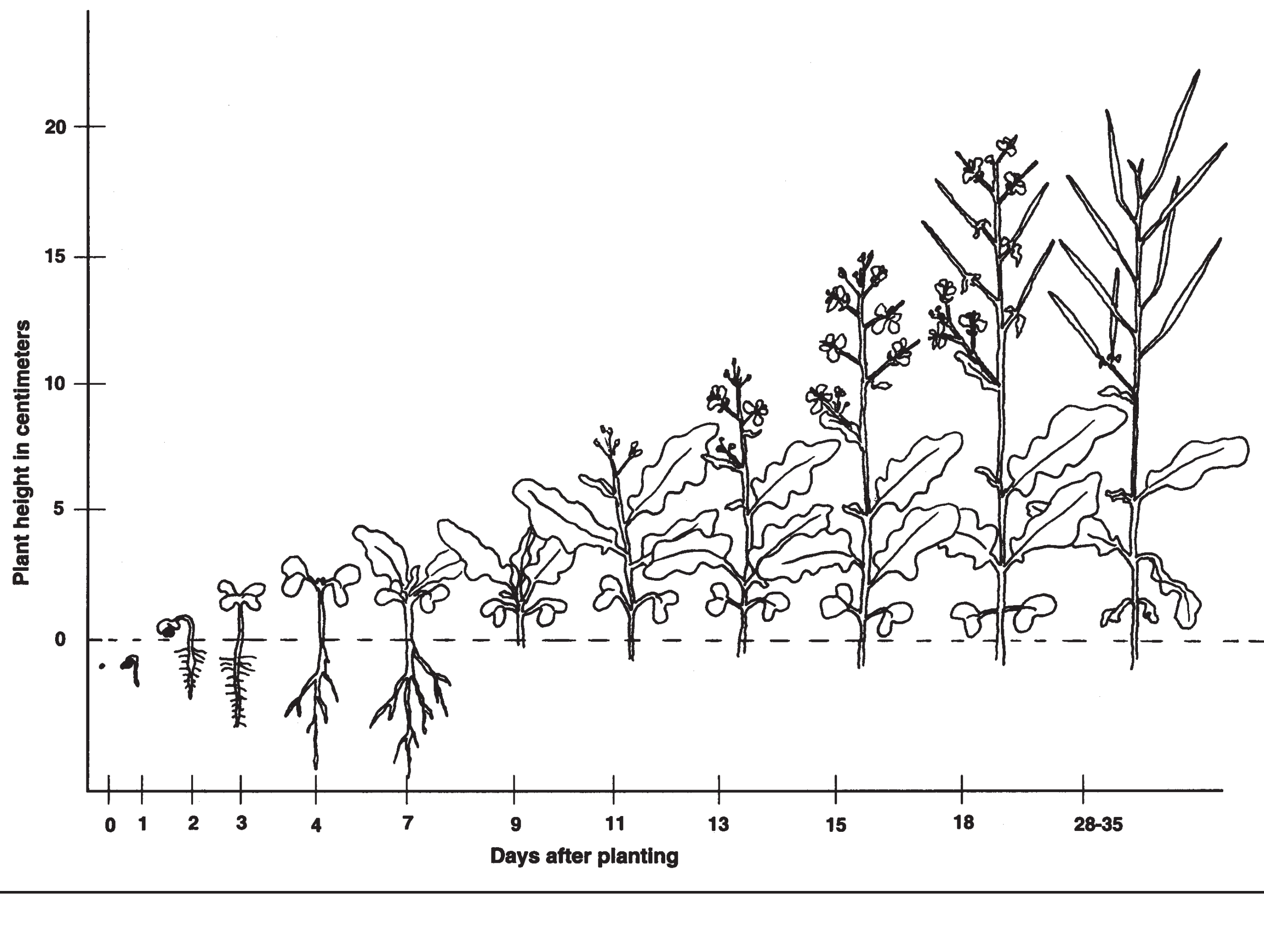
Growth, Development and Reproduction Booklet



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For additional activities, student pages and related resources, please visit the Wisconsin Fast Plants' website at www.fastplants.org

Growth, Development and Reproduction

Activity Materials

Wisconsin Fast Plants™ Growth and Development Kit Components

- 1 pack of 200 Standard Wisconsin Fast Plants™ Seeds
- 1oz pelleted fertilizer
- 2 watering trays
- 2 watering mats
- wicks (package of 70)
- 1 packet anti-algal square (2 squares per packet)
- 8 watering pipettes
- 1 L potting soil
- 1 package of dried bees
- our 4-cell quads
- 16 support stakes
- 16 support rings
- Growing instructions

Germination Activity Materials

Each student will need:

- 1 Petri dish
- 1 Transparency-plastic Ruler Disk, cut out (see Black-line Master)
- 5 Wisconsin Fast Plants™ seeds
- paper towels
- eye dropper
- hand lens
- shallow tray or bottom from a 2-liter soda bottle
- 1 copy of the Black-line Master Germination Observation

Growth and Development Activity Materials

Each student will need:

- 1 copy of the Black-line Master Tracking Growth and Development
- metric ruler
- 10x hand lens
- at least 1 Wisconsin Fast Plant™ growing through approximately days 3 – 12.

Flower Dissection Activity Materials

Each student will need:

- Wisconsin Fast Plants™ flowers
- 1 copy of the Black-line Master: Parts of the Flower (optional: answer key)
- 1 copy of the Black-line Master: The Brassica Flower
- tweezers or round toothpicks
- hand lenses
- Scotch tape

Pollination Activity Materials

Each student will need:

- 1 dried bee
- 1 Wisconsin Fast Plants™ flower
- round toothpicks
- glue
- hand lens
- forceps
- 2 flowering Wisconsin Fast Plants™ (Day 14 to 16)
- 1 copy of the Black-line Master: Pollination Observational Exercise
- 1 copy of the Black-line Master: The Honeybee (optional: answer key)

Fertilization and Seed Development Materials

Each student will need:

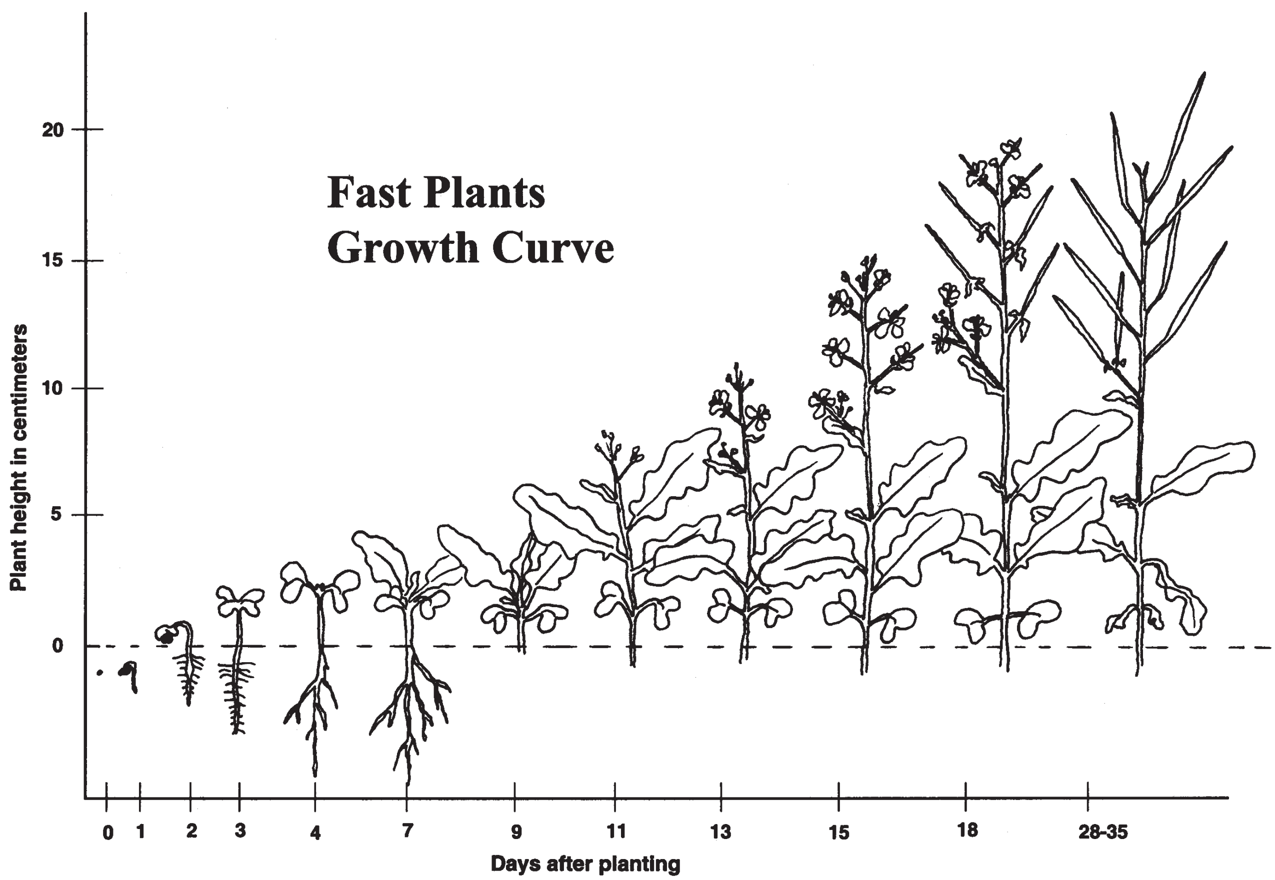
- Wisconsin Fast Plants™ with developing pods
- strong straight-pins
- hand lenses
- 1 copy of Black-line Master: Seed Dissection
- 1 copy of Black-line Master: Pistil Length Class Data Sheet
- 1 copy of Black-line Master: Pistil Length Summary of Class Data

Growth, Development and Reproduction Booklet

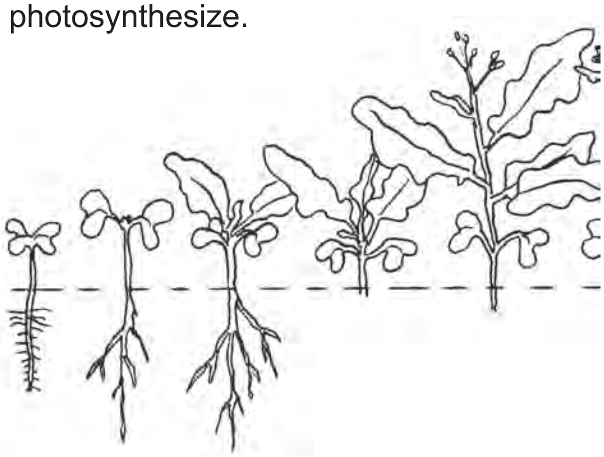
Welcome to the amazing world of growing and exploring Wisconsin Fast Plants™! Through activities spanning the life cycle of Wisconsin Fast Plants™, you and your students can explore many aspects of plant growth and development and reproduction. In its 35 – 45 day life cycle, the Wisconsin Fast Plant™ rapidly passes through all the life stages of a flowering plant.

Each section in this booklet focuses on a single stage of the Wisconsin Fast Plants™ life cycle. For each stage, there are growing tips, background information, one or two activities, and black-line masters. These materials are provided to be used and modified to suit your needs as you join the many teachers around the world in using Wisconsin Fast Plants™ to bring science to life in the classroom.

Your students can take a plant through its entire life cycle following all the activities in the booklet or focus on a single section or even on a single activity. While each activity stands on its own and can be taught in isolation, the investigation of more activities will lead to a deeper understanding of how the stages of the life cycle interact and interrelate.



Days 0 – 2 Germination starts with the structure of a seed and goes through the first days of the life of a new plant. Germination is the beginning of growth of a plant from the seed, which contains the embryo. The seed swells, a root and shoot emerge, and cotyledons (first leaves) begin to photosynthesize.

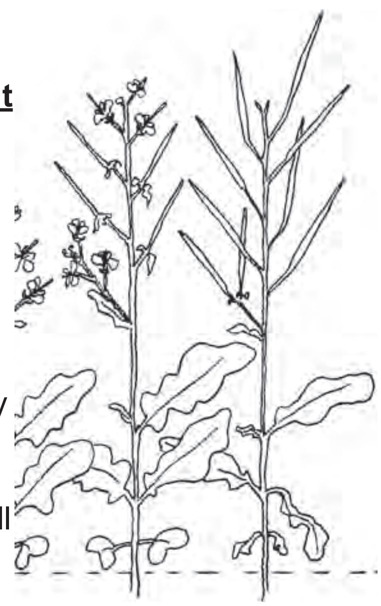


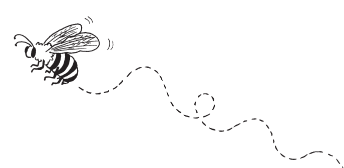
Days 3 – 12 Growth and Development follows Wisconsin Fast Plants from the seedling stage through to flowering. As plants increase in size (up to 20 cm) and develop into mature plants, individual differences can be observed. The plant height, number of leaves, number of hairs on leaf margins, and number of flower buds are all examples of measurable traits that can be observed, recorded, and analyzed to learn about individual plant development and diversity among individuals in a population.

Days 13 – 15 Flowering is the time when the flower structures can be observed directly and their functions are introduced. Learning about flower anatomy and each structure's purpose is important for preparing students to understand and conduct pollination.

Days 15 – 17 Pollination is the stage when reproduction takes place. Pollination activities engage students actively in spreading pollen among plants so that they successfully reproduce and develop seed in the next stage. In addition, this stage opens up the opportunity for linking students' use of bee sticks with explorations into the interactions of plants and insects.

Days 18 – 35 Fertilization and Seed Development brings the Wisconsin Fast Plants™ back to the beginning of the life cycle. After pollination, fertilization yields a new and genetically unique single cell. *Embryogenesis* takes this single cell and sees it through to a seed.





GERMINATION

Days 0 – 4

QUESTIONS

- How does a seed become a plant?
- Would the seeds germinate if you changed the environment?
- Do all seeds germinate as fast as Wisconsin Fast Plants™?

Key Concepts

- Germination is the stage in the plant life cycle when growth of a new plant begins from a seed.
- Germination begins when the seed takes up water (*imbibition*) and the seed coat cracks.
- A seed is a dry, inactive, embryonic plant complete with a reserve of stored energy to keep it alive and sustain germination.
- Germination commonly involves emergence of an embryonic root followed by an embryonic stem that, in the case of Wisconsin Fast Plants™, pushes the cotyledons and shoot meristem through the soil.

Activity Overview

Students will germinate Wisconsin Fast Plants™ Seeds on moist paper towel in a Petri dish so the process of germination can be observed, measured, and recorded effectively. By placing a Transparency-plastic Ruler Disk (see page 9 Blackline Master) in the cover of the germination Petri dish, students can make quantitative observations as the embryonic root and stem emerge and grow.

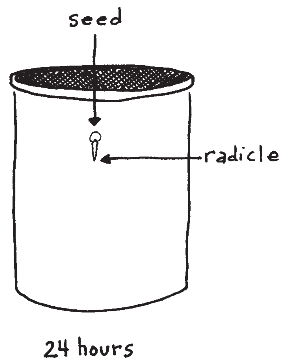
- If possible, arrange for students to make observations twice on the first day of the activity as there will be significant changes to observe after several hours, and after 24 hours there will be a remarkable difference. If started on Monday, the investigation can be completed by Friday
  - o Day 1: one 50-minute class period on first day to set up germination plates and record initial data.
  - o Days 2–4: 10–20 minutes on each day to observe and record data.

Growing Tips

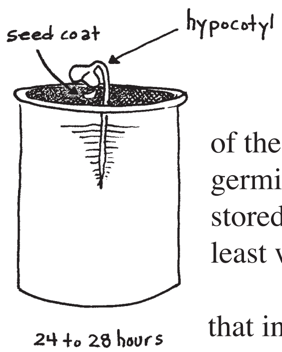
(See ***Growing Instructions*** for complete guide)

- Seeds planted or placed in the germination Petri dish on a Monday will complete germination during the first week.
- When planted in a Petri dish, after germination, the seedlings can be carefully removed with tweezers and placed in soil to grow with good success
- If planting in soil, use planting mix NOT potting soil
  - o plant on a Monday so that seeds germinate during the school week
  - o plant seeds in soil shallowly—use only enough planting mix or vermiculite to just cover the seed
  - o fill containers loosely with soil, do not press or pack
  - o remember fertilizer
  - o wet soil and wick thoroughly before planting
- Keep room temperature above 60°F (15.5°C)

Background Information



A seed contains a tiny, new plant (embryo). The outside of the seed is called the **seed coat**. During germination, the *radicle* (embryonic root) and *hypocotyl* (embryonic stem) emerge from the seed. Two *seed leaves*, called **cotyledons**, unfold. The cotyledons look different than the *true leaves* that will develop as the plant grows.



Germination is the awakening of a seed from a resting state. This resting state represents a pause in growth of the embryo. The resumption of growth, or germination, involves the harnessing of energy stored within the seed. Germination requires at least water, oxygen, and a suitable temperature.

For many seeds, water is the "on" switch that initiates germination. As the dry seed imbibes or takes up water, the seed's cells enlarge and the seed coat cracks. A radicle emerges and rapid development of the fine root hair cells vastly increases the surface area of the root, facilitating the uptake of more water. In Wisconsin Fast Plants™ and many other *dicots* (plant with two cotyledons), this uptake of water drives the elongation of the hypocotyl, which pushes the cotyledons upward through the soil.

Not all plants germinate in such a fashion. Cotyledons from pea plants remain below the ground. The shoot tip is lifted out of the soil by the elongation of the *epicotyl* (the embryonic stem above the cotyledons). *Monocots* (plants with a single cotyledon), such as grasses, push the *coleoptile* (a protective sheath) from the seed upward through the soil. The shoot tip then extends through the coleoptile and out of the soil.

In Wisconsin Fast Plants™ germination, cotyledons emerge from the soil, expand, cast off the protective seed coat, turn green, and become photosynthetically active. At this point the plant becomes independent of its stored reserves and dependent on the energy of light. Launch has been successful! All of these events happen on Days 1, 2, and 3 of the Wisconsin Fast Plants™ life cycle.

We still do not completely understand seed germination and scientists are very interested in learning more about it. Because germination holds so many unanswered questions, it can be an excellent topic for investigation.

Materials

Each student will need:

- 1 Petri dish
- 1 Transparency-plastic Ruler Disk, cut out (see Black-line Master)
- 5 Wisconsin Fast Plants™ seeds
- paper towels
- eye dropper
- hand lens
- shallow tray or bottom from a 2-liter soda bottle
- 1 copy of the Black-line Master ***Germination Observation***

Germination Activity

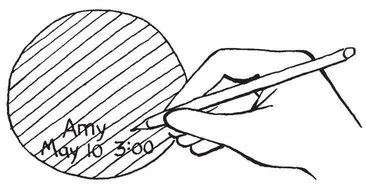
When placed under favorable conditions, Wisconsin Fast Plants™ seeds will germinate quickly. Germination involves the expanding and propelling of two growing points of the seed outward (upward and downward if guided properly). The following activity provides an easy way to observe and carefully record the events of germination.

Variations in the physical environment such as temperature and light will alter the rate of germination and appearance of Wisconsin Fast Plants™ seedlings. Use this activity to investigate the interactions between the environment and germination.

Procedure

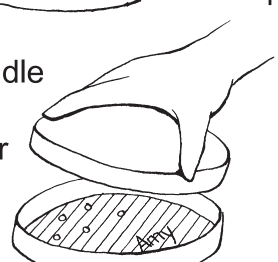
How does a seed become a plant? In this activity, you will germinate Wisconsin Fast Plants™ seeds and make careful observations to answer this question.

1. From a paper towel or a piece of filter paper, cut a circle 8.5 cm in diameter to fit in the cover (larger half) of a Petri dish. With a pencil, label the bottom of the paper circle with your name, the date and the time.

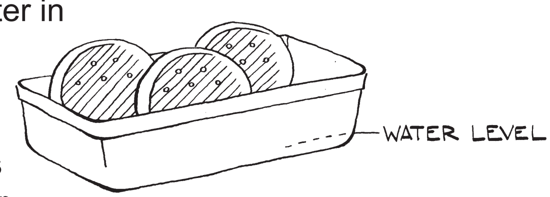


2. Place a Transparency-plastic Ruler Disk in the cover of the germination Petri dish; place the paper circle on top. (The ruler will show through the paper circle once it is wet.)
3. Moisten the paper circle in the Petri dish with an eyedropper.

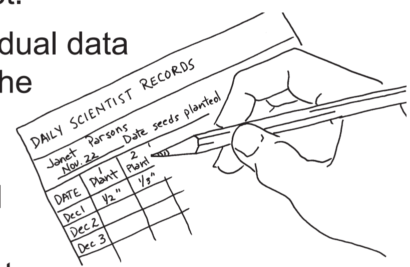
4. Place five Wisconsin Fast Plants™ seeds on the paper circle along the middle dark line on the ruler and cover with the bottom (smaller half) of the Petri dish.



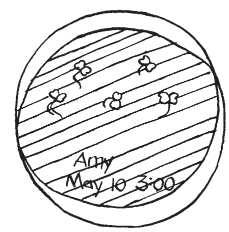
5. Place the Petri dish at a steep angle (80˚– 90˚) in shallow water in a tray so that the bottom two centimeters of the paper is below the water's surface.



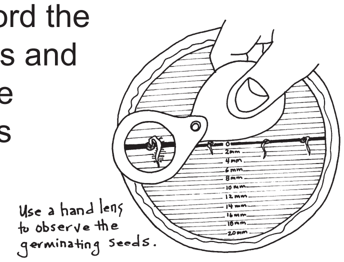
6. Set the experiment in a warm location (optimum temperature: 65–80˚F). Check the water level each day to be sure the paper circle stays wet.
7. On your individual data sheet record the day, time, and initial environmental conditions for the experiment.



8. Over the next 3 – 4 days observe the germinating seed and seedlings using a magnifying lens. (See www.fastplants.org for instructions on making an inexpensive film can hand lens.)

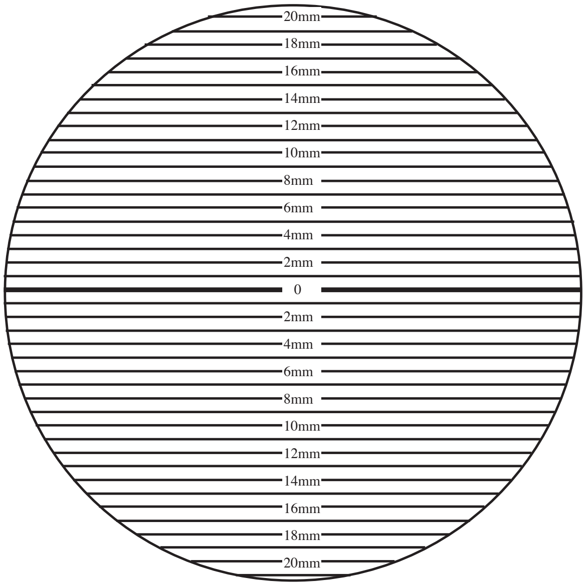


9. Measure and record the growth of the roots and shoots. Sketch the germinating seeds and young plants using a hand lens/magnifying glass. Record all data in a data chart.



10. Graph the combined length of the Wisconsin Fast Plants™ roots and hypocotyl (dependent variable = y-axis) over time (independent variable = x-axis), and look for patterns in your and your class' results.
    - Would your graph look different if you plotted only root or hypocotyl growth?
    - Does a germinating seed "know" which way to grow?
    - Consider compiling a class data set. Does a larger sample size affect your conclusions?

Note: Germinated seedlings can be carefully transplanted into wickpots at Day 5 and grown to maturity. This may slow the developmental cycle by a few days.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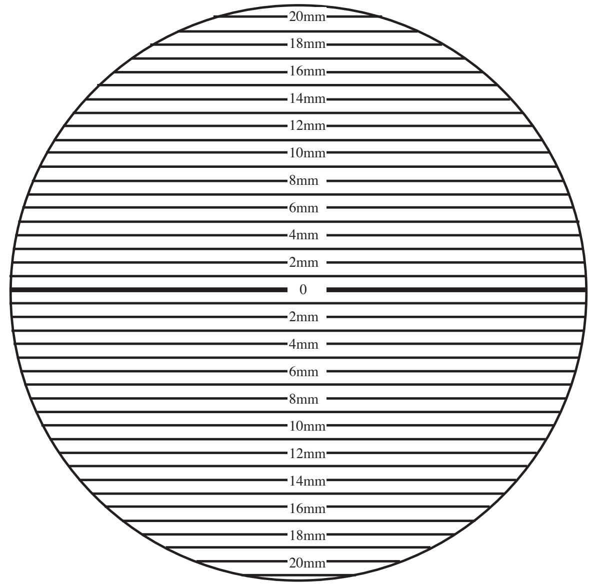
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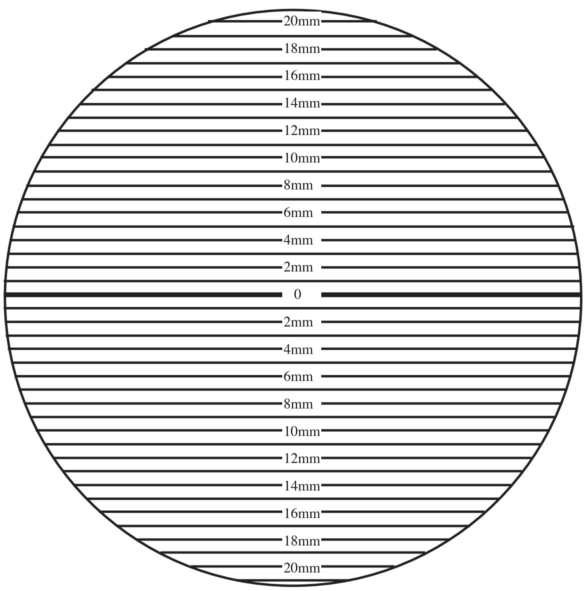
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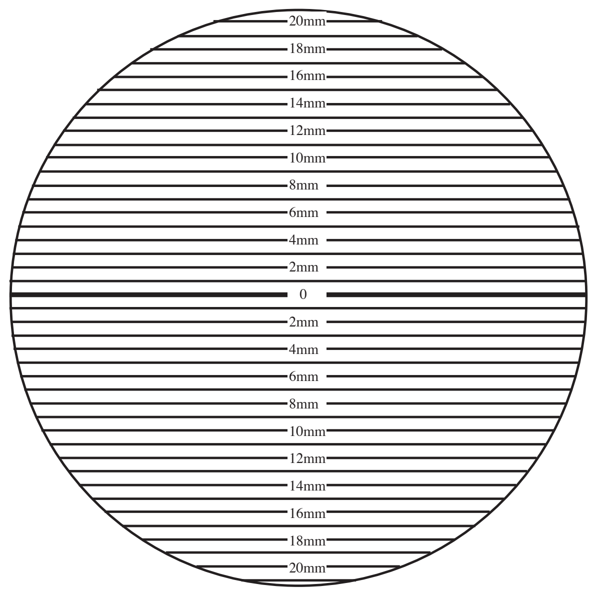
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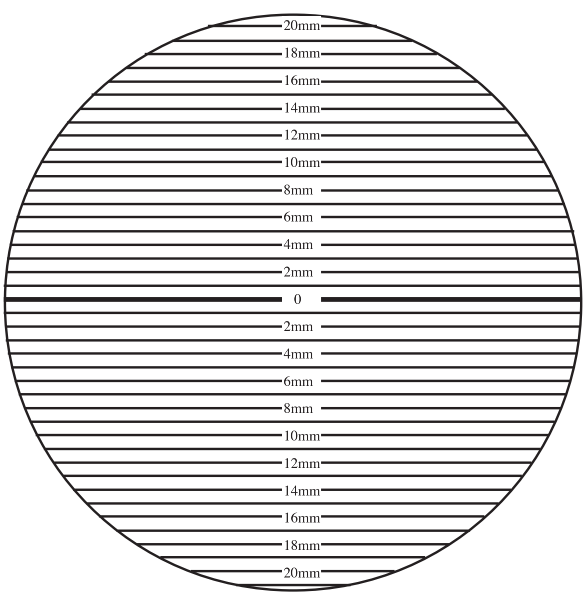
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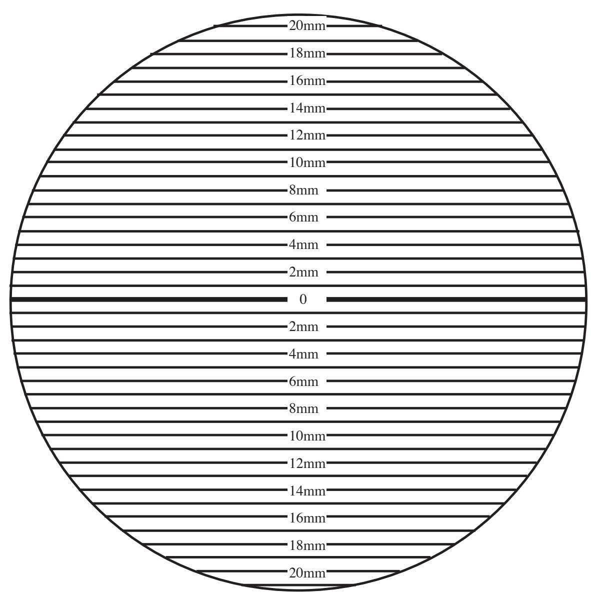
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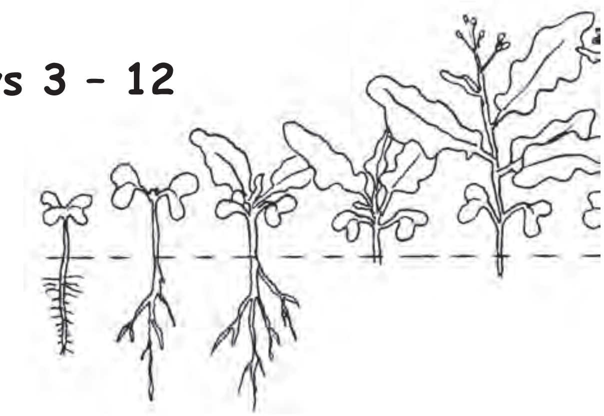
GROWTH AND DEVELOPMENT

Days 3 – 12



QUESTIONS

- What changes when a Wisconsin Fast Plant™ seedling grows?
- What special structures develop when a Wisconsin Fast Plant™ seedling grows, and what is their function?
- What similarities and differences are there among individual Wisconsin Fast Plant™ seedlings that grow under the same conditions?
    - o *Extension: What similarities and differences are observable among individual Wisconsin Fast Plant™ seedlings grown under **different** conditions?*

Growing Tips

(See ***Growing Instructions*** for complete guide)

- Adjust lights as the plants grow so that lights are 5 – 10 cm from the growing tip.
- Keep room temperature above 60°F (15.5°C).
- Keep water reservoirs filled, especially before the weekend.
- Thin to one plant per cell; transplant if necessary to obtain one plant in every cell.

Key Concepts

- Plants grow and change, and there are stages in the life cycle of a plant.
- Growth occurs both through the appearance of new parts (for example, leaves, stems, and flowers) and the increase in size of the new plant parts.
- Each of the different parts of the plant (root, leaves, stems, flowers) performs specialized tasks supporting growth and the life cycle of the plant.
- Plants need adequate space to grow (thinning).
- Individuals within a population vary in their growth.
- Normal growth requires a favorable environment.

Activity Overview

During growth and development, students follow the maturation of Wisconsin Fast Plants™ from seedling to flowering. During this time period, students can track their plants' height as well as a number of other traits. After collecting this information, students analyze and synthesize the data both to understand the structures that develop during this stage and their functions. In addition, students have an opportunity to analyze what traits are most variable among individual plants and wonder why.

Materials

Each student will need:

- 1 copy of the Black-line Master ***Tracking Growth and Development***
- metric ruler
- 10x hand lens
- at least 1 Wisconsin Fast Plant™ growing through approximately days 3 – 12.

Background Information

Plants grow new parts, and the parts grow bigger. Above ground, new stems, leaves, and flowers originate at a point at the very top of the plant, called the growth tip. Each part emerges gradually, then grows larger—and the growth is measurable from day to day.

As a plant germinates and matures, it undergoes the processes of growth and development. *Growth* arises from the addition of new cells and the increase in their size. *Development* is the result of cells differentiating into a diversity of tissues that make up organs such as roots, shoots, leaves, and flowers. Each of these organs has specialized functions coordinated to enable the individual plant to complete its cycle in the spiral of life.

As the plant grows, the stem elongates at the **internodes**, which is the space between the **nodes** (where the leaves attach). This allows the plant to grow taller and spread out the leaves and flowers so they are in the best position to do their jobs. Stems also allow food, water, and minerals to move throughout the plant.

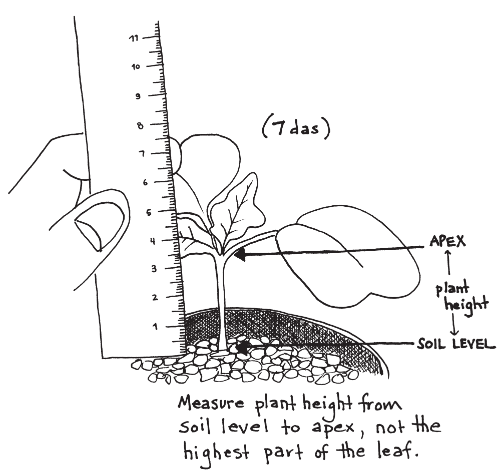
Leaves contain many pores (called stomata) on their surfaces, which allow the plant to “breathe” by taking in carbon dioxide (CO_2) from the air, and expelling oxygen. A green pigment called **chlorophyll** makes the leaves appear green and captures energy from light. When carbon dioxide and water are combined in the presence of light, the plant makes its own food, called **carbohydrates** (or sugar). This amazing process is called **photosynthesis**. (See *www.fastplants.org* for activities with Wisconsin Fast Plants™ and photosynthesis)

In Wisconsin Fast Plants™, growth and development occur rapidly and continuously throughout the life cycle of the individual. Things are most dramatic in the 10–12 days between seedling *emergence* (arrival at the soil level) and the opening of the first flowers. Using the following activities you can explore growth, development, and variation through the Wisconsin Fast Plants™ life cycle.

Procedure

By carefully observing Wisconsin Fast Plant™ from seed to mature plant, you can answer the questions, What changes when a Wisconsin Fast Plant™ seedling grows? In addition, What special structures develop when a Wisconsin Fast Plant™ seedling grows, and what is their function?

1. In this activity, you will work with a team of 4 students to make and record observations to answer those questions as your plants grow. Watch for the appearance of each new plant part.
    - Identify the part of the plant by name and discuss its function.
    - Look for and record observations about changes in the plant's appearance.
2. Each day, from Day 3 to Day 12, make careful observations and measurements to record on your ***Tracking Growth and Development*** data sheet. Include the following observations:
    - count and record the number of leaves and flower buds on each of the plants.
    - measure and record the height of the plant.
    - notice the change in the distance between the leaves (internodes).



3. Choose one plant and make a life-size sketch twice a week. Record the measurements for that day on the sketch.

4. After five days, begin to look for evidence in your data about how Wisconsin Fast Plants™ grow and develop. Record and consider the following questions as well as your own.
    - Do the plants continue to make new leaves?
    - Do they continue to produce new flowers?
    - Do the leaves continue to lengthen?
    - Which traits show the most variety

Observing Growth and Development

Team Data Sheet

Student Name 1________________________________

Student Name 2________________________________

Student Name 3________________________________

Student Name 4________________________________

Group number______________

Environment

Distance in cm of plants from bulbs: _______________

Avg. daily temp. of growing environment: _________ ˚C

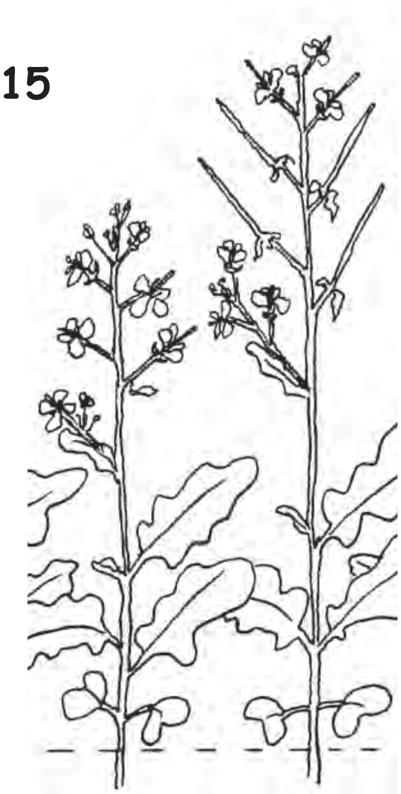
Nutrient used: _________________________________

Seed type: ____________________________________

das	**Character**	**Plant Measurements**								**Statistics**			
	Students:	**Student 1**		**Student 2**		**Student 3**		**Student 4**		**Team germ %**		**Class germ %**	
3	**# seedling emerged & germ %**												
	Plant Number:	**1**	**2**	**3**	**4**	**3**	**4**	**4**	**5**	**n**	**x**	**r**	**s**
7	plant height cm												
11	plant height cm												
11	number of leaves on stem												
14	plant height (cm)												
14	# of hairs on leaf margin												
17	plant height (cm)												
17	number of open flowers												
	day to first open flower (das)												

FLOWERING Days 13 – 15

QUESTIONS
- What is a flower?
- What do flowers do?
- Why are flowers colorful?



Key Concepts

- The flower is the reproductive center of most plants.
- Flowering plants have unique structures for accomplishing successful sexual reproduction.
- Although all flowers have common parts, variations occur among these parts.
- The colorful petals of flowers attract insects.

among your team?

Activity Overview

In this activity, students explore the parts of a Wisconsin Fast Plants™ flower. The activity begins with observations made using a hand lens to view an intact flower. Then, students dissect a flower and make a floral dissection strip to identify individual structures in the flower and discuss their functions. This activity is an important step for students to engage in to understand and engage in successful pollination.

NOTE: For excellent pollination extension resources, look online at *www.fastplants.org*

Growing Tips

(See ***Growing Instructions*** for complete guide)

- Keep flowers from contacting lights directly (flowers are damaged by heat from the bulbs if they touch them)
- Keep plants below 80°F (26.7°C) or flowers will become sterile
- Continue to keep water reservoirs filled, especially before the weekend

Materials

Each student will need

- Wisconsin Fast Plants™ flowers
- 1 copy of the Black-line Master: *Parts of the Flower* (optional: *answer key*)
- 1 copy of the Black-line Master: *The Brassica Flower*
- tweezers or round toothpicks
- hand lenses
- Scotch tape

Background Information

What is a flower? In human eyes, it is something to enjoy, with colorful petals and fragrance. However, for many plants, the critical part of the flower is not the dramatic blossom. Within that blossom are the organs of reproduction that allow the plant to reproduce sexually and create offspring slightly different from itself.

Sexual reproduction requires the union of two gametes, a male sperm and female egg, to form a *zygote* (fertilized egg). Uniting eggs and sperm from different flowers or different plants provides a challenge. Plants, which are largely immobile, have evolved strategies to move their male gametes long distances to fertilize the female gametes. One common strategy involves employing animals, often insects, to carry *pollen* (male gametes) to the *pistil* (female reproductive organ).

In order to attract the insects into such service, the plants provide food, in the form of nectar or pollen. However, the plant must first attract the insects. This attraction must happen when the reproductive organs within a flower are ready to provide and receive pollen. Plants have evolved a constellation of intriguing features by which they can "advertise" the availability of pollen and nectar to the pollinators. These "advertisements" include familiar flower characteristics such as dramatic colors and color patterns, distinctive fragrances, and large or complex shapes. The flower advertises the availability of nectar, which lures the pollinators into service.

So the answer to the question *"What is a flower?"* is a matter of the perspective of the viewer. For an insect, the flower is an essential source of sugar-rich nectar and protein-rich pollen. To humans, it is a delightful gift of beauty. But for plants, the flower is the means by which they are able to generate, through sexual reproduction, the variation necessary for evolution and survival of their species.

What is inside a flower? Most flowers have the same basic parts, though they are often arranged in different ways. Each of the four main parts of a flower, the *sepals*, *petals*, *stamens*, and *pistil* serve particular functions in flowering and sexual reproduction. The sepals are the green leaf-like structures that enclose and protect the developing flower. The petals are the colored leaf-like structures that lie within the ring of sepals and frequently serve to attract pollinators.

The stamen consists of the *filament*, a slender stalk upon which is borne the *anther*. Within the anther are the pollen grains, which contain the male gametes or sperm cells.

The pistil usually has three parts, the *stigma* (which traps the pollen), the *carpel* (ovary), and the *style* (the neck between the two). Brassica (genus of Wisconsin Fast Plants™) flowers have two carpels fused together and separated by a thin membrane. The carpels house the *ovules*, each of which contains the female gametes.

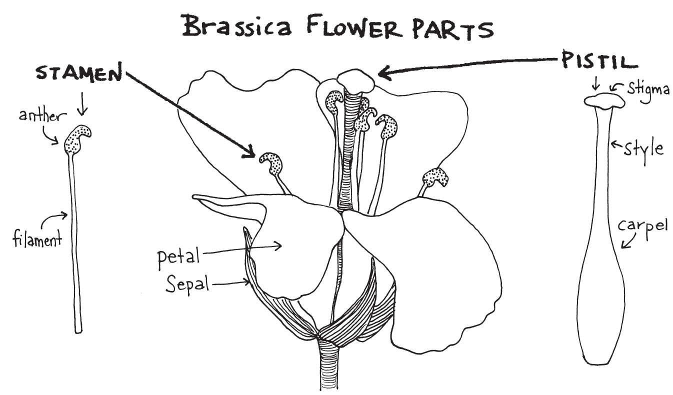
In brassicas and many other species that need to attract specific pollinators, *nectaries* are also present. These nectaries, strategically located in the flower, secrete sugar-rich nectar. Their location ensures that nectar-gathering insects and other animals will receive pollen from anthers and transmit it to its stigmas as they forage.

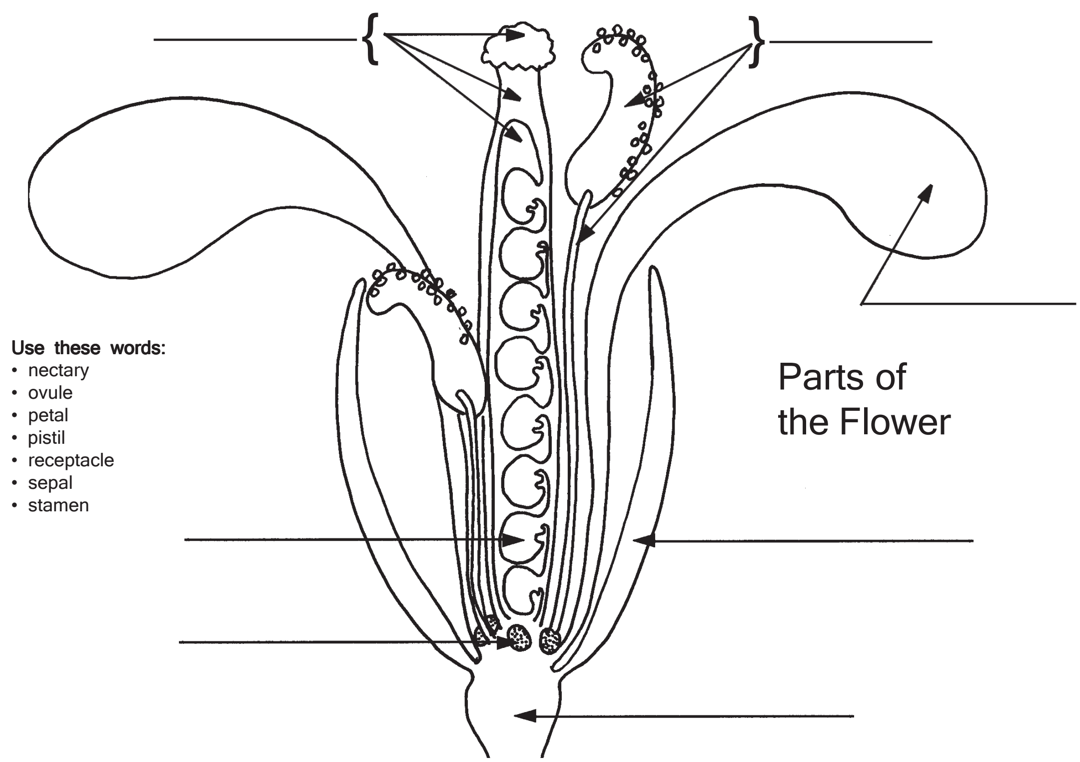
Procedure

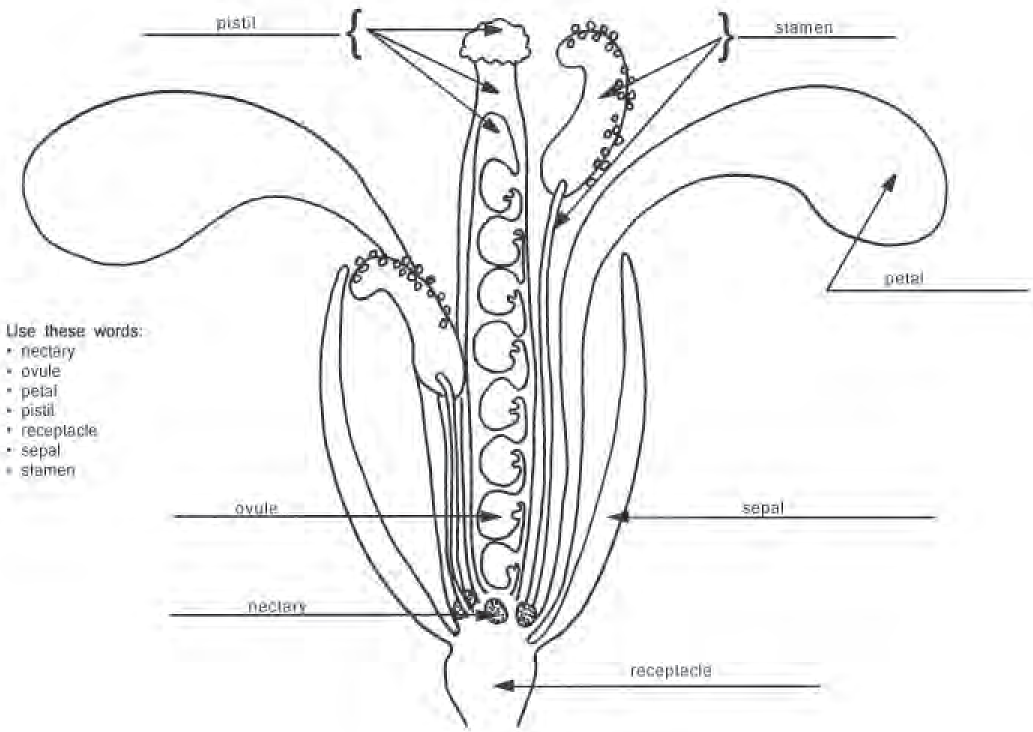
Have you ever looked closely at a flower and wondered why some plants develop flowers? What *is* a flower, and what is its function for a plant? In this activity, you will carefully observe flowers to learn more about what they are and what they do.

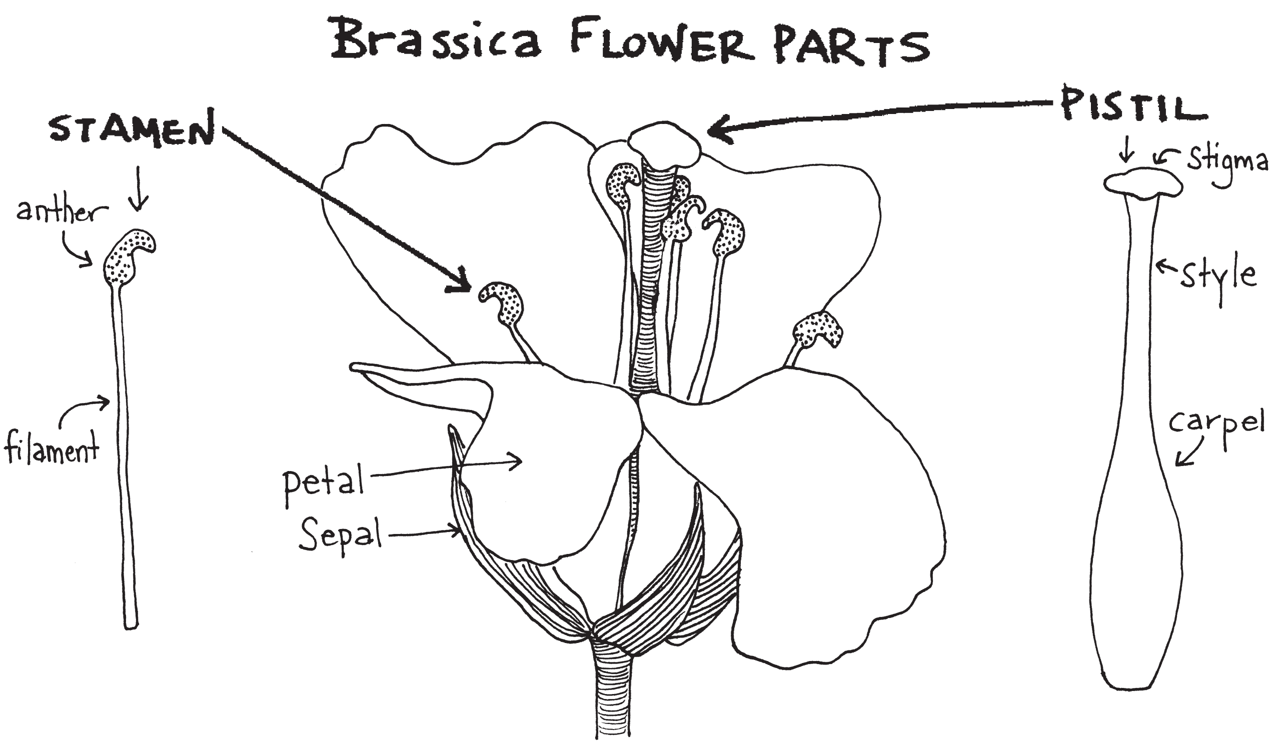
1. Take the top open flower of the first plant and carefully remove it with a forceps.
2. Compare your flower to the Black-line Master: *Parts of the Flower*. Work with a partner to label the parts of the flower on your Black-line Master.
    a. Discuss with your class the structures and functions that are pictured.
3. Draw a sketch of your flower, and label the parts in your drawing.
4. While observing with a hand lens or microscope, carefully remove the flower parts with fine tipped forceps, a dissecting needle, or a sharp-tipped toothpick.
    a. For each part, notice the relative positions on the base of the flower.
5. Place each part on the sticky side of a piece of tape, taped to a card as shown in the illustration. Refer to the illustrated and labeled brassica flower image for help in identifying the floral parts.

Extension: Compare the Wisconsin Fast Plant's flower parts to those of another flower such as a tulip or lily.

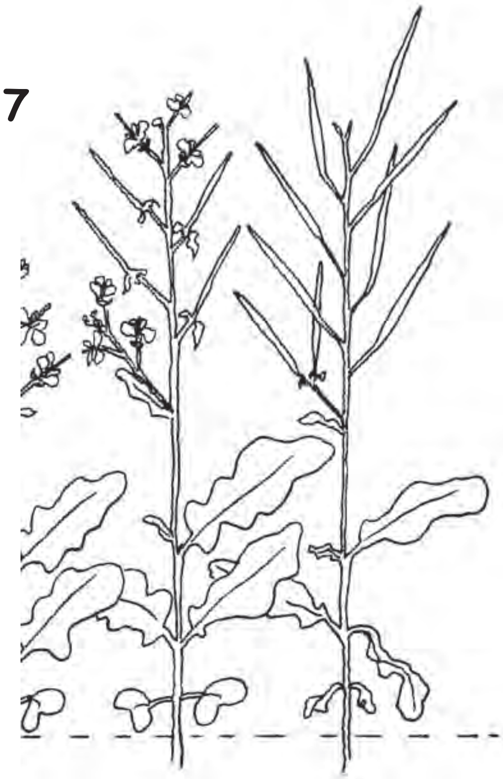





pistil
stamen
petal
Use these words:
• nectary
• ovule
• petal
• pistil
• receptacle
• sepal
• stamen
ovule
sepal
nectary
receptacle


Brassica FLOWER PARTS
STAMEN
PISTIL
anther
Stigma
style
filament
petal
Sepal
carpel

POLLINATION Days 15 – 17



QUESTIONS

- What is pollination?
- What would happen if you did not pollinate Wisconsin Fast Plants™?
- What is the relationship between bees and Wisconsin Fast Plants™ flowers?
- Are flowers pollinated by any means other than bees?
- What would happen if you pollinated only one plant?

Key Concepts

- Pollination is the transfer of pollen from the anther to the stigma.
- Insects, specifically bees, aid in pollination.
- Wisconsin Fast Plants™ need to be cross-pollinated to produce seeds.
- Cross-pollination is the transfer of pollen from the anther of one plant to the stigma of the flower of another plant.
- Self-pollination is the transfer of pollen from the anther of one flower to the stigma of the same flower of another flower of the same plant. Wisconsin Fast Plants™ DO NOT self-pollinate.
- Pollen germinates on the stigma and grows through the style to reach the egg.

Activity Overview

Students actively engage in pollinating their plants in this activity. First, they learn about a honeybee's body structure and its ability to transfer pollen and insects' role in pollination. Next, students make "beesticks," a pollination tool, and, finally, they actively pollinate their Wisconsin Fast Plants™.

Growing Tips

(See ***Growing Instructions*** for complete guide)

- Beesticks should be made one or two days prior to pollination.
- When making beesticks the bees may be very dry and brittle. Soften the bees by placing them in an airtight container with a little moist paper towel overnight.
- Keep flowers from contacting lights directly
- Keep plants below 80°F (26.7°C)

Background Information

Pollination is the process of mating in plants whereby pollen grains developed in the anthers are transferred to the stigma. The pollen grains then germinate, forming pollen tubes that carry the sperm to the eggs that lie within the pistil. Not all flowering plants rely on animal pollinators to transfer pollen from anthers to stigmas. Some plants self-pollinate within the unopened flower bud, while wind or water moves the pollen in other plant species.

The evolution of flowering plants and their pollinators has resulted in a diversity of mechanisms that deliver pollen to the stigma. Flowers may be pollinated by a specific bee, bird, bat, or beetle, or by several different organisms. Flowers often attract certain pollinators by the color, fragrance, or structure they possess. Insects, for their part, often have specialized sensory apparatus, body parts, and behaviors that allow them to successfully collect pollen and nectar from the flowers they visit.

The Bee and the Brassica

In brassicas, bees and other insects distribute pollen. Brassica pollen is heavy and sticky—unable to be easily wind-borne. Bees are marvelously coevolved pollen vectors (transferring devices) for brassicas.

Bees depend on flowers for their survival. Sugars in the nectar provide carbohydrates to power flight and life activities. Pollen is the primary source of proteins, fats, vitamins, and minerals to build muscular, glandular, and skeletal tissues in bee larvae.

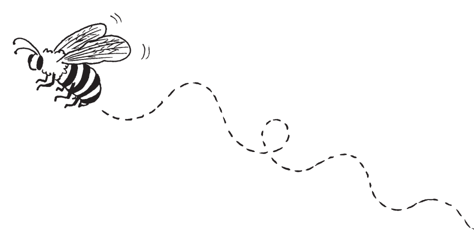
Bees are members of the insect family Apidae, which are unique in that their bodies are covered with **setae** (feather-like hairs). The bright yellow petals of brassica flowers act as both beacons and landing pads for the bees, attracting them to the flower and guiding them to the nectaries. The bee drives its head deep into the flower to reach the sweet nectar secreted by the nectaries, brushing against the anthers and stigma in the process. Quantities of pollen are entrapped in its body hairs.

As the bees work from plant to plant, pollen on the setae is carried from flower to flower. The transfer of pollen from an anther to a stigma is known as pollination. When pollen is transferred from one plant to another, the process is called **cross-pollination**.

Materials

Each Student Will Need

- 1 dried bee
- 1 Wisconsin Fast Plants™ flower
- round toothpicks
- glue
- hand lens
- forceps
- 2 flowering Wisconsin Fast Plants™ (Day 14 to 16)
- 1 copy of the Black-line Master: *Pollination Observational Exercise*
- 1 copy of the Black-line Master: *The Honeybee* (optional: *answer key*)



Procedure

What needs to happen for flowers to produce seeds? In this activity, you will learn about the role that bees play in Wisconsin Fast Plants™ pollination and then use a ***beestick*** to pollinate your flowers.

1. Using a hand lens or microscope, examine a bee. Look at the legs and hairy body.
2. Identify the bee's body parts. Refer to the Black-line Master: *Pollination Observational Exercise* for help identifying key structures and recognizing the role they play in pollination.
3. Sketch the bee and label the parts. Think about the how each part helps the bee do what it needs to do to live and how some parts are particularly well suited for pollination.
4. Put a drop of glue on the end of a round toothpick. Push the "glue" end of the toothpick into the top of the bee's thorax.
5. Dry the beesticks overnight (or at least for a couple of hours).
6. To pollinate, "fly" bees into the flowers and brush the bee back and forth across the anthers and pistil.
   - Roll the beestick over the anthers to collect pollen, then deposit the pollen on the stigma by brushing the beestick across them.
7. Be sure that you make the "BUZZ" sound while you pollinate!

NOTE: Many teachers play Nikolai Rimsky-Korsakov's *Flight of the Bumblebee* in the background, while students pollinate their flowers.

BEES AND BEESTICKS
Sketch Sheet

How is the anatomy of the bee related to the anatomy of the brassica flower?

What is the magnification of your drawing?

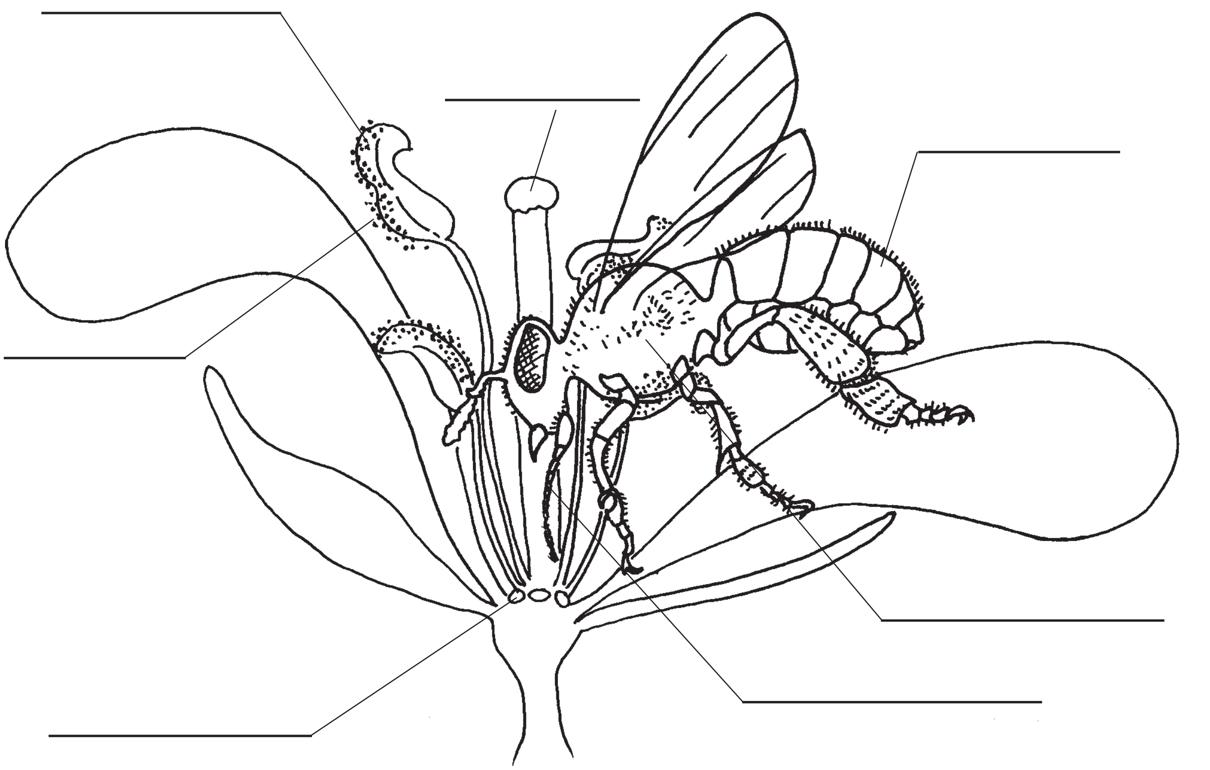
<u>Sketch of Bee and Brassica</u>

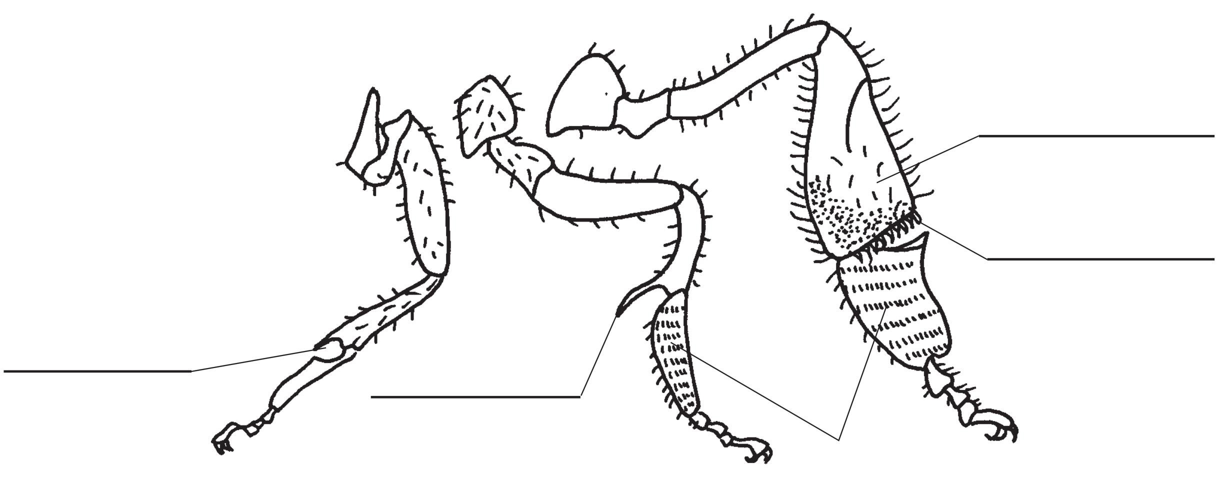
Bee

Brassica Flower

The Honeybee

Name ____________________



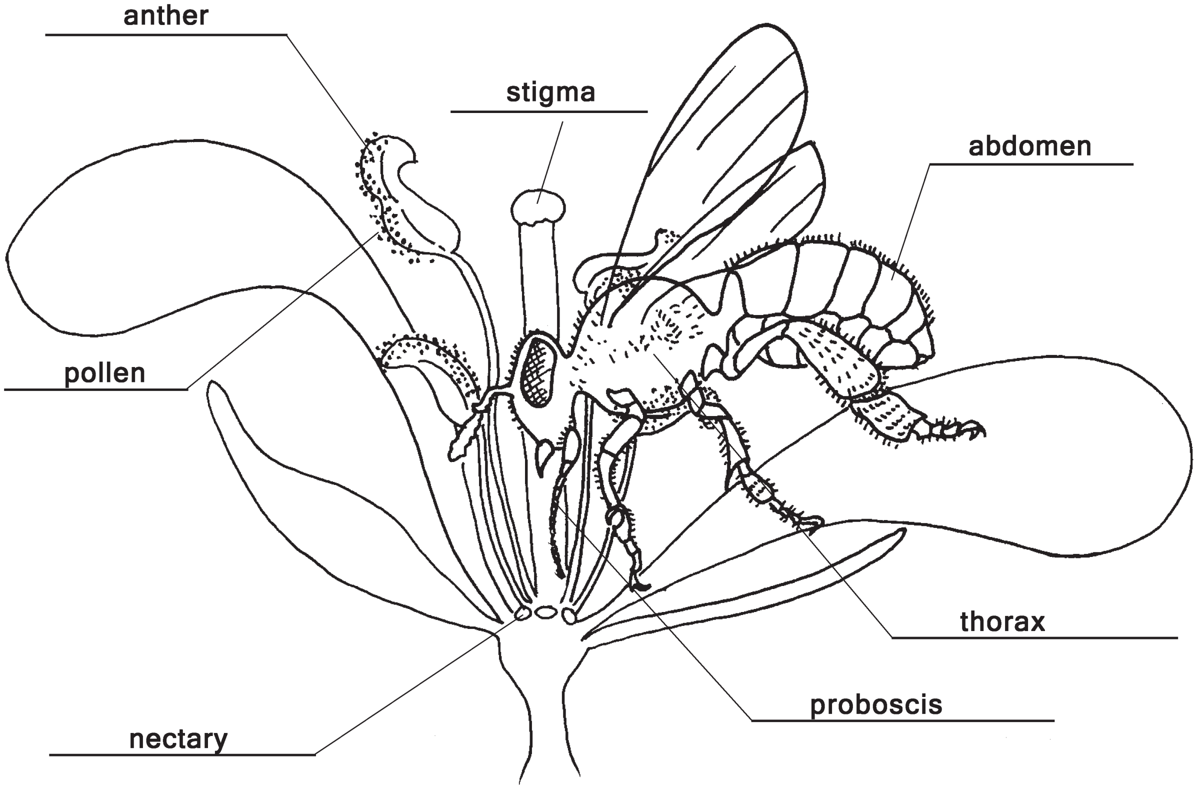


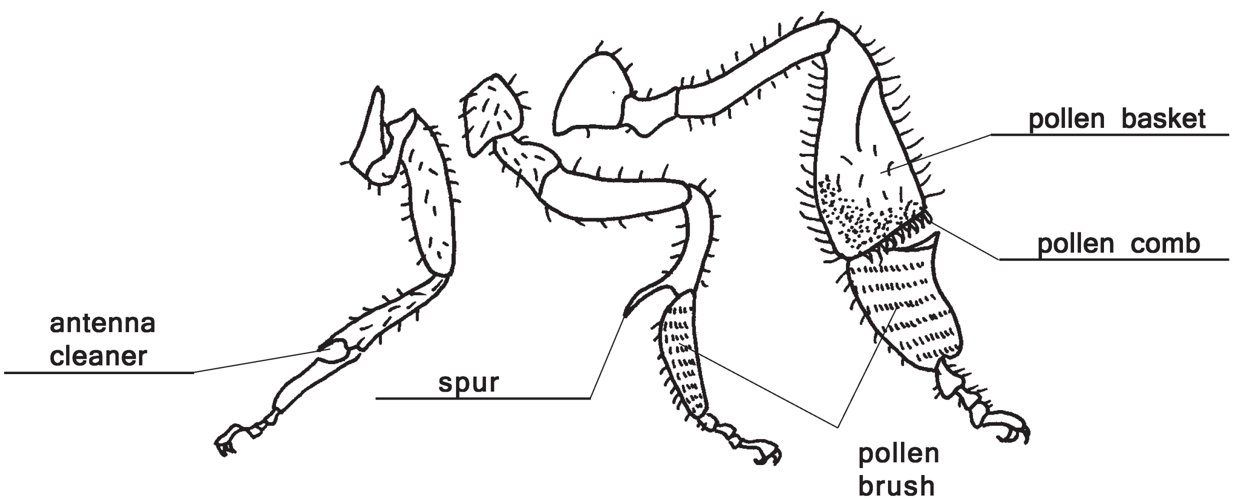
Use these words to identify important bee and flower parts used during pollination:

- abdomen
- antenna cleaner
- anther
- nectary
- pollen
- pollen basket
- pollen brush
- pollen comb
- proboscis
- spur
- stigma
- thorax

Name ______________________

The Honeybee (Key)





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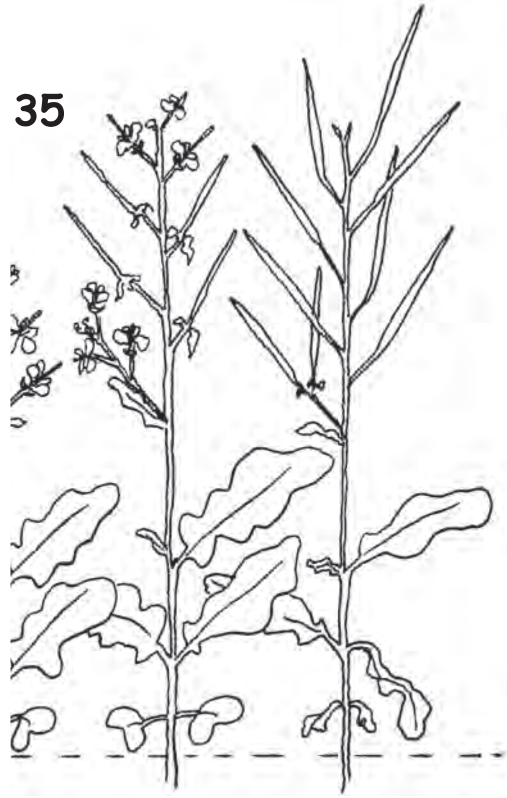
- stigma
- thorax

FERTILIZATION AND SEED DEVELOPMENT

Days 18 – 35



QUESTIONS

- Where do seeds come from?
- What is a seed?
- What happens after pollination to produce seeds?
- Do un-pollinated flowers produce seeds?
- How long can a seedpod grow to be?
- Do longer seedpods produce more seeds?
- How many seeds does a single Wisconsin Fast Plant™ produce?

Key Concepts

- Fertilization is the union of male (sperm) and female (egg) reproductive cells (gametes) in the ovules.
- Fertilization occurs within 24 hours of pollination.
- Within 3-5 days of fertilization, the flower parts drop and the pistil swells and elongates.
- The fertilized egg develops through various stages over the next twenty days until it becomes a mature embryo (seed).

Growing Tips

(See ***Growing Instructions*** for complete guide)

- 20 days after the final pollination, stop watering plants so that seed pods dry

Activity Overview

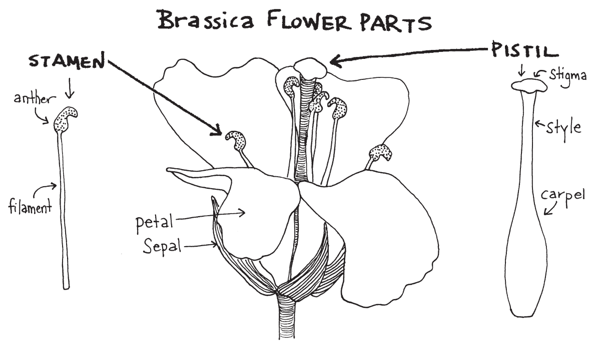
This activity provides you and your students the opportunity to explore what happens between fertilization and seed harvest. In the activity, students observe and record the growth and development of reproductive structures that result from pollination. Pistil length is measured as an indicator of seed maturation and development. Embryo dissection provides the opportunity to observe embryogenesis and endosperm development. Exploring this stage reinforces for students the role of the seed as a living part of the Wisconsin Fast Plants™ life cycle.

The following is a general timeline for the activity:

- Day 0 (0 Days after pollination): 20 minutes to label, terminate flowering, and record pistil position.
- Day 3 (3 Days after pollination): 10 minutes to record pistil length.
- Day 6 (6 Days after pollination): 10 minutes to record pistil length.

Background Information

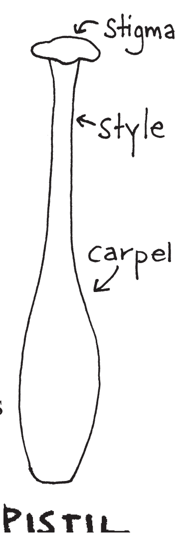
What happens after pollination between fertilization and seed harvest? **Fertilization** in sexually reproducing organisms represents the beginning of the next generation. Immediately following fertilization, the pistil and other maternal structures will grow and change functions. Within the ovules, the embryos also grow and differentiate through a series of developmental stages known collectively as **embryogenesis**.



FERTILIZATION

Fertilization is the reproductive process in which a male and female gamete fuses to form a zygote. In Wisconsin Fast Plants™, fertilization also results in the development of endosperm to nourish the developing embryo. Double fertilization, as in Wisconsin Fast Plants™, follows pollination with a pollen tube growing from each of the many compatible pollen grains adhering to the stigma. Each tube contains two sperm cells and its own nucleus. Only a few of the hundreds of pollen tubes that enter the ovary cavity will successfully fuse with an ovule, and each ovule is joined to only one tube.

One sperm from the pollen tube then unites with the egg cell nucleus (1n) in the ovule to produce a zygote (2n), which will develop into the embryo. The second sperm unites with the ovule's two polar nuclei (each of which are 1n) to form the endosperm (3n). This process is sometimes referred to as double fertilization because it involves two sperm uniting with two separate nuclei.



- Day 9 (9 Days after pollination): 50–60 minutes to record pistil length, dissect and sketch embryo.
- Day 12 (12 Days after pollination): 50–60 minutes to record pistil length, dissect and sketch embryo.
- Day 21 (21 Days after pollination): 10 minutes to record pistil length.

NOTE: *The above estimates reflect only the time necessary for the laboratory activities. Additional time is necessary for data analysis and discussion.*

Materials

Each student will need:

- Wisconsin Fast Plants™ with developing pods
- strong straight-pins
- hand lenses
- 1 copy of Black-line Master: *Seed Dissection*
- 1 copy of Black-line Master: *Pistil Length Class Data Sheet*
- 1 copy of Black-line Master: *Pistil Length Summary of Class Data*

Background Information (continued)

Embryogenesis

Embryogenesis is the development of a healthy seed and its accompanying fruit, following fertilization. It is a highly coordinated sequence of developmental events within the ovule and supporting maternal ovary tissues. The following processes of embryogenesis are responsible for the production and packaging of the next generation (the seed):

- the endosperm is formed;
- the zygote develops into an embryo;
- ovule cells differentiate to produce a seed coat; and
- the ovary wall and related structures develop into a fruit.

After fertilization, and before embryo development, the endosperm and supporting maternal tissues rapidly grow and develop. The triploid (3n) endosperm nucleus that formed during fertilization divides very rapidly and repeatedly to form the nutrient-rich, starchy liquid endosperm. This liquid endosperm bathes the developing embryo, providing it with nutrients. In the latter stages of embryo development of brassicas and other plants, the embryo converts the starchy reserves in the endosperm into lipids that are stored in the embryonic cotyledons. As the embryo matures to a seed, it comes to occupy the space that was filled by the endosperm.

As endosperm formation begins, the first mitotic division of the zygote marks the beginning of embryogenesis. After successful pollination and fertilization, Wisconsin Fast Plants™ embryos mature into seeds in 20 days.

While the embryo develops, the integuments (the walls of each ovule) develop into a seed coat. This coat of maternal tissue protects the new generation until favorable conditions for seed germination are present.

Finally, as the ovule develops into a seed, the ovary wall and other maternal structures in the pistil grow to become the fruit. In some plants, this tissue (which surrounds the enlarging seeds) may thicken, differentiate and develop into a fleshy fruit. In other plants, such as with Wisconsin Fast Plants™, it may dry into a pod. In addition to protecting the developing ovules, the fruit often serves as a means of seed dispersal.

Senescence

As a plant ages and matures, certain tissues and organs no longer have any use. From a casual observation it may seem that they are simply discarded by the plant. However, plants actually initiate a complex sequence of events (called *senescence*) before disposing of these tissues and organs (called *abscission*). In the Wisconsin Fast Plants, the nectaries (located at the base of the pistil) dry up and the the sepals, petals, and stamens wither and fall as they are no longer needed following fertilization.

Senescence is an active developmental process. At the genetic level, sets of senescence-associated genes (SAGs) are expressed and a corresponding array of proteins are synthesized and become active. In turn, these proteins are responsible for the recovery of valuable resources (including amino acids, sugars, nucleosides, and minerals) from the tissues that are about to be discarded.

For Wisconsin Fast Plants™, the process of senescence allows the plants to transfer accumulated resources from the tissues to be discarded into the synthesis and maturation of seeds. In this instance, senescence is genetically preprogrammed. Other ***annuals*** (plants with a one-year life cycle) also have genetically regulated senescence. In other cases of senescence, such as the falling of leaves from trees in autumn, the trigger is mainly environmental.

Procedure

Once a Wisconsin Fast Plant™ grows, develops, flowers, and is pollinated, what happens next? What do you know about where seeds come from? What is a seed? In this activity, you will learn about fertilization and seed development in your Wisconsin Fast Plants™.

1. Observe the pistils on un-pollinated flowers.
2. On the first day when you pollinate, record observations and measurements about pistil length on the Black-line Master: *Pistil Length Class Data Sheet*.
   - You will continue recording observations and measurements about the same plants and flowers at three-day intervals over the next 21 days.
3. Three days after pollination, look for signs of pistil elongation (growth in length).
   - Observe the flower petals. Are they withering?
   - Make a drawing of your plant.
   - Measure the length of each pistil. Record the measurement next to the picture you drew of the pistil.
4. Repeat the drawing and measurements twice a week for two weeks.

5. On Days 10, 11, or 12 after pollination, examine seed development along the length of the pod with a hand lens or microscope.
   a. Carefully strip-off a seed pod.
   b. Use one or two strong pins to open (dissect) the pod. Observe the size of the ovules.
   c. Illustrate and label what you see inside the pods. Date the drawings.
   d. Prick the ovule and squeeze out the developing embryo. Look carefully with the hand lens. What do you see?

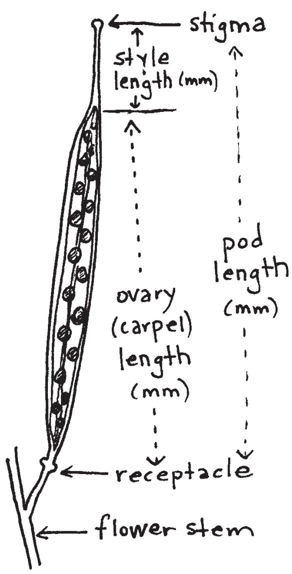
SEED DISSECTION
Sketch Sheet

What stages of embryogenesis can you find?

length of embryo __________
magnification of drawing __________

9 dap
Sketch embryo, include scale bar

length of embryo __________
magnification of drawing __________



12 dap
Sketch embryo, include scale bar

PISTIL LENGTH

Individual Data Sheet

How does pistil length change following pollination?

dap†	Character	Plant #1 Flower number: 1	2	3	4	5	Plant #2 Flower number: 1	2	3	4	5
0*	stigma/pod length										
3*	stigma/pod length										
6*	stigma/pod length										
9*	stigma/pod length										
12*	stigma/pod length										
21*	stigma/pod length										

† *dap* = days after pollinating

* measurements should be taken at approximately 0, 3, 6, 9, 12, and 21 *dap,* but actual measurement day may vary slightly due to the development of the plant.

Statistics on Pistil Length

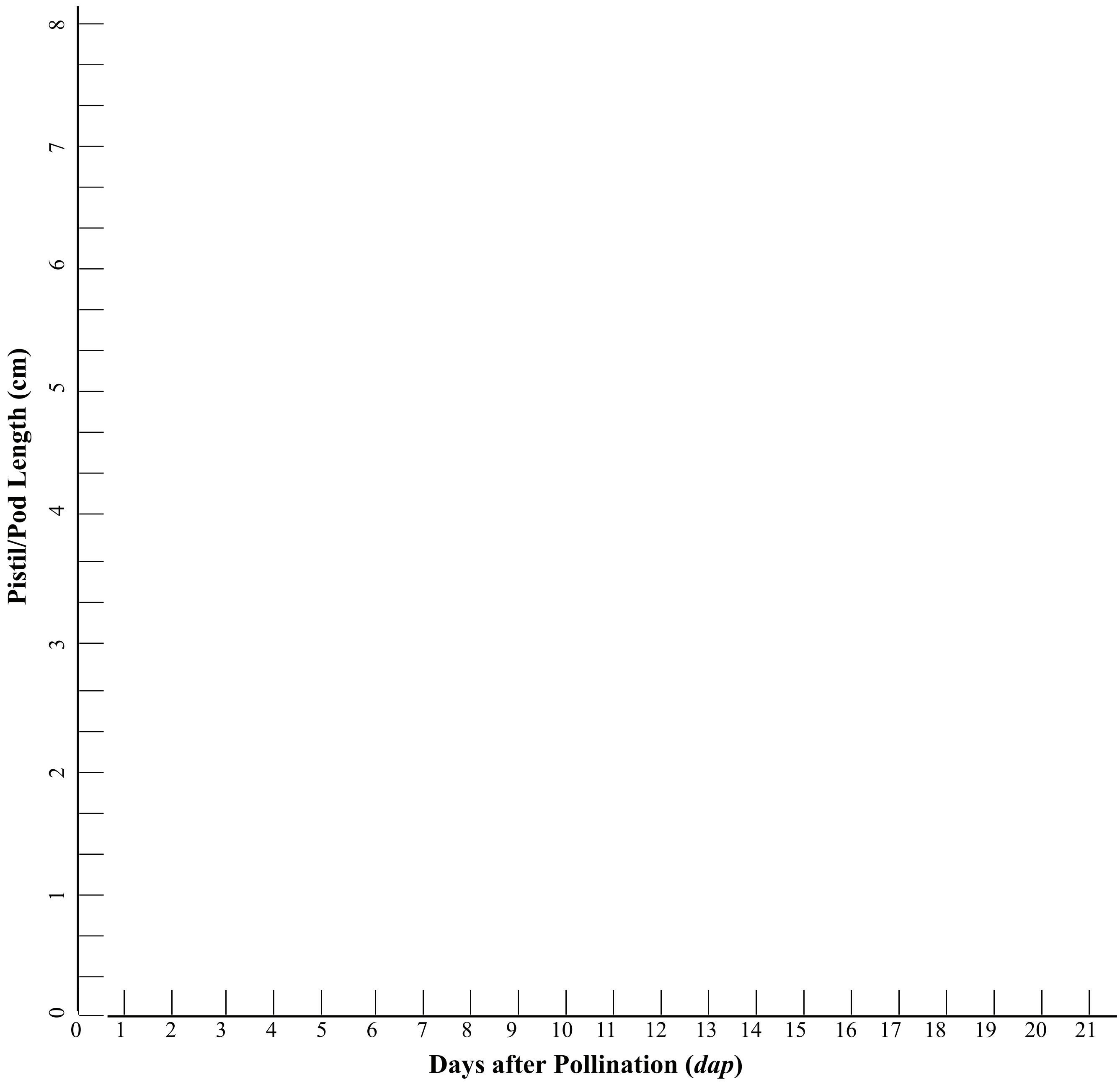
Day	*dap*	Pistil Length n	$\bar{x}$	r	s

n = number of measurements, r = range (maximum minus minimum), $\bar{x}$ = mean (average), s = standard deviation

PISTIL LENGTH

Summary of Class Data

Does a seed pod grow at a constant rate?



Is there a correlation between the length of seed pod and the number of seeds produced in the pod?