SBI3U-C

Lesson 15

Reproductive Mechanisms of Plants

Introduction

Plants can reproduce in a great variety of ways: from seeds, spores, rhizomes, bulbs, tubers, cuttings, grafts, and buds. Seeds are made by flowers in some plants, and by cones in other plants. In this lesson, you will learn about the different reproductive mechanisms of plants and how we have learned to manipulate them to our benefit.

Plants can't reproduce without pollen. Pollen is one of the major reasons flowering plants and trees have been able to colonize almost every habitat on the planet. Plants have evolved some very beautiful and complex ways to ensure their pollen gets delivered to an egg of their own species. One way is through animal pollinators, like bees. Many plants are so dependent on their pollinators that if the pollinators disappeared the plants would become extinct. That is why the conservation of pollinators has become part of biodiversity conservation efforts.

This lesson may take you a bit longer to finish than the others in this unit since there are two activities, one online and one that you can carry out at home.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Importance of Pollinators	¼
Asexual Reproduction in Plants	½
Sexual Reproduction in Angiosperms	½
Sexual Reproduction in Gymnosperms	½
Writing a Formalized Hypothesis	¼
Activity: Examining Pollen Samples	1
Activity: Alfalfa Seed Germination	1
Careers in Plant Science	¼
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- explain the importance and dependence of pollinators on the agricultural system
- explain the reproductive mechanisms of plants in natural reproduction and artificial propagation (for example, germination of seeds, leaf cuttings, and grafting of branches onto a host tree)
- identify and describe a variety of careers related to the fields of biology
- formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and formulate educated hypotheses to focus inquiries or research

Importance of Pollinators

Plants have several methods of reproduction, although the one used by most plants is pollination. Some plants have evolved to disperse their pollen (male gametes) randomly using wind and water, while others have evolved ways to entice animals to carry the pollen directly to another plant of the same species. Animal pollination is based on the principle of a mutually beneficial relationship between the pollinated (plants) and the pollinator. The pollinator gets a free meal of nectar or fruit from the plant, and the plant gets its pollen transported to another flower very efficiently.

About three-quarters of the 275 000 species of flowering plants rely on pollinators—insects, birds, bats, and other animals—to carry pollen from the male to the female parts of flowers for reproduction. Pollinators are vital to agriculture because almost all crops, including fruits, vegetables, seed crops, and others that provide fibres, drugs, and fuel are dependent on pollinators. Every year, the crops need to be pollinated again so they can produce the fruits, vegetables, and seeds we love to eat.

The best-known pollinators are honeybees (Figure 15.1). They are the most important pollinator of commercial crops. In fact, every year, beekeepers rent out their colonies for the purpose of pollination, placing them in or around crops. Highly developed transportation techniques have been developed for moving honeybee colonies from area to area as they are needed.

Figure 15.1: A honeybee visiting a flower. Notice the clumps of pollen sticking to its lower leg.

Source: Wikipedia

Like much of the earth's biodiversity, pollinators are threatened by many factors, but climate change is potentially the most severe threat. Scientists report that the small climate changes we have experienced over the last few decades have already reduced the populations of some pollinator species such as butterflies, bees, and birds in Europe and North America. Other threats to pollinators come from antibiotic-resistant pathogens, pesticide-resistant mites, and the encroachment of Africanized honeybees. Declines in many pollinator species are also associated with habitat loss, fragmentation, and deterioration.

Today, many areas of agriculture are threatened by a lack of pollinators. Pollinator shortages can lower crop yield, resulting in food shortages and higher prices for many people. Beekeepers have increased their transport of bees around the country to help make up for the decline in local pollinators and keep agriculture going. Pollinator species are also critical in maintaining biodiversity. Any changes in the abundance and diversity of pollinators will influence the abundance and diversity of plant species and, ultimately, the animals that depend on them.

Pollinators and Pesticides

Pesticides are chemicals used to manage unwanted organisms, especially on agricultural crops. Sometimes their toxicity or application methods can have negative effects on non-target animals, including pollinators. Even if a chemical pesticide does not kill a particular organism, it can alter it in ways that are difficult to measure. With honeybees, for example, sub-lethal exposure to residual pesticides can adversely affect nesting behaviour, orientation, learning, and reproduction, as well as increase the mortality of immature bees.

For pollinators, pesticides designed to kill insects (insecticides) are potentially the most destructive of all pesticides, because most pollinators are insects. Other forms of pesticide, such as fungicides and herbicides, do not usually kill insect pollinators directly. However, pollinators may be indirectly harmed by herbicides when they destroy the flowers on which foraging pollinators depend. Other pollinators, like bats and birds, may also be affected by exposure to pesticides in ways that are difficult to predict.

Support Questions

Be sure to try the Support Questions on your own before looking at the suggested answers provided.

38. Explain how the action of beekeepers is preserving pollination, and the beneficial effect this has on farmers. Suggested answer

39. What impact will pollinator decline have on biodiversity? Suggested answer

Vegetative Propagation

Vegetative propagation means using tissue of the adult plant to produce new plants. All plant organs (stems, leaves, roots) can be used for vegetative propagation, but stems are the most common. In some species, stems naturally arch over and take root at their tips, forming new plants. Strawberries, whose horizontal stems (stolons) produce new daughter plants at alternate nodes (Figure 15.2), reproduce this way.

Figure 15.2: Strawberry plant reproducing asexually from its stolon

Source: Wikipedia

Leaves can also be used for asexual reproduction. In some plants, mitosis at meristems along the leaf margins can produce tiny plantlets that fall off and form a new plant. In others, deeply veined leaves or succulent leaves like those found in cacti, are all capable of producing plantlets from the leaves. The aquatic plant duckweed, which you see everywhere in Ontario ponds during the summer, reproduces in this way, which is why it can spread across a pond so rapidly.

Roots can be used for asexual reproduction. The dandelion is a common example, as new plants can sprout from root branches underground. Trees, such as the poplar or aspen, can send up new stems from their roots, producing new trees. In time, an entire stand of trees may form this way, all cloned from the original tree. Many plants and trees send out shoots or suckers directly from the roots. These suckers can easily develop into new plants.

Gardeners have learned to use the asexual reproduction of plants to their advantage, and are now using it to increase the abundance of a plant via cuttings and grafting. These methods are considered to be artificial, as they do not occur naturally. Commercially-important plants are often deliberately propagated by asexual means in order to preserve particularly desirable traits (such as flower colour, flavour, or resistance to disease). If sexual reproduction were used instead, it is likely that many of the offspring would show different traits from their parents, as you learned earlier.

Grafting and Cutting

Two main techniques are used in commercial asexual plant propagation: cutting and grafting. A cutting is any part of the plant, usually a stem branch, that is subsequently rooted. Grafting is a process in which pieces of stem from one plant are physically attached to the stem of another plant, possibly a plant of a different variety or even a different species. The piece added (graft) is aligned with the host plant (stock) so the cambiums of both are united (Figure 15.3). If precautions are taken to prevent infection and drying out, then the graft will grow. The graft will get all its water and minerals from the root system of the stock.

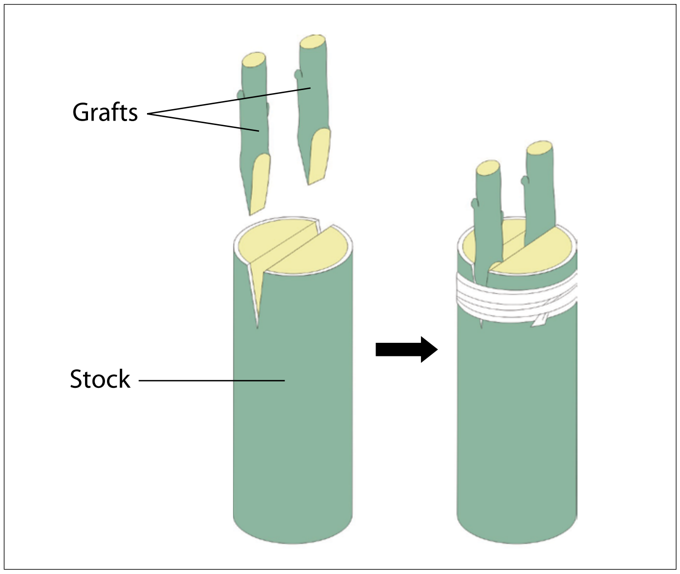

Figure 15.3: Two grafts added to a stock trunk and then bound with tape to keep the connection tight to speed bonding

Source: Wikimedia Commons

Grafting is widely used to propagate a desired variety of shrub or tree. All apple varieties, for example, are propagated this way. Apple seeds are planted only for the root and stem system that grows from them. After a year's growth, most of the stem is removed and a twig (graft) taken from a mature plant of the desired variety is inserted in a notch cut in the stump of the stock. All McIntosh apple trees presently grown have been reproduced this way from the original McIntosh discovered in 1729 in Dunelda, Ontario. This guarantees that all MacIntosh apples today are the same as they were in 1729.

It is possible to put more than one graft on a particular tree, even combining different fruit trees into one tree. That is why it is possible to purchase one tree at a garden centre that will produce three different varieties of apple and one type of pear at the same time.

Apomixis

Apomixis is a type of reproduction where flowering plants reproduce asexually through seeds. The seeds are formed from the tissue of the maternal plant and are diploid. But, because they are not fertilized, the seeds contain identical genetics to the parent plant. Citrus trees and many other species of angiosperms use apomixis as a method of asexual reproduction. This method of asexual reproduction is available to sterile hybrids which could not otherwise reproduce. For example, the many varieties of Kentucky bluegrass growing in lawns across North America and the many varieties of blackberries are two examples of sterile hybrids that propagate successfully by apomixis.

Many valuable crop plants (such as corn) cannot be propagated by asexual methods like grafting. Agricultural scientists would like to convert these plants to apomixis to guarantee specific features will show up in the offspring. After twenty years of work, an apomictic corn plant has been produced, but it does not produce enough viable kernels to be useful commercially.

Support Questions

40. What parts of a plant can be used for vegetative propagation? Suggested answer

41. Explain how it is possible to obtain different types of fruit from a single tree. Suggested answer

42. What is apomixis? Suggested answer

43. What is the benefit of propagating plants by asexual reproduction? Suggested answer

Sexual Reproduction in Angiosperms

Sexual reproduction in flowering plants involves meiosis and the fusion of gametes, usually from different plants, and results in seedlings that are genetically different from their parents. The male gamete is called pollen. Pollen grains are produced in great amounts by plants, and are dispersed widely by wind and animals.

Recommended Activity:

[Taking a Closer Look at Pollen]

Pollination in Angiosperms

Angiosperms, the flowering plants, are the most advanced among terrestrial plants. They use flowers as their organ for sexual reproduction. Flowers produce gametes (sex cells), and are the place where fertilization takes place.

Flower Anatomy

Flowers are categorized into two groups: perfect and imperfect. Perfect flowers contain both male and female structures. Imperfect flowers contain the structures of only one sex. Within each category, flowers can be further classified as either complete (possessing sepals, petals, stamens, and pistils) or incomplete (lacking one or more of these structures). The parts of a typical mature flower are shown in Figure 15.4.

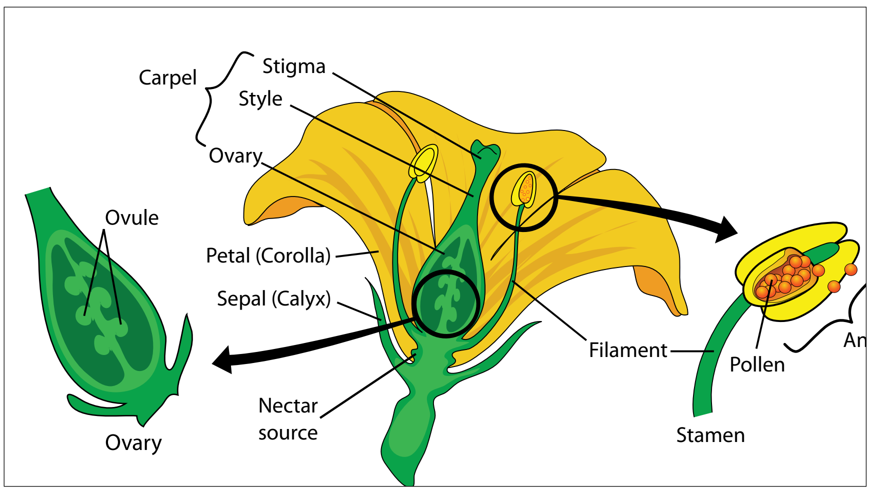

Figure 15.4: Anatomy of a mature flower showing close-ups of the ovary and stamen

Source: Wikipedia

Sepals enclose and protect the flower as it is forming during the bud stage. The collection of sepals is called the calyx. Inside the calyx lie the petals which, together, form the corolla. The corolla is usually the showy part of the flower, and serves to attract potential pollinators. Inside the corolla lie the stamens, or male structures, which consist of pollen-bearing anthers that sit on top of stalk-like filaments. In the centre of the flower is the female reproductive organ, or pistil, which may consist of one to several carpels. The carpel is composed of a stigma, where the pollen is received, a style upon which the stigma develops, and an ovary. The ovary contains one or more ovules, which contain the egg cells.

Pollination

Before seeds can develop inside a flower, pollen grains from the anthers must reach the stigma. This process is called pollination. Pollination can occur within a single flower, among different flowers of a single plant, and among flowers of different plants. It is common for plants to receive mixtures of pollen grains of their own and from other plants, especially if the male and female parts are in the same flower. There are two main types of pollination: self-pollination and cross-pollination.

Self-pollination

In self-pollination, both male and female gametes come from the same plant. Self-pollinating plants are not very common; some examples include peanuts, peppers, strawberries, and tomatoes. There are several advantages to self-pollination, such as not being dependent on the presence of pollinators to reproduce, and being able to propagate rapidly. For example, plants found on islands where pollinators may not be present have a higher likelihood of being able to self-pollinate than plants on the mainland. The main disadvantage to this form of reproduction is that it can result in decreased genetic diversity, as the parent passes on only its own genes to its offspring.

Cross-pollination

Cross-pollination occurs when pollen from one flower is transferred to a flower on a different plant. Many plants rely on wind or water for cross-pollination, but they must produce large amounts of pollen to ensure the chance interception of pollen by the stigma. Other plants rely on pollination by animals such as insects, birds, and bats, which wastes less pollen compared with pollination by wind or water. On the other hand, the plant may need to expend additional energy to promote pollination by animals; for example, by providing nectar to reward pollinating animals.

Advantages of cross-pollination include the rapid transfer of beneficial genes to offspring and the maintenance of high genetic diversity throughout the population. One disadvantage of cross-pollination is that the plant does not have the ability to self-pollinate if animal pollinators are absent. This means the plant population could die out. Another disadvantage is that the pollinator may transfer diseases from one plant to another along with pollen.

Flower Adaptations for Successful Pollination

Pollination between two flowers requires that the pollen be transferred in some way. Flowers pollinated during the day by flying pollinators tend to be very visually impressive, their bright colours serving to guide flying pollinators by sight. Night-pollinated flowers are often white, because white is the most visible colour under low light conditions. Fragrance also plays an important role in guiding flying pollinators toward flowers, particularly in night-pollinated flowers. If the plant uses wind for pollen dispersal, the flower tends to be optimized for wind-aided dispersal and tends not to be showy, since it does not have to attract pollinators.

Fertilization

Pollination occurs when a pollen grain lands on the stigma. Pollination is only one stage of fertilization (the meeting of the male and female sex cells). Upon pollination, the male sex cell lies inside the pollen grain, which is on the surface of the stigma. The female sex cell (the ovule) lies inside the carpel, in a different part of the flower. The pollen grain must therefore grow an extension called a pollen tube to reach the ovule. The pollen tube grows through the stigma and style, and into the carpel (Figure 15.5). A sperm cell travels down the tube; eventually, it reaches an ovule, and the male and female sex cells fuse to form a zygote.

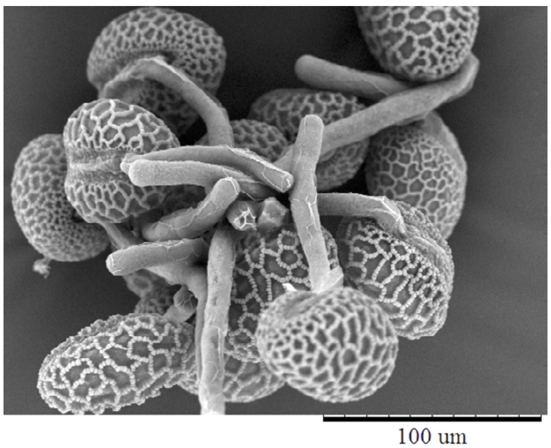

Figure 15.5: Electron microscope image of pollen with pollen tubes

When all the ovules have been fertilized, the rest of the flower also changes. There is no longer any need for petals, and these fall off. The anthers, and sometimes the stigma and style, also fall from the flower. The carpels start to grow larger as the seeds inside them develop. The whole structure is now called a fruit.

Recommended Activity:

Do an Internet search using the terms "flower pollination" and find a video to watch as a review of the pollination process.

Seed Development

Once fertilized, the ovule begins its development into a seed. While the pollen tube is growing, cells inside the ovule have been developing into a cotyledon. The zygote itself will now go through mitosis to form a multi-celled embryo with a miniature leaf, root, and stem. The cotyledon(s) will develop into the first leaves. The sac around the ovule will harden and thicken into a seed coat. The endosperm contains the food needed to nourish the new plant as it begins to grow (Figure 15.6).

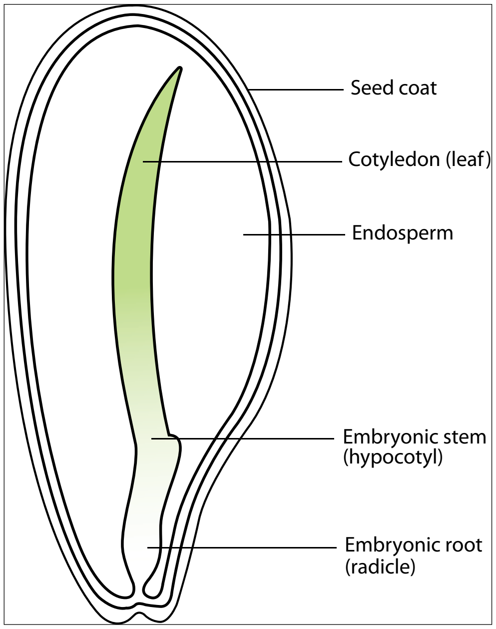

Figure 15.6: Anatomy of a monocot seed

Source: Wikipedia

Seed Germination

Seeds wait to germinate until three needs are met: water, correct temperature (warmth), and a good location where oxygen is available (such as in soil). If a seed is not allowed to germinate, or sprout, within a certain length of time, the embryo inside will die. Each species of seed can stay dormant for a certain length of time before it dies. For example, some maple species have seeds that need to sprout within two weeks or they die. Some seeds of lotus plants, however, are known to be up to 2000 years old and can still germinate.

All seeds need water before they can germinate. When a seed comes in contact with water, some water gets absorbed into the seed by the process of osmosis, raising the water content level within the seed. This stimulates enzyme activity for the metabolic processes involved in germination. Seeds vary in the amount of water needed for germination depending on their variety. Rice seeds, for example, need to achieve 32–35% water content. Some seed varieties do not need much water, and may even die from rot if they are surrounded by too much water.

The germination processes of dicots and monocots are slightly different, but follow the same general pattern. During the germination process, the primary root (radicle) emerges through the seed coat. It grows down between the soil particles, and root hairs appear in the region where elongation has ceased. Water and salts from the soil are absorbed by the root hairs on the radicle and are passed on to the rest of the seedling. Once the radicle is firmly anchored in the soil, the embryonic stem (hypocotyl) starts to grow. When the hypocotyl emerges from the soil, it straightens up under the influence of light. The rapid growth of the hypocotyl pulls the cotyledon(s) out of the seed coat and through the soil (Figure 15.7). The cotyledon(s) act as the primary leaf that begins photosynthesis to fuel future growth.

Figure 15.7: A 3-day-old sunflower (dicot) showing the cotyledons breaking free of the seed case

Source: Wikipedia

Support Questions

44. What is a seed? Suggested answer

45. What is the role of a flower? Suggested answer

Seed Dispersal

Dispersal is the transport of seeds away from the parent plant. Seed dispersal provides many advantages. A seed that stays near its parent will be competing with a mature plant for resources such as light, soil, and water. Also, dispersal can increase the likelihood that the offspring will be able to colonize a new area.

Plants have developed numerous adaptations to ensure the spread of their seeds to other areas.

- Exploding flowers: Some plants are able to project their own seeds a good distance when they are disturbed, such as the Jewel weed and pea plant.
- Wind: the helicopter-like blades of maple seeds help carry them on the wind, while the silky white tufts of dandelion and milkweed seeds act like parachutes.
- Water: the seeds of coconuts, water lilies, and purple loosestrife all float, and can travel long distances across water bodies.

- Dispersal by animals:
  - some seeds use spines, hooks and barbs, or sticky substances to attach themselves to the fur of passing animals;
  - the seeds of many plants are dispersed after passing through the digestive system of birds and mammals that have eaten the fleshy fruits;
  - the uneaten, buried caches of seeds and nuts made by mice, squirrels, and some birds may also develop into plants.

Support Questions

46. Describe two advantages of seed dispersal. Suggested answer

Sexual Reproduction in Gymnosperms

Gymnosperms can also reproduce sexually, but their method of reproduction and seed formation is different from that of angiosperms because they do not have flowers. The most common type of gymnosperm alive today are the conifers (from the Latin *coniferae*, meaning "bearing cones"). There are more than 500 conifer species distributed worldwide. Probably the most familiar conifers to Canadians are pine trees. The easiest method of identifying a conifer is to look at the leaves. Conifers are usually evergreen trees or shrubs with linear, needle-like, or scale-like leaves. Most conifers reproduce by seeds that are usually formed in cones.

The next section will guide you through the reproductive cycle of a conifer.

Gamete Formation and Fertilization in Conifers

Like all vascular plants, gymnosperms, including conifers, reproduce using gametes and seeds. In conifers, the gametes have a complex life cycle that lasts about a year. During most of this period, the gametes are developing inside a cone. A cone is made of tough, thick scales that are actually modified leaves.

Gamete Production

Conifer trees of most species bear both pollen (male) cones and ovulate (female) cones, usually on a single tree. For example, pines produce soft male cones in clusters at the base of the new spring shoots (Figure 15.8).

Figure 15.8: A male pine cone in spring

Source: Wikipedia

These cones only last about one to two weeks, and produce haploid male gametes called pollen. The thick wall around the pollen (exine) sometimes bulges out to form two lobes, or wings, which help the pollen get carried farther by the wind (Figure 15.9).

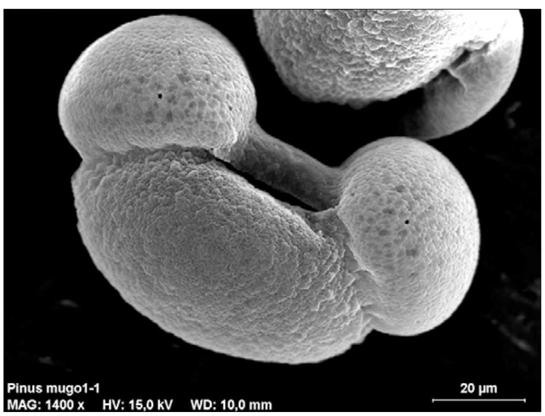

Figure 15.9: Electron microscope image of pine pollen. Notice the two lobes on either side.

Source: Wikimedia Commons

The female cones of conifers are much larger and harder than the male cones (Figure 15.10a) and they become quite woody as they mature (Figure 15.10b). The typical pine cone that you might see on a forest floor is a woody female cone.

Figure 15.10: a) an immature seed cone in early spring; b) a seed cone in summer with its scales open.

Source: Wikipedia

Fertilization and Seed Development

The wind or insects transfer pollen from male cones to female cones that have open scales. Once some pollen reaches the female cones and is drawn into the ovule, the scales close up. The pollen grains germinate inside the ovule and form a pollen tube used to inject the sperm into the egg. However, it will be more than a year before fertilization takes place. During that year, cells in the female cone undergo meiosis to produce four haploid cells each. One of the four cells survives and grows into an egg. By the time eggs are ready to be fertilized, two sperm cells have developed in the pollen grain. Fertilization occurs when one of the sperm nuclei, injected into an egg cell by the pollen tube, unites with the egg nucleus. All the eggs in an ovule may be fertilized, but usually only one zygote develops into an embryo. The embryo becomes a pine seed, which consists of an embryo, its food supply (made from tissue in the ovule), and a surrounding seed coat.

Support Questions

47. Match the structure to its function in gymnosperms. Suggested answer

Structure	Function
1. Scales	A. This structure, which often possesses distinct, uniquely identifiable features, is the coating surrounding a pollen grain.
2. Ovule	B. This structure is used to transport sperm into egg cells.
3. Pollen tube	C. This structure consists of an embryo, its food supply, and a surrounding coat.
4. Seed cone	D. This structure is made of modified leaves that are tough and thick.
5. Exine	E. This structure contains cells that undergo meiosis to become eggs.
6. Seed	F. This structure is the female reproductive organ.

Writing a Formalized Hypothesis

What we know about vascular plant reproduction comes from careful observation and experiments. These scientific activities are guided by hypotheses, which help focus the researcher on a particular feature or process.

A hypothesis is a statement that proposes a possible explanation of some phenomenon or event. A useful hypothesis is a testable statement, which includes a prediction. The role of the formal hypothesis is to help make a testable prediction based on our understanding of how something works. To test a hypothesis, observations can be made or an experiment can be conducted. Because the hypothesis makes a clear and testable prediction, each time a hypothesis is rejected or accepted, we know a little more about the object of the study. This is how scientific knowledge accumulates over time.

Here are two examples of formalized hypotheses:

1. If skin cancer is related to ultraviolet (UV) light, then people with a high exposure to UV light will have a higher frequency of skin cancer.
2. If leaf colour change is related to temperature, then exposing plants to low temperatures will result in changes in leaf colour.

Notice that these statements contain the words **if** and **then**. They are necessary in a formalized hypothesis. But not all if–then statements are hypotheses.

For example:

If I play the lottery, then I will get rich.

This is a simple prediction, not a hypothesis, because it does not describe how the first thing is related to the second. In a formalized hypothesis, a tentative relationship is stated.

For example:

If the frequency of winning is related to the frequency of buying lottery tickets, then people who buy more tickets should win more often.

This is a good hypothesis because it makes a testable prediction and tells you what to measure. If you ask yourself how one thing is related to another, then you should be able to make a formal hypothesis about their relationship. The value of creating a formalized hypothesis is that it forces you to think about what results you should look for in an experiment.

Formalized hypotheses contain two variables. One is called the independent variable, and the other is called the dependent variable. The independent variable is the one you control, and the dependent variable is the one that you observe or measure. The value of the dependent variable will *depend* on the value of the independent variable. The value of the independent variable does not change in response to the dependent variable—it only changes when you manipulate it. That is why it is called the independent variable.

In the following hypothesis, the dependent variable is highlighted in italics and the independent variable is highlighted in bold:

If *lung cancer* is related to **smoking**, then people who smoke more should have a higher incidence of lung cancer.

Lung cancer is the dependent variable in this hypothesis because it depends on the independent variable (smoking). To test this hypothesis, you could find a population of smokers and rank them from lightest to heaviest smokers. If your hypothesis is correct, you would predict that the heaviest smokers in your study would show a higher incidence of lung cancer.

Support Questions

48. Consider the following sentences. Suggested answer

a) Chocolate may cause pimples.

b) Salt in soil may affect plant growth.

c) Plant growth may be affected by the colour of the light.

These three sentences are examples of hypotheses because they use the tentative word "may." However, their form is not particularly useful. Using the word "may" does not suggest how you would go about proving it. Rewrite the sentences as formalized hypotheses, and identify the dependent and independent variable.

	Formalized hypothesis	Independent variable	Dependent variable
a			
b			
c			

Activity: Alfalfa Seed Germination

The life functions in a seed are almost completely dormant until the time is right to start growing (germination). But how does a seed know when the conditions are right to begin germination? In this activity, you will investigate the effects that temperature and moisture have on seed germination.

You will perform two experiments to see how differences in temperature or moisture affect germination success. Each experiment can be set up in about 30 minutes or less, but it will take two days for the seeds to germinate. You will know that a seed has germinated when it has broken open to reveal some tissue poking out.

The only material that may be difficult to obtain will be the plastic Petri dishes (Figure 15.11). These are available at some garden supply stores and hobby shops as well as through online suppliers. Dollar stores often have dishes like this in their craft sections for beading and necklace-making. If you can't get Petri dishes, then you can try using any flat, clear plastic container with a tight-fitting lid.

If you are unable to perform these experiments, sample data is provided. You can use that sample data to answer the Support Questions that follow the activity.

Figure 15.11: Picture of a petri dish

Experiment 1: Effect of Temperature on Germination

In this experiment, you will determine how different temperatures affect seed germination. You will make 10 identical germination chambers, then vary the temperature of each to see how different temperatures affect seed germination.

Materials

- 200 alfalfa seeds (available at health food stores, some grocery stores, as well as garden supply stores)
- 10 plastic Petri dishes with lids (or any clear plastic container with a lid). Plastic food wrap can be used in place of a lid as long as it is sealed tightly, not letting any air in.
- Marker pen to label the Petri dishes (or tape and a regular pen)
- Paper towels
- Water dropper
- Tap water
- Tweezers
- A warm surface such as the top of a radiator or heat vent that you can leave undisturbed for 48 hours. If the surface is too hot to the touch (like some radiators), you may want to put a magazine or book under the Petri dishes so you don't "cook" the lower dishes.

Procedure

You will make 10 identical germination chambers. Each chamber will consist of a Petri dish with a lid, a circle of wet paper towel, and 20 alfalfa seeds. Each chamber will also be labelled with a number from 1 to 10.

Making the Germination Chambers:

- Wash your hands carefully to reduce any contamination.
- Label each of the 10 Petri dishes with a number from 1 to 10 using the marker (or put tape under each dish and mark the number on the tape with a regular pen).
- Cut the paper towel into round circles that will fit inside the bottom of the Petri dishes. Make one paper towel circle for each of the 10 Petri dishes.
- Place one paper towel circle into the bottom of each Petri dish.
- Add the same amount of water (about one dropper full) to each Petri dish. You want the paper towel to be soaking wet and have some unabsorbed water lying on top of it.
- Using tweezers, very gently place 20 seeds into each Petri dish.
- Place the covers securely on the Petri dishes. (An improperly secured cover will let air in, allowing moisture to escape and, therefore, changing the growing conditions.)
- Stack the 10 Petri dishes vertically with dish #1 on the bottom, dish #2 on top of it, dish #3 on top of that, and so on, until you have a stack of 10 dishes with dish #10 on top.

- If you are using plastic food wrap as a lid, you may have to put thin pieces of cardboard in between each dish so that they do not crush the ones below.
- Move your stack of Petri dishes to the warm surface. Make sure the stack is steady.

What Have You Done?

By stacking your Petri dishes on a hot surface, you have created a temperature gradient. The Petri dish on the bottom of the stack is the hottest, and the temperature continues to drop as you move up the stack, with the top dish in the stack being the coolest. This enables you to test the effect of temperature on germination. Because each dish was set up in exactly the same way except for their position in the stack, the only variable is the temperature they experienced. In other words, you have controlled for the effects of any other variable. This ensures that any changes in germination are due to temperature and not some other aspect of their preparation.

Recording Your Results

After 48 hours, record the germination success within each Petri dish in Table 15.1, below, as follows:

a) Record the number of seeds you planted.

b) Record the number of seeds that germinated.

c) Write a fraction showing the number of seeds that germinated in the numerator, and the number of seeds that were planted in the denominator.

d) Show each fraction as a percentage.

Petri dish label	Relative temperature	Number of seeds planted	Number of seeds that germinated	Fraction of seeds that germinated	Percentage of seeds that germinated
1	Hottest				
2					
3					
4					
5					
6					
7					
8					
9					
10	Coldest				

Table 15.1: Experiment 1: Effect of temperature on germination of alfalfa seeds

For example, if you planted 20 alfalfa seeds in dish number 1, and 15 seeds germinated, you would fill in the table as follows:

Petri dish label	Relative temperature	Number of seeds planted	Number of seeds that germinated	Fraction of seeds that germinated	Percentage of seeds that germinated
1	Hottest	20	15	15/20	75%

Experiment 2: Effect of Moisture on Germination

In this experiment, you will determine how different levels of moisture affect seed germination. You will make 10 germination chambers as in Experiment 1, but this time you will vary the amount of water you add to each one.

Materials

- 200 alfalfa seeds
- 10 Petri dishes with lids (or any clear plastic container with a lid)
- a marker to label the Petri dishes (or tape and a regular pen)
- Paper towels
- Water dropper
- Tap water
- Tweezers

Procedure

- Cut circles of paper towel to place into each of the 10 Petri dishes.
- Label the Petri dishes with the amount of water drops you will add to each, in increments of five. Label the first Petri dish '0,' the second dish '5,' the third dish '10,' the fourth '15', and so on. When you are done, you should have 10 dishes labelled 0, 5, 10, 15, 20, 25, 30, 35, 40, and 45.
- Add drops of water to each dish according to the number on the label. Do not add any water to the dish labelled 0; add 5 drops of water to the dish labelled 5; add 10 drops to the dish labelled 10, and so on.
- Using tweezers, very gently place 20 seeds into each Petri dish.
- Place the covers securely on the Petri dishes.
- Store the Petri dishes where they will not be disturbed for 48 hours **(2 days). Keep them at room temperature (20–23 degrees Celsius)**, away from heating radiators and out of direct sunlight.
- After the time has elapsed, record the germination rate for each Petri dish in Table 15.2, below.

Petri dish label	Number of water drops added	Number of seeds planted	Number of seeds that germinated	Fraction of seeds that germinated	Percentage of seeds that germinated
0	0				
5	5				
10	10				
15	15				
20	20				
25	25				
30	30				
35	35				
40	40				
45	45				

Table 15.2: Experiment 2: Effect of moisture on germination of alfalfa seeds

What Have You Done?

By adding a different amount of water to each dish, you have created a moisture gradient. The Petri dish numbered '0' is the driest, and the moisture level increases as the number on the label gets larger, with the dish labelled '45' being the wettest. This enables you to test the effect of moisture on germination. Because each dish was set up in exactly the same way except for the number of water drops, the only variable is the level of moisture they experienced. In other words, you have controlled for the effects of any other variable. This ensures that any changes in germination are due to moisture levels and not some other aspect of their preparation.

Support Questions

49. State the independent variable in:

a) Experiment 1

b) Experiment 2 Suggested answer

50. State the dependent variable in:

a) Experiment 1

b) Experiment 2 Suggested answer

51. State the formalized hypothesis in:

a) Experiment 1

b) Experiment 2 Suggested answer

52. In experiment 1, which chambers showed the highest germination success? Suggested answer

53. In experiment 1, what effect did heat have on seed germination? Was your hypothesis supported or refuted?

Suggested answer

54. In experiment 2, which chambers showed the highest germination success?

Suggested answer

55. In experiment 2, what effect did moisture on seed germination? Was your hypothesis supported or refuted?

Suggested answer

56. Based on your results, how might a farmer increase his crop yield in areas where there is too much or too little moisture?

Suggested answer

Recommended Activity:

Follow this link to learn about a variety of Careers in Plant Science.

Key Questions

Now work on your Key Questions in the online submission tool. You may continue to work at this task over several sessions, but be sure to save your work each time. When you have answered all the unit's Key Questions, submit your work to the ILC.

(17 marks)

45. List three factors that are contributing to the decline of pollinator populations. **(3 marks)**

46. From an agricultural perspective, describe two advantages of vegetative propagation. **(2 marks)**

47. For a plant colonizing a remote island, describe one advantage and one disadvantage of:

a) cross-pollination **(2 marks)**

b) self-pollination **(2 marks)**

48. Match the structure to its function in angiosperms. **(4 marks: ½ mark each)**

Structure	Function
1. Corolla	A. This structure produces pollen.
2. Stamen	B. This structure contains the fertilized zygote.
3. Carpel	C. This structure attracts pollinators.
4. Anther	D. This structure is a collection of sepals.
5. Sepal	E. This structure is the male sex organ.
6. Seed	F. This structure is where meiosis takes place to produce eggs.
7. Calyx	G. This structure contains the stigma, style, and ovary.
8. Ovule	H. This structure protects the developing flower.

49. A botanist wanted to see if a new strain of corn could germinate in soil that was too salty for regular corn. She conducted a study on the germination success of seeds from the new strain that were exposed to various levels of salty soil, from zero to normal (100 mg/L) to high (200 mg/L) to very high (400 mg/L) to normally lethal (800 mg/L).

The table below shows her data for this study.

Petri dish label	Salt concentration (mg/L)	Number of seeds planted	Number of seeds that germinated	Percentage of seeds that germinated
1	0	20	16	80%
2	100	20	18	90%
3	200	20	18	90%
4	400	20	11	55%
5	800	20	7	35%

a) Write a formal hypothesis for this study. **(2 marks)**

b) Does her data support or reject the hypothesis? Explain your reasoning. **(2 marks)**

Now go on to Lesson 16. Send your answers to the Key Questions to the ILC when you have completed Unit 4 (Lessons 13 to 16).