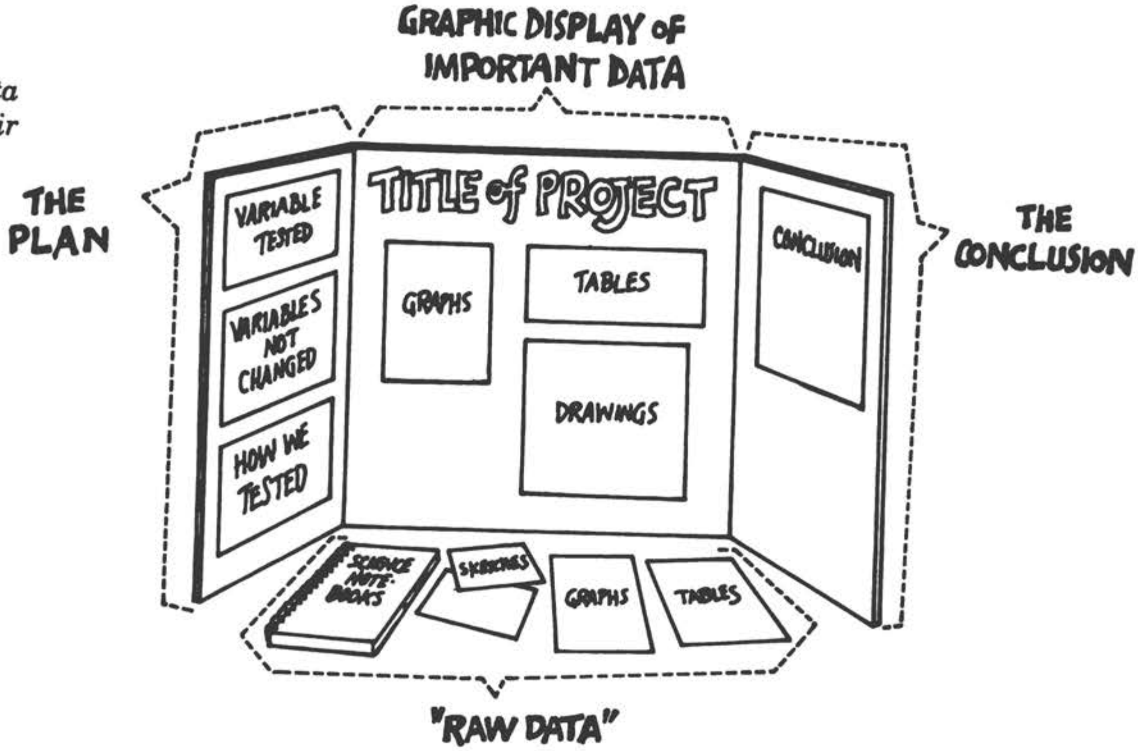
A debate could be exciting. Did some good debatable questions come up during the project, such as "Is more food better for a plant?" or "Which is more important for producing a good seed harvest: light or fertilizer?"

The Panel Discussion

A panel discussion on the effects of changing one variable might work well for your team. The advantage of a panel is that it explores one question thoroughly, such as "What are the effects of not pollinating the plant?"

Figure 11-1

Presenting data in a science-fair format



The Interview

A "reporter" from a newspaper could interview a team of student scientists, then write an article for the school newspaper. Or the interview could be staged as if it were for radio or television.

4. Now that you have some ideas buzzing around in your head, go to work. Think of the very best way to present your project.

5. Once you have decided what kind of scientific conference to have, it is time to start planning the details. Your teacher will tell you how you can assist with some of these jobs.

   - You will need some adults to help with this big job. Can you recruit someone to help?
   - Send your guests invitations. Who should you invite? Another class, your family, the principal?
   - Get some publicity. Notify the school newspaper, take a note home, make a big poster. Attract attention!
   - Arrange for refreshments. Food is always a good idea! Why not feature some healthy, crunchy crucifers. (Wisconsin Fast Plants™ are members of the Crucifer family of plants; see pg. 55.)
   - Props can add a lot of interest to a presentation. Think about including a model of a bee and a *Brassica* plant. Or try to use some audiovisual equipment, such as an overhead

transparency and a projector, a tape recorder and a microphone, or a video camera. Official identification badges might help create the atmosphere of a conference.

- You may have to help rearrange and borrow furniture. For instance, if your team is holding a panel discussion, you will need tables and chairs set up in front of the group. If you have invited an audience, seats will be required. If you are going to display standing projects, you will need extra tables.
- Costumes can help you get into the role. If you are playing the part of a scientist at a conference, "dress-up" clothes should be authentic (no laboratory coats and wild hair, please!). If you are a television reporter, watch your favorite real reporter for a few days to get the flavor of how to dress.

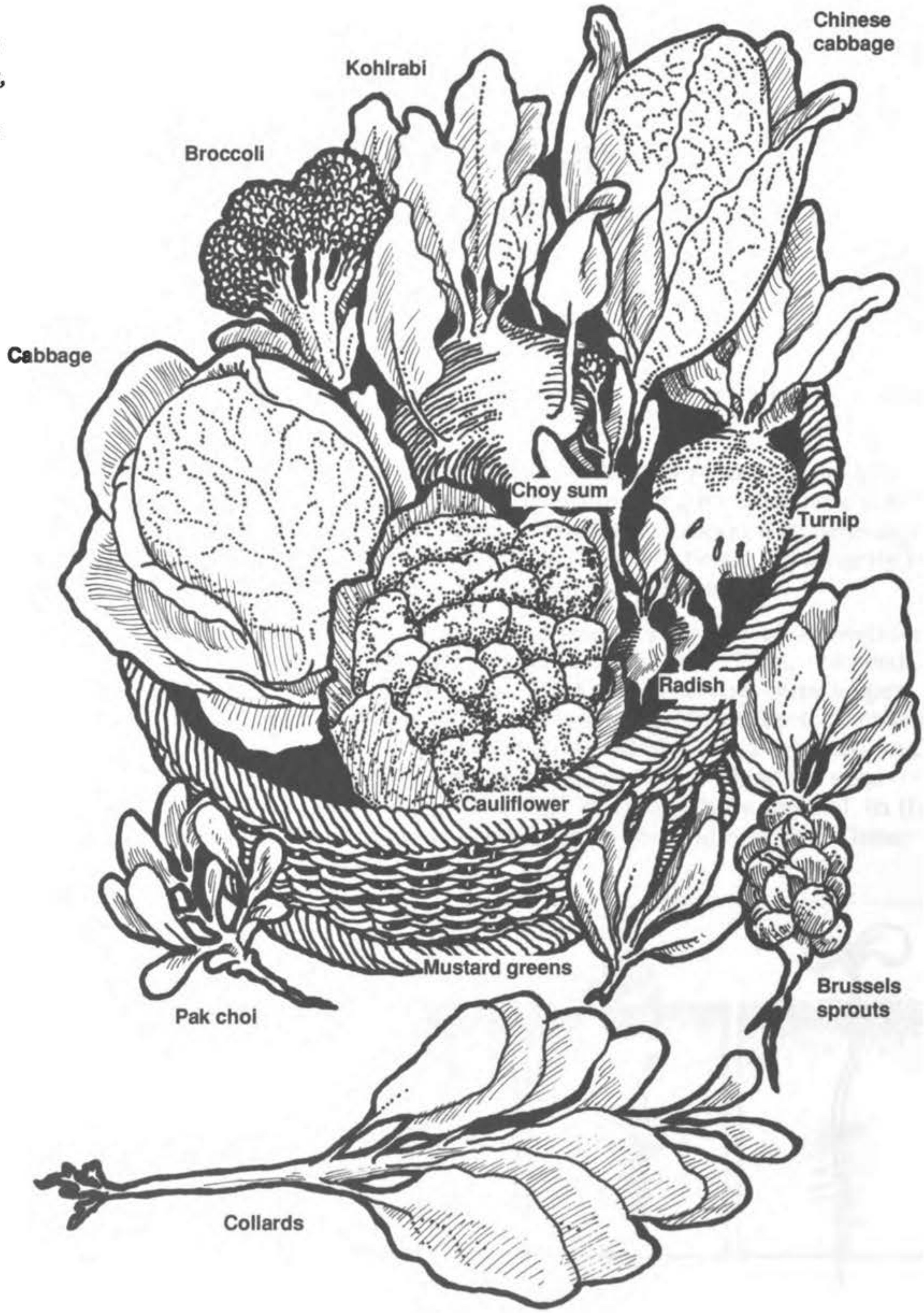
Once you have planned the details of your presentation and scientific conference, think about how to bring your project to a fun conclusion.

- A *Brassica* banquet might be fun. Look at the illustration of plants in the Crucifer family in Figure 11-2. These plants are all relatives of Wisconsin Fast Plants. Have you eaten any of them? Are there some you have never heard of?

  Do some research in cookbooks that specialize in "around the world" kinds of recipes. Find some dishes that use crucifers. Get an adult to help you make one of the recipes to share with the class.
- Think about how much you have learned about plants. Use your notebook to help you remember. Write a letter to a parent or friend who did not do the experiment, explaining everything that happened. Or, write a story of what you have learned so far, featuring the student-researcher as the hero or heroine.
- Think, too, of what you have learned about how to do an experiment. Have your ideas of how scientists work changed? Do you feel that you could plan an experiment on your own now?

Figure 11-2

Members of the Crucifer family, relatives of Wisconsin Fast Plants



LESSON 12

Planning and Setting Up Germination Experiments

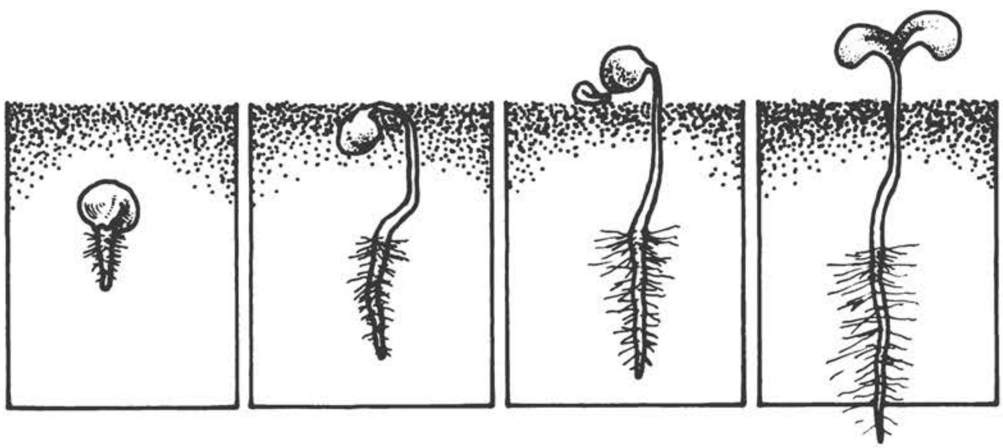
Think and Wonder

Think back to when you planted your seeds in Lesson 4. Over those first 2 or 3 days, some amazing things were going on under the soil. In this lesson, you will use the seeds harvested in Lesson 8 to investigate the beginning stages of a new life cycle. This will be an opportunity for you to plan and set up your own scientific experiment.

The process of a seed sprouting, or germination, is one of the wonders of nature. Yet, it follows a very predictable sequence. First, the seed takes in liquid, softens, and swells. Then, the seed coat bursts open. The first part to emerge from the seed is the embryonic root, or radicle. It grows quickly downward, putting out fine hairs to absorb food and water. Next, the embryonic stem pushes upward, pulling the seed leaves, or cotyledons, along with it until they are above the soil. In the Wisconsin Fast Plant, all of this happens in three short days! These steps are shown in Figure 12-1.

Figure 12-1

How a seed germinates



A. The seed coat splits and the embryonic root, or radicle, emerges.

B. The radicle grows downward and develops root hairs.

C. The stem grows upward and pulls the cotyledons above the soil. The seed coat falls off.

D. The cotyledons open

Materials

For you

1 student notebook
1 **Activity Sheet 7, Planning the Germination Experiment**
1 **Activity Sheet 8, Observations and Data Collection for Germination Experiment**
1 sheet of transparency film
1 paper towel
2 small resealable plastic bags
4 *Brassica* seeds (harvested in Lesson 8)
1 toothpick

For your four-member team

1 cup of water (or other liquid you brought in)
1 dropper

Find Out for Yourself

1. What is germination? At what time of year does germination take place in nature? What conditions are necessary for a seed to germinate? Be ready to discuss these questions with your class.
2. Next, join in the discussion about which variables should be considered for an experiment on germination. Your teacher will help you organize your ideas on the planning board.
3. Three of the conditions for germination make good variables to test in an experiment: light, moisture, and temperature. Select one of these for your own experiment and develop a specific question that you will answer. For example, if you choose light, you might ask: "Will seeds germinate faster in the light than in the dark?" What questions would you ask if you were testing moisture or temperature?
4. Now that you have had time to discuss and think about your project, it is important for you to plan the details on **Activity Sheet 7**. Answer every question.
5. Either your teacher will distribute **Activity Sheet 8** or will show you how to set up observation and data collection pages in your notebook.
6. Go to the distribution center and collect all of the materials you need to make your two germination chambers. Follow the directions on the next page to assemble the chambers.
7. Work independently on your experiment. You may set up the plastic bags in any reasonable location, such as tacking them to the bulletin board, hanging them from the warm cafeteria ceiling, setting them on a dark library shelf, or even snuggling them under a pillow at home. Also, if you have ideas about how to collect data and make data charts, go ahead and try them out.
8. Discuss with the class where to keep the control germination chambers. In order for this to be a fair test, the control chambers

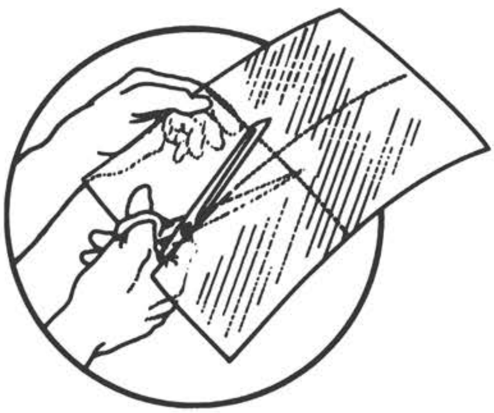
should be kept together in a location that gets light, is reasonably warm (60°F, or 15°C), and is monitored easily.

9. Remember, keep careful records of the germination experiment for the next three or four days, depending on the schedule your teacher has set up.
10. Your teacher will select three students experimenting with different variables to give brief descriptions of their experimental plans. You may want to comment on the strengths of the plans, offer alternative plans, and predict the outcome of the experiments.

How To Make Germination Chambers

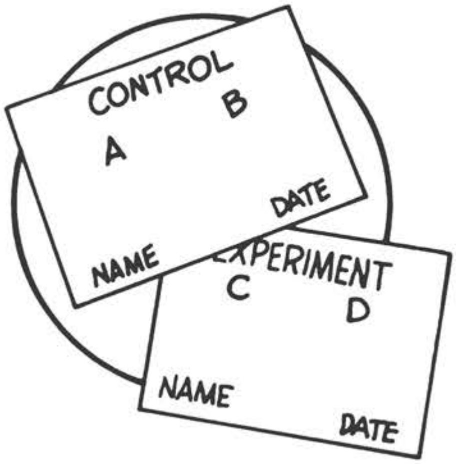
You will make two germination chambers, one for your control seeds and one for your experimental seeds. Follow these instructions step by step.

1. Cut the sheet of transparency film into four pieces the same size.

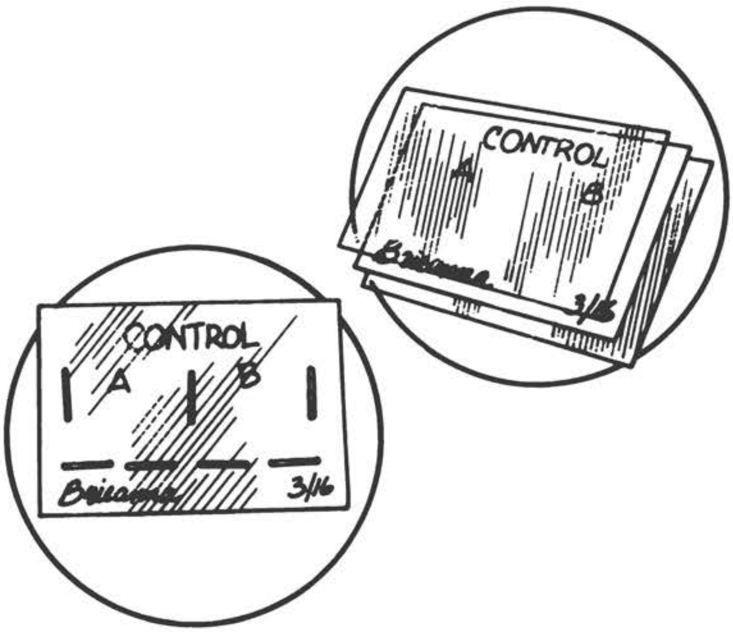


2. Cut the paper towel into two pieces the same size as the transparency film.

3. Use a pencil (ink might run) to label your paper towels. Include your name and today's date. Label one towel "control," and label its two seed compartments A and B. Label the other towel "experimental," and mark its two seed compartments C and D.

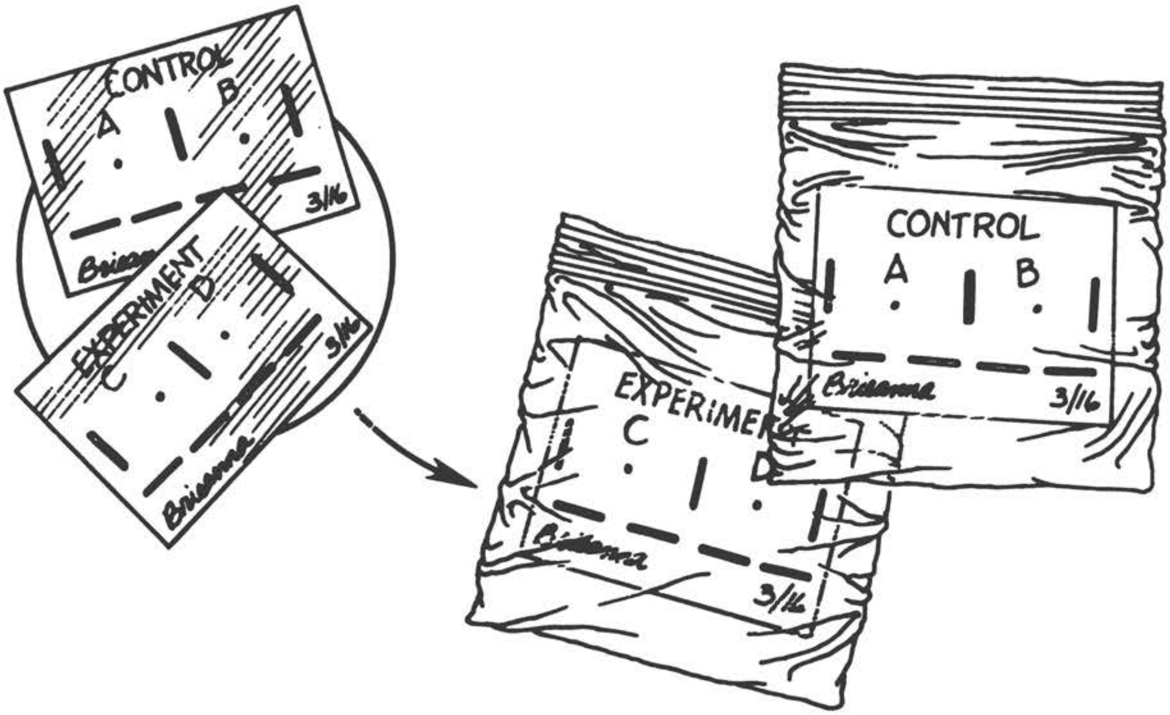


4. Put each labeled paper towel between two pieces of transparency film. Staple the towel and the transparency film together as shown. Don't get carried away; seven staples are plenty.



5. Use the toothpick to place one seed in each of the four compartments you labeled A, B, C, and D.

6. Put each germination chamber into a separate plastic bag and use a dropper to add water (or the liquid of your choice if this is the variable with which you have chosen to experiment with). Soak the paper towel thoroughly, then stop. Do not leave more than a drop or two of extra liquid standing in the bottom of the plastic bag.



7. Close the plastic bags and place them in the locations of your choice.
8. Be sure to record the starting time of your experiment in your notebook.

Ideas to Explore

Experiment with other seeds. Do you think that Wisconsin Fast Plants are faster germinators than other seeds? How could you find out if they germinate faster than grass or beans? Try sprouting some free seeds, such as acorns, dandelion, apple, or orange seeds.

LESSON 13

What Did We Find Out about Germination?

Think and Wonder

Today, you will analyze the data you have been collecting on germination. Then you will pool your data with other students who have experimented with the same variable.

Materials

For you

1 student notebook
1 **Activity Sheet 8, Observations and Data Collection for Germination Experiment** (from Lesson 12)
2 germination chambers

Find Out for Yourself

1. First, look at your own data and observations on germination. What question were you trying to answer? Did your experiments give you the answer? What data support your conclusion?
2. Now, join the group of classmates who have been experimenting with the same variable as you. Your group's goal is to pool all of the data you collected on the same variable. There is something to be learned from every piece of data, so make sure that everyone contributes his or her findings.
3. Next, your group is going to discuss the data and what it means. Here are some questions to guide your group's discussion:
   - What happened when you...? (whatever you did to experiment with that variable)
   - How does that compare with what happened to the control group of seeds?
   - How do you explain those results.
   - What part of your question can you answer now?
   - What data can you point to as proof?

- If you repeated the experiment, do you think the results would be the same?
- If different students did the same experiments, did they get the same results?

4. At this point, your group will rejoin the class for a discussion. Your teacher will record your findings on the chart called, "What did we learn about how seed germination is affected by light, moisture, and temperature?" Remember, offer only conclusions that you can back up with data.
5. How could you improve the experiment? Why was it a good idea to have several students research the same topic?
6. Clean up. Your teacher will tell you what to do with the germination chambers.

Ideas to Explore

In the next two lesson, you may be conducting experiments on **tropisms**. Find out what a tropism is.

LESSON 14

Two Tropism Experiments (Days 12, 13, or 14)

Think and Wonder

Today, you will work with your classmates on an experiment exploring two additional characteristics of plants—phototropism and geotropism. Before you begin, read the selection beginning on pg. 69 about tropisms.

Materials

For you

1 student notebook

1 **Activity Sheet 9, Experiments in Plant Tropisms**

Find Out for Yourself

1. Before the lesson begins, be sure you read the selection beginning on pg. 69, *Plant Tropisms*. The reading selection defines words you need to know—phototropism and geotropism.
2. Study the picture in Figure 14-1.

Figure 14-1

How does this tree illustrate tropisms?

3. How is this tree an example of phototropism? Of geotropism? Which influence do you think is stronger on a plant—light or gravity?

4. Let's do two brief experiments to find out more about how Wisconsin Fast Plants respond to light and to gravity. Think about which variables would be involved in one of these experiments. Which ones would you keep unchanged? Which one would you change? Use the Planning Board to discuss the variables.

5. Here are plans for two different experiments. Read them carefully, then be prepared to discuss them with the class.

The Question: Do plants grow upward in response to light?

Experiment 1: In the light

How we will test: Place a quad of control plants upright under the lights. Place a quad of experimental plants on its side under the lights.

What we will measure: Measure the angle of the plant stems with a protractor. Record the data on **Activity Sheet 9** every 30 minutes for 2 hours.

Experiment 2: In the dark

How we will test: Place a quad of control plants upright under a lightproof box. Place a quad of experimental plants on its side under a lightproof box.

What we will measure: Measure the angle of all of the stems once at the end of two hours and record the data on **Activity Sheet 9**.

6. Discuss the plans for the two experiments with your class. Consider some of these topics:

   - Is the question clear? Is it interesting?
   - Is the experiment doable? Will you need any special equipment?
   - What will you measure? How will you measure it (or them)? How often? Why is it best to measure plants in the dark only once?
   - How will you record the data? How often?
   - What kinds of observations will you make?
   - What do you think will happen?

7. Now, carry out the experiments on phototropism and geotropism. Each person will have something different to do during this experiment. Some will set up the plants, some will be timekeepers, others will measure the angle of the stems with a

protractor, and still others will record the data on the chalkboard for the class to see.

Everyone will copy the data from the board onto their **Activity Sheet 9** every half hour. Make entries in your science notebook about your observations, too.

8. At the end of the experiments, return all of the plants to their correct positions.
9. Keep your **Activity Sheet** in your notebook until the next class, when we will use the data to draw some conclusions.

Ideas to Explore

1. Here are a few ideas for more experiments in tropisms:
   - Allow all of the plants to grow upright again for another day or two. Then set up the same experiment a second time. Do you think you will get the same data?
   - Repeat the experiment at different plant ages in order to find out more about the response of the plant's tissue at different ages.
   - Set up a source of light below your plant. Do you think the stem will grow up, against gravity, or down, toward the light?
   - Hang a plant upside down. You will have to think of a way to keep it, and the potting mix, in the pot!
2. More practice with protractors.

   Measure the angle of the slope that the tree is growing on in the illustration of the old tree on pg. 65.

   Roger uses this ramp to get to his science class each day. Measure the angle of the ramp. Is it greater or smaller than the angle of the slope on which the tree is growing? Which incline would it be harder for Roger to roll up?

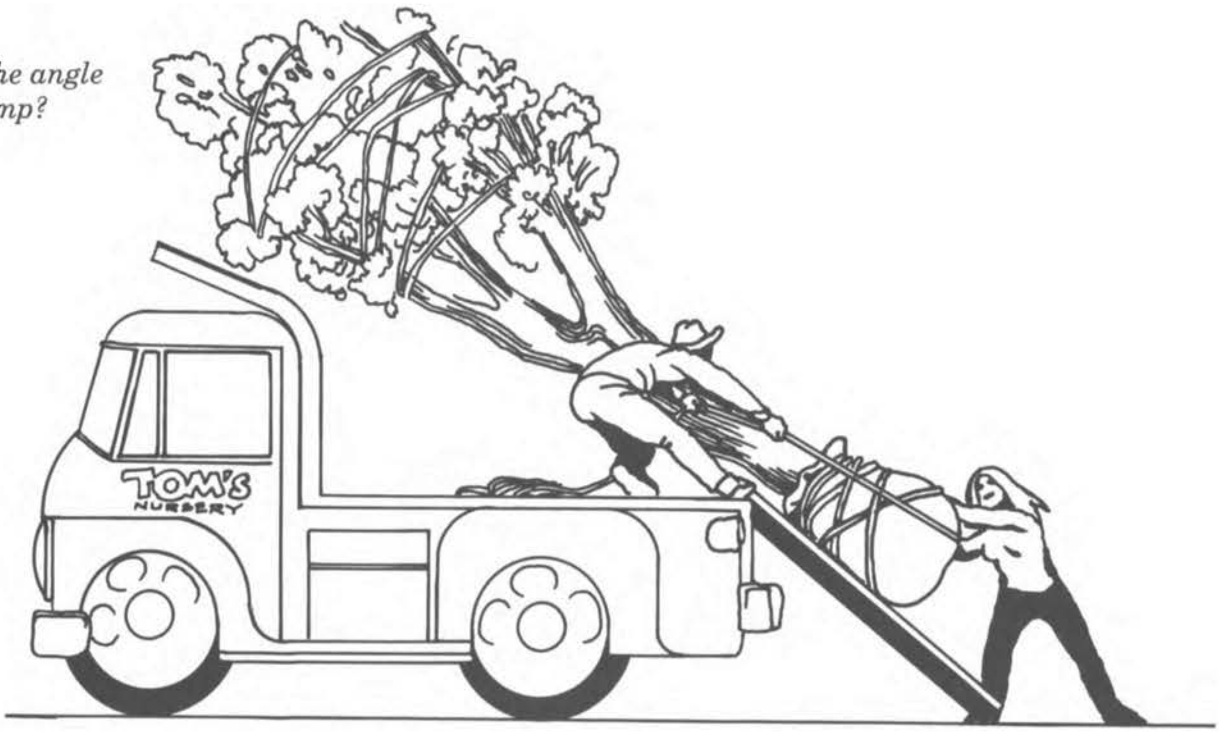
Figure 14-2

How steep is the ramp?

When the new tree was delivered to Jenny's house, the delivery people put it on a rolling platform, then rolled it gently down a ramp from the truck to the hole. Measure the angle of this ramp.

Figure 14-3

What is the angle of this ramp?



Reading Selection

Plant Tropisms

Have you ever wondered how seedlings "know" which way to grow? Why do their roots go down and their shoots go up? This seems like a simple question but, for the plant, it is a matter of life and death. It must send its roots down into the soil for food and water. It must send its shoot up into the light and air so that it can manufacture its food.

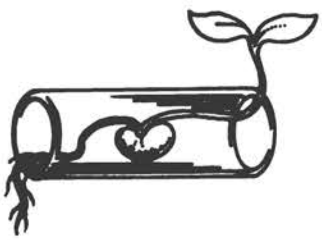
It is fortunate for farmers that seeds have this built-in ability to grow straight up and down no matter how they fall to the ground. Imagine the problems if that were not the case. Farmers would have to examine each seed and make sure that it was planted with the right side up. It is nearly impossible to tell which side is which on some seeds, like the tiny Wisconsin Fast Plant or the radish. Imagine how long it would take to plant an acre of seeds if you had to examine each one.

In growing straight up and down, the plant is responding to a very powerful force—gravity. This response is called "geotropism" (tropism = growing or bending in response to some force + geo = earth). What is more, parts of the plant are responding in two different ways:

- The roots are responding positively, growing toward gravity.
- The stem and leaves are responding negatively, growing up against gravity.

Figure 14-4

An example of geotropism—roots grow down and shoots grow up



Another kind of growing or bending in response to force is called "phototropism" (photo = light). It is triggered by light. Look at the following examples of phototropism.

Have you ever noticed a plant that has been sitting on a windowsill for a long time? Its stem and leaves have turned toward the light.

Figure 14-5

Why is the plant turning toward the light?

How about a field of sunflowers in the morning? (Figure 14-6A.) Then in the late afternoon (Figure 14-6B.)

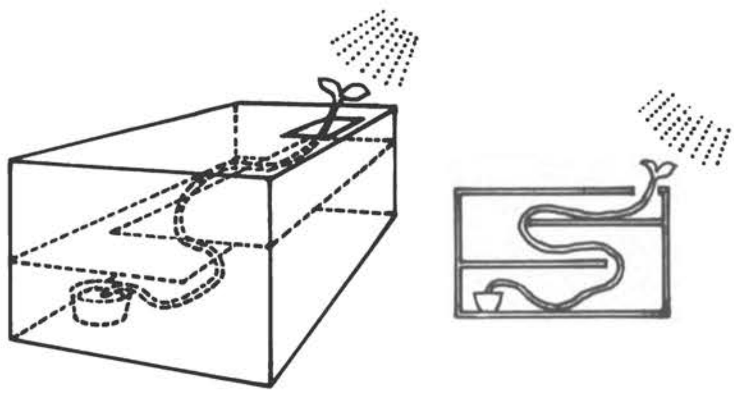
Figure 14-6

A. In a field, the sunflowers face the sun in the morning

B. By late afternoon, the sunflowers look like this

Or can you imagine this? A plant will go through a maze to get to light.

Figure 14-7



All of this leads us to some new questions. Do plants actually move? Well, yes, they do. In fact, they move continuously in order to survive. But plant movement is caused by growing and other very slow processes that we do not notice easily.

Why must a plant move in order to survive?

LESSON 15

What Did We Find Out about Tropisms in Wisconsin Fast Plants?

Think and Wonder

In this lesson, you will use the data you collected in the two tropism experiments to try to find out more about how Wisconsin Fast Plants™ respond to light and to gravity. You also will take a closer look at how the two experiments were planned. You may be able to suggest other plans that would work as well, or even better.

Materials

For you

1 student notebook
1 completed **Activity Sheet 9, Experiments in Plant Tropisms** (from Lesson 14)

Find Out for Yourself

1. You are going to use the data from **Activity Sheet 9** to try to answer the question, "Do plants grow upward in response to light?" But, in order to answer that question, you need to take a careful look at the data and to pull out from it all the conclusions you can find. Every conclusion that you find must have data to support it. You should be able to state a conclusion and then point your finger at the data that support it.
2. Jot down your conclusions quickly; they will be discussed shortly!
3. Join your class in pooling the information that you have sifted from the data. Your teacher will record the list of your conclusions.
4. Now that you have the facts from these two experiments, can you answer the question, "Do plants grow upward in response to light?" Why or why not?
5. Criticize how the two experiments were planned. Suggest other ways to find the answer to the question. Keep these questions in mind as you work:
   - What worked well? What did not work well?

- Did you have enough data to answer the question?
- What other information would have been useful?
- What new experiments could help answer the question?
- How could you have improved the measurements?
- How could you have collected more data from the same experiment?
- How could the experiment have been controlled better? In other words, was it a fair test?

6. Turn to the **Reading Selection**, *The Case of the Spaced-Out Bean*, on pgs. 73 to 74. What does it tell you about growing plants in a situation without gravity?
7. Make a brief list of new questions you could ask about tropisms. A good title would be, "I wonder what would happen if ..."

Ideas to Explore

1. Are you interested in tropisms? If so, there are two fascinating plants you should know more about—the mallow weed and the banyan tree. Use the library to find out more about the mallow weed and phototropism and the banyan tree and geotropism.
2. There are also other tropisms to explore. Find out more about one of these:
   - chemotropism—the way a plant's roots respond to chemicals
   - thigmotropism—the way a plant's stem responds to coming into contact with an object: for example, by wrapping itself around a pole
3. Make a graph using your data.

Reading Selection

The Case of the Spaced-Out Bean

by *Beatrice S. Smith*

Plants grown in space can't decide which way is up. At least those grown aboard the Space Shuttle Columbia couldn't.

How well plants grow in space is important because they could provide food for future space station crews. They also could keep the air fresh in the station. And they could boost the spirits of workers who are confined for months and are far removed from the good green Earth.

Scientists conducted the eight-day experiment in 1982, using pine, oat, and Chinese mung bean plants. The plants were placed aboard Columbia in two miniature gardens, and tended with care. All returned to Earth healthy enough but distorted in shape.

"More than 50 percent sent roots sprouting out of the soil instead of into it," said Dr. Joe Cowles, a University of Houston biologist. The mung bean was the worst. While in space, it twisted and turned in several directions, and never did make up its mind in which direction to grow.

On Earth, the roots of all plants grow downward into the soil toward the force of gravity. The stems grow upward toward the light. On Earth, if you tip a potted plant on its side, its roots will still eventually bend downward and its stem upward. Not so in space.

The color and size of the plants aboard Columbia were the same as those grown on Earth as control specimens. Only their shapes were different. Thus, said Dr. Cowles, the distortions obviously were caused by the absence of gravity.

Does it matter how distorted a plant's roots are?

Yes, it matters. The roots of a plant absorb water from the soil. To grow, a plant must have water. All substances that enter plant cells must do so in water. Water transports nutrients and foods up the stem to other parts of the plant. Water also keeps the cells stretched, a condition essential for them to function. And water prevents a plant from overheating.

If the roots of a plant grow upward out of the soil, they cannot properly absorb the water in the soil. A shortage of water early in the life of a plant results in retarded growth. Later in the plant's development, a water shortage may cause ripening too early and produce poor seed. If the water shortage continues, sooner or later a plant will wilt and die. Since large plants need the most food, they will die first. Smaller ones will hang on longer. But they too are doomed. No plants will grow well in space—or so it seems.

Dr. Cowles, however, is confident that in time plants can be grown successfully in space. "I think from what we have observed, it will be possible," he said. "It's not as simple as a lot of people thought. The size of the plants that can be grown may be limited. There also will have to be different ways to anchor and feed them. But I see no problem that is insurmountable."

Plans call for an American space station to be constructed sometime in the 1990's. Dr. Cowles and his co-workers have at least until then to figure out how to convince the mung bean and its companions that, if necessary, gravity is something they can manage to do without.