THEME FOCUS Stability and Change
The alternation of generations provides stability and structure in plant reproduction.

BIG Idea The life cycles of plants include various methods of reproduction.

Reading Preview

Essential Questions

- What are advantages of vegetative reproduction?
- What are the stages of alternation of generations?
- What are the similarities among the reproduction of mosses, ferns, and conifers?

Review Vocabulary

flagellated: having one or more flagellum that propel a cell by whiplike motion

New Vocabulary

vegetative reproduction
chemotaxis
protonema
prothallus
heterosporous
megaspore
microspore
micropyle

Multilingual eGlossary

Introduction to Plant Reproduction

MAIN Idea **Like all plants, the life cycles of mosses, ferns, and conifers include alternation of generations.**

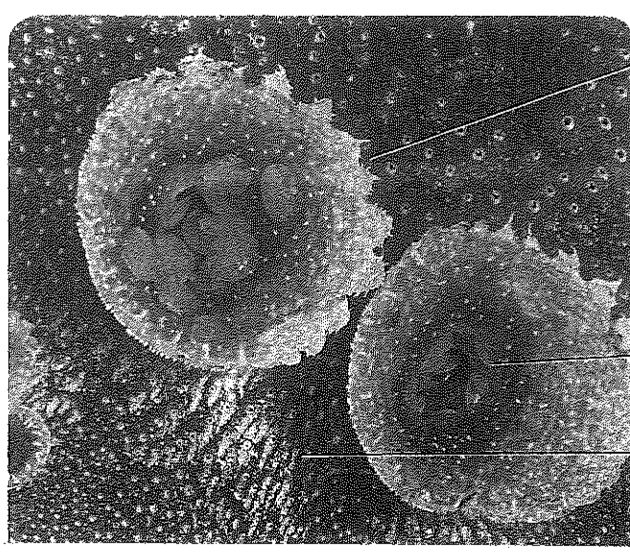
Real-World Reading Link Have you ever seen photos of your friends when they were younger? Were you able to recognize most of them? Some plants differ greatly in appearances throughout their life stages. Recognizing the same plant throughout the different life stages is not as easy as recognizing your friends from their old photos.

Vegetative Reproduction

Recall that reproduction without the joining of an egg and a sperm is called asexual reproduction. **Vegetative reproduction** is a form of asexual reproduction in which new plants grow from parts of an existing plant. The new plants are clones of the original plant because their genetic makeups are identical to the original plant.

There are several advantages of vegetative reproduction. It usually is a faster way to grow plants than from a spore or a seed. Remember that an organism produced sexually will have a combination of features from its parents. However, plants produced vegetatively are more uniform than those that result from sexual reproduction. Also, some fruits do not produce seeds, and vegetative reproduction is the only way to reproduce them.

Naturally occurring vegetative reproduction There are many examples of natural vegetative reproduction. When conditions are dry, some mosses dry out, become brittle, and are easily broken and scattered by animals or wind. When conditions improve and water is available, some of these fragments can resume growth. Liverworts reproduce asexually by producing small, cuplike structures on the gametophyte thallus, as shown in **Figure 1.** Strawberry plants produce horizontal stems called stolons. A new strawberry plant can grow at the end of a stolon, and if the stolon is cut, the plant can continue to grow.



M. I. Walker/Science Source

Figure 1 Gemmae (JE mee) cups or splash cups contain small pieces of liverwort tissue. If knocked from or splashed out of the cup, they can grow into plants.
Infer ***the genetic makeup of the new liverworts.***

Directed vegetative reproduction Farmers, horticulturists, and scientists have been using vegetative reproduction for years. Leaves, roots, or stems, when cut from certain plants, can grow and become new plants if kept under proper environmental conditions. For example, white potatoes can be cut into sections. As long as each section contains an eye or bud and is planted in a favorable environment, a new plant can grow from the section and produce new potatoes. Some plants can be grown from a few cells of plant tissue using a technique called tissue culture. The plant tissue is grown on nutrient agar in sterile conditions, as shown in **Figure 2.** Eventually, hundreds of identical plants can be produced.

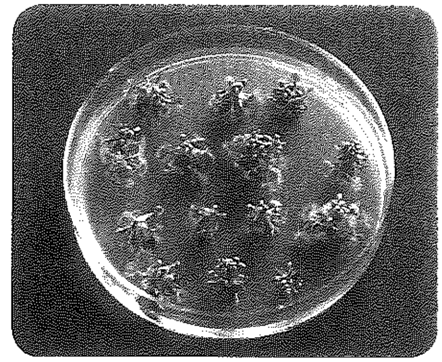


Figure 2 These sundew clones were produced using tissue culture techniques.

Alternation of Generations

The life cycle of a plant includes an alternation of generations that has a diploid (2*n*) sporophyte stage, and a haploid (*n*) gametophyte stage. As shown in **Figure 3,** the sporophyte stage produces haploid spores that divide by mitosis and cell division and form the gametophyte generation. Depending on the plant species, the size of a gametophyte can be tiny or a larger structure. In the plant kingdom, there is an evolutionary trend for smaller gametophytes as plants become more complex.

The gametophyte stage produces gametes–eggs and sperm. One distinguishing characteristic among plants is how a sperm gets to an egg. Sperm of nonvascular plants and some of the vascular plants must have at least a film of water to reach an egg. Sperm of flowering plants do not need water for the sperm to reach the egg.

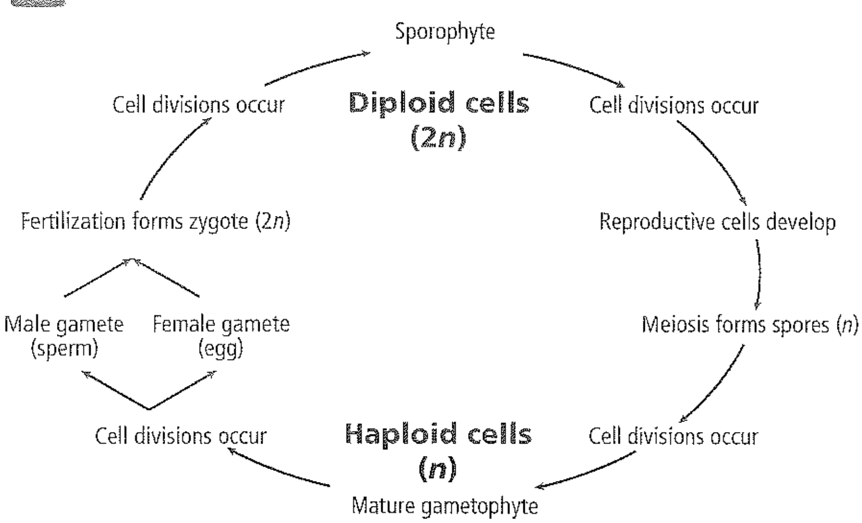
Fertilization of an egg by a sperm forms a zygote that is the first cell of the sporophyte stage. As plants evolved and became more complex, sporophytes became larger. In addition to the size of the sporophyte, another distinguishing feature among plants is the growth pattern of the sporophyte. Flowering plants and other vascular plants have sporophytes that live completely independent of the gametophyte. Most nonvascular plants have sporophytes that depend on the gametophyte for support and food.

CAREERS IN BIOLOGY

Tissue-Culture Technician
Working with plant tissue while maintaining sterile conditions is one of many tasks performed by a technician in a tissue-culture lab. Besides knowledge of plants, a tissue-culture technician needs excellent eye-hand coordination, good concentration skills, and the ability to keep accurate records.

Figure 3 The form of the sporophyte (blue) and gametophyte (yellow) is different for different plant species.

Animation



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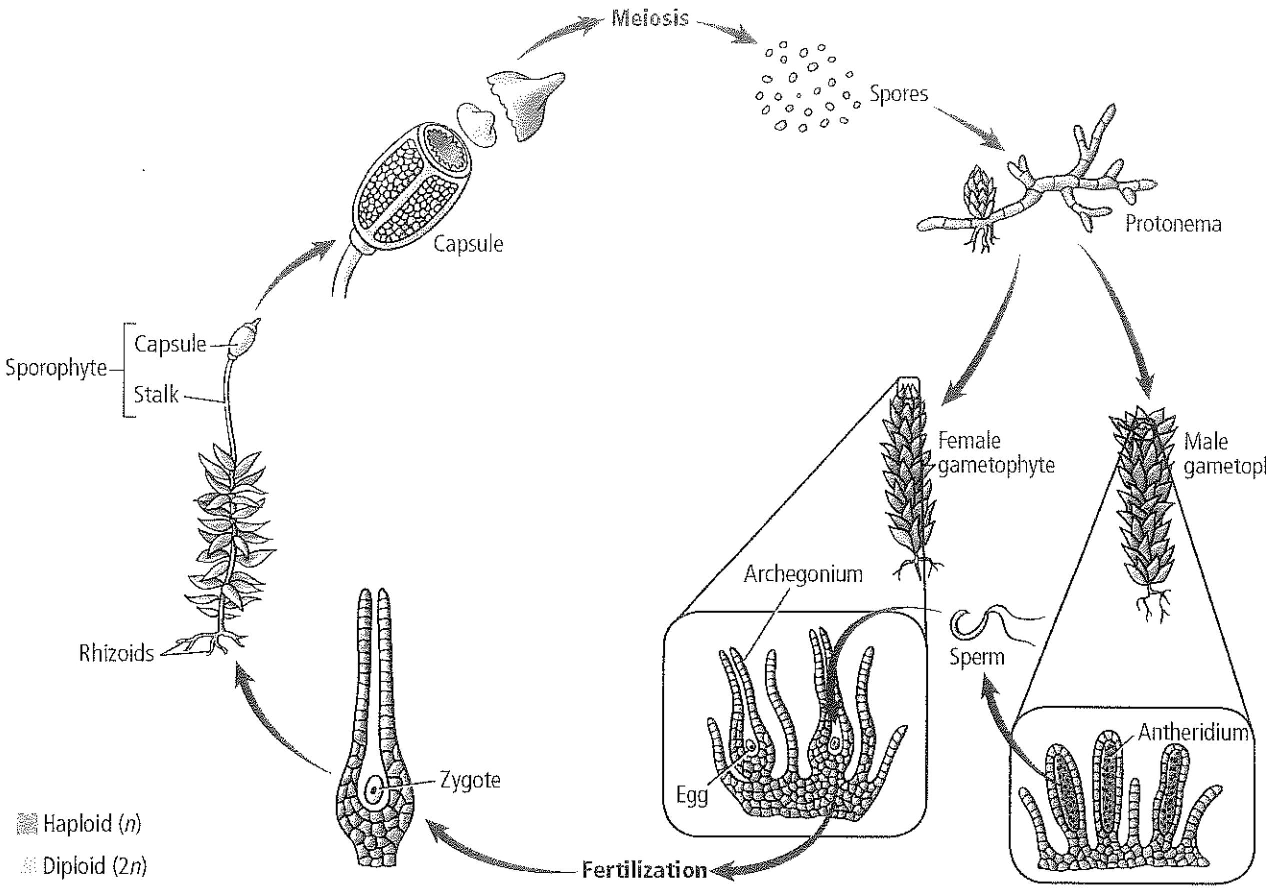


Animation

Figure 4 Spores produced by a moss sporophyte grow into moss gametophyte plants. Following fertilization, the sporophyte develops while attached to the gametophyte and eventually will release spores, continuing the cycle.

VOCABULARY

WORD ORIGIN

Chemotaxis

chemo- comes from the late Greek word *chemeia,* meaning *alchemy*

-taxis comes from the Greek word *taxis,* meaning *responsive movement*

Moss Reproduction and Life Cycle

The reproduction and life cycle of mosses, as shown in **Figure 4,** exhibits alternation of generations and is typical of most nonvascular plants. The dominant stage is the gametophyte stage that you might see growing in damp shady places or on rocks along a stream. Gametophytes produce archegonia and antheridia. These structures can be on the same moss plant or, as is often the case, on separate plants. Depending on the moss species, an archegonium produces one or more eggs. The tissues of the archegonium surround the egg or eggs with a protective layer.

Antheridia produce flagellated sperm that need water to get to the archegonia. If a film of water covers the moss, sperm can move toward archegonia. This is a response to chemicals produced by archegonia and is called **chemotaxis** (kee moh TAK sus). When a sperm fertilizes an egg, it forms the first cell of the sporophyte stage called the zygote. Tissues of the archegonium protect the new sporophyte. The new sporophyte absorbs nutrients from the archegonium as it grows and matures. Because most mature moss sporophytes cannot undergo photosynthesis, they are dependent upon their gametophytes for nutrition and support.

A mature sporophyte consists of a stalk with a capsule at its tip. Certain cells within the capsule undergo meiosis and produce spores. Some species produce up to 50 million spores per capsule. When conditions are favorable, the capsule opens, releasing the spores. If a spore lands in a suitable place, mitotic cell divisions begin. The resulting growth forms a **protonema**–a small, threadlike structure–that can develop into the gametophyte plant, and the cycle repeats.

Fern Reproduction and Life Cycle

When you visit a forest or a plant conservatory, you might see the lacy fronds of ferns. Fronds are part of a fern's sporophyte stage. If you look closely at a frond, you might find spore-producing structures called sori on it. Each sorus consists of sporangia. Certain cells in a sporangium undergo meiosis and the resulting spores are the beginning of the new gametophyte generation.

If a fern spore lands on damp, rich soil, it can grow and form a tiny heart-shaped gametophyte called a **prothallus** (pro THA lus) (plural, prothalli), as shown in **Figure 5.** Cells of the prothallus contain chloroplasts; therefore, photosynthesis can occur. Most prothalli develop both antheridia and archegonia. Antheridia produce flagellated sperm that need water to move to archegonia. Each archegonium contains one egg. If fertilization occurs, the resulting zygote is the first cell of the sporophyte generation. Chemical reactions between sperm and eggs of the same prothallus can prevent fertilization.

The zygote undergoes mitotic cell divisions and forms a photosynthetic, multicellular sporophyte. Initially, the sporophyte grows on the prothallus and receives support and nutrition. Later, the prothallus disintegrates and the sporophyte develops fronds and a rhizome—a thick underground stem that produces roots and supports the photosynthetic fronds.

Conifer Reproduction and Life Cycle

Have you ever seen the surface of a car or a pond covered with fine yellow dust? It's possible that this dust came from one or several plants called conifers. The tree or shrub that you might recognize as a pine or other conifer is that plant's sporophyte genera-tion. Conifers, like a few lycophytes and pterophytes, are **heterosporous** (he tuh roh SPOR us). They produce two types of spores that develop into male or female gametophytes.

Female cones Each female cone is composed of many scales. At the base of each scale are two ovules. Within each ovule, meiosis of a cell in the megasporangium produces four **megaspores.** Three of these megaspores disintegrate. The remaining megaspore undergoes mitotic cell divisions and becomes the female gametophyte. When fully developed, the female gametophyte consists of hundreds of cells and contains two to six archegonia. Each archegonium eventually contains an egg.

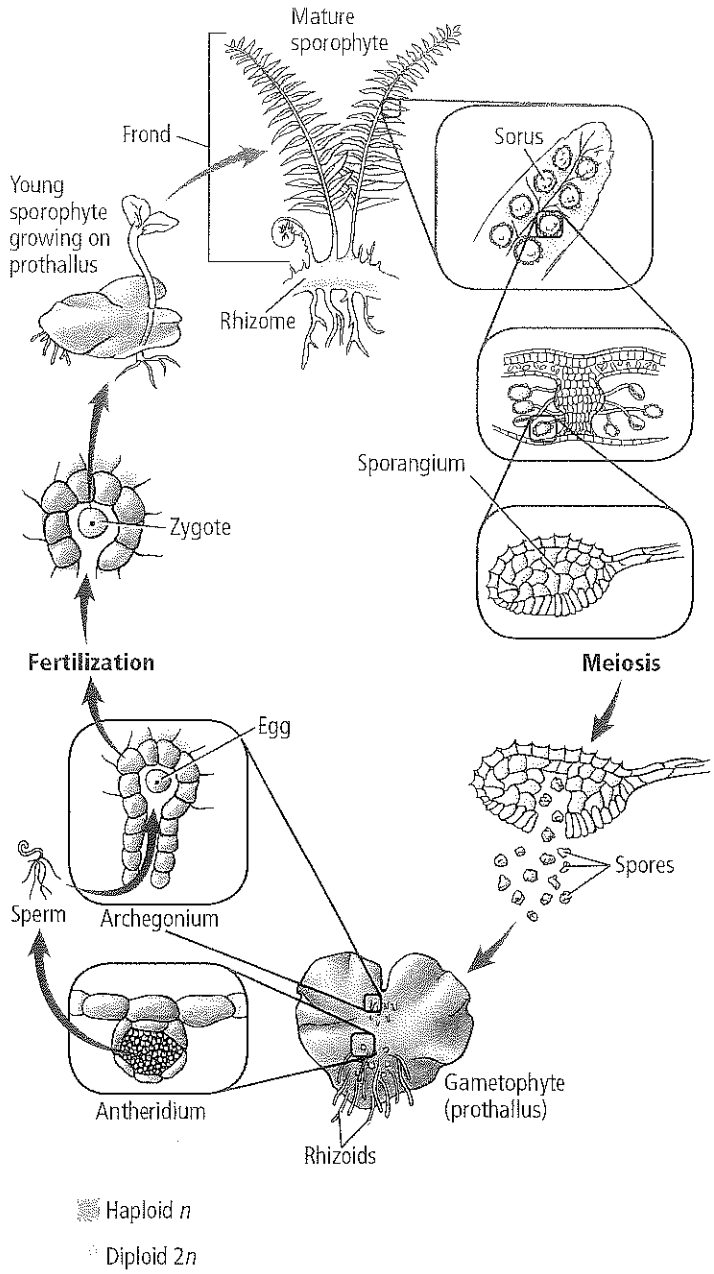


Figure 5 In fern reproduction there usually is a substantial size difference between the sporophyte and gametophyte stages.

Male cones The pollen-producing cone, commonly called the male cone, consists of small reproductive scales that have hundreds of sporangia. Certain cells in these sporangia undergo meiosis and form **microspores.** A pollen grain, the male gametophyte, consists of four cells and develops from a microspore. Pollen grains are transported on air currents.

Reading Check **Compare** the sizes of a moss gametophyte and a pine gametophyte.

Study Tip

Group Study With two other classmates, study the life cycles of mosses, ferns, and conifers. Each of you should choose one of these life cycles and prepare a summary of it. When you study together, teach each other your life cycle summaries.

Pollination When a pollen grain from one species of seed plants lands on the female reproductive structure of a plant of the same species, pollination occurs. If a conifer pollen grain lands near the **micropyle,** or the opening of the ovule, it can be trapped in a sticky substance called a pollen drop. As the pollen drop slowly evaporates or is absorbed into the ovule, the pollen grain is pulled closer to the micropyle. Over the next year, the pollen grain will continue to develop.

Seed development Following pollination, the pollen grain generates a pollen tube. It grows through the micropyle, and into the ovule. This process can take a year or longer. One of the four cells in the pollen grain undergoes mitosis, forming two nonflagellated sperm. The sperm travel in the pollen tube to an egg, as shown in **Figure 6.** Fertilization occurs when an egg and a sperm join to form the zygote. The remaining sperm and the pollen tube disintegrate. The zygote is dependent on the female gametophyte for nutrition as it undergoes mitotic cell divisions that result in the formation of an embryo with one or more cotyledons. These undergo photosynthesis and provide nutrition for the embryo when the seed sprouts.

As the embryo develops, the outside layer of the ovule forms a seed coat. Seed development can take as long as three years. When seeds mature, the female cone opens and releases them.

MiniLab 1

Compare Conifer Cones

MiniLab

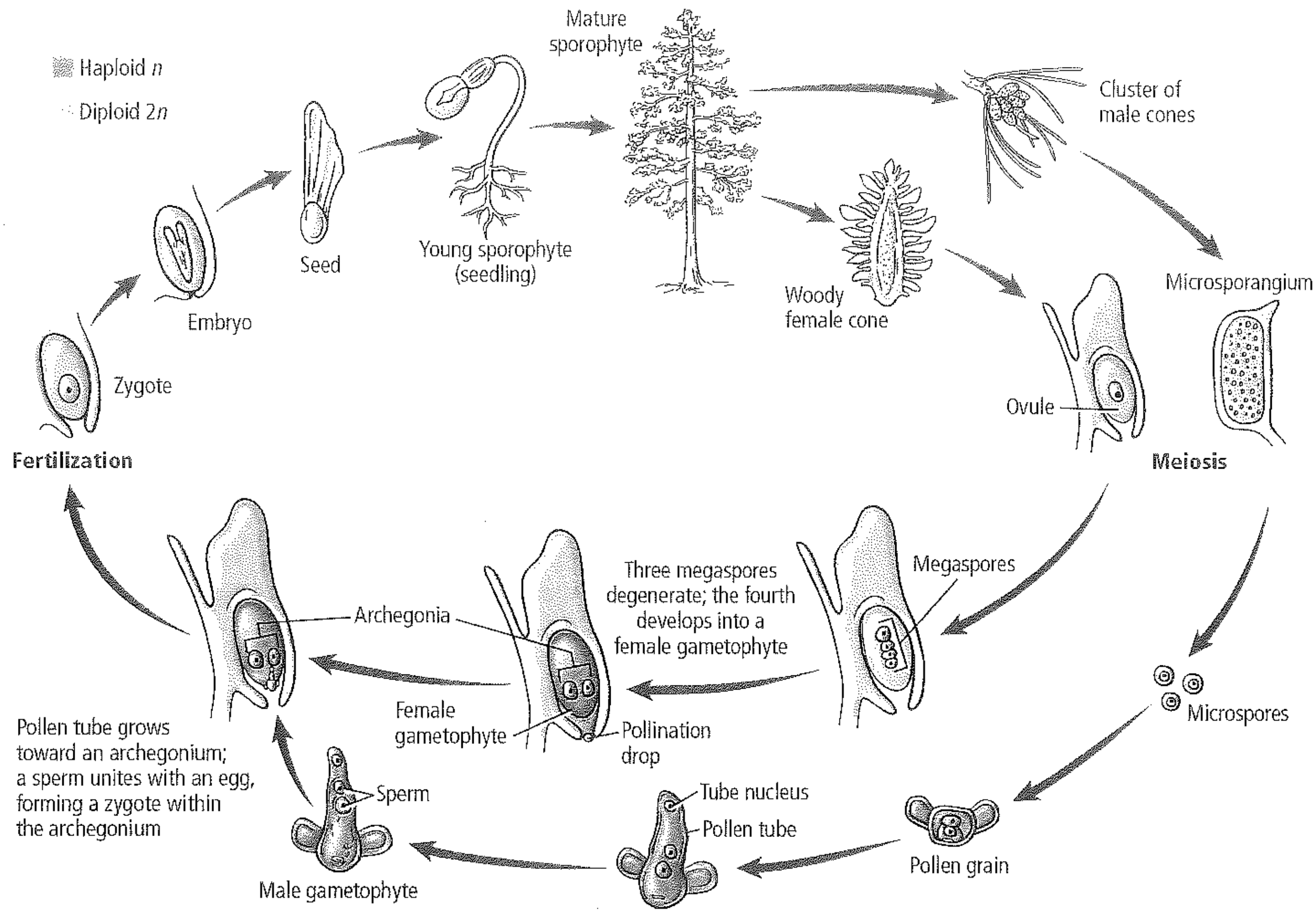
How do cones from the different conifers compare? Have you ever noticed the many different types of cones that fall from conifers? Investigate the types of cones during this lab.

Procedure

1. Read and complete the lab safety form.
2. Create a data table for recording your observations, measurements, and comparisons of cones.
3. Obtain **cones** from your teacher.
4. Observe the physical characteristics of your cones and record your observations and measurements in your data table. Do not damage the cones in any way.
5. Identify the conifer species of your cones by using a **tree identification guidebook.** Record this data.
6. Return the cones to your teacher.

Analysis

1. **Compare and contrast** the cones.
2. **Determine** whether there were any seeds present. Describe how seeds form in conifers.



Reproduction in conifers is diverse. The time for a conifer life cycle varies from species to species. Not all conifers produce cones. For example, yews produce ovules covered by fleshy tissue. Juniper seed cones look like berries. Regardless of differences, conifer reproduction ensures the survival of this plant division.

Figure 6 The sporophyte generation is dominant in the life of a conifer.

Animation

Section 1 Assessment

Section Summary

- Vegetative reproduction produces new plants without sexual reproduction.
- The life cycles of plants involve the alternation of generations.
- The moss sporophyte depends on the gametophyte.
- A fern sporophyte can live independently of the gametophyte.
- Conifer gametophytes develop within sporophyte tissues.

Understand Main Ideas

1. MAIN Idea **Describe** the stages of alternation of generations.
2. **Identify** advantages of vegetative reproduction.
3. **Explain** how the fern sporophyte is dependent upon the gametophyte.
4. **Compare and contrast** the life cycles of mosses and conifers.

Think Critically

5. **Determine** how the distribution of conifers might be affected if water was needed for reproduction.

MATH in Biology

6. Calculate the number of spores that could be released in three square meters if the density of moss plants is 100 plants per square meter and the average number of spores released per plant is 10,000.

Section 2

Reading Preview

Essential Questions

- What are the parts of a flower and what are their functions?
- What are complete, incomplete, perfect, and imperfect flowers?
- What is the difference between monocot and eudicot flowers?
- What is photoperiodism?

Review Vocabulary

nocturnal: active only at night

New Vocabulary

sepal
petal
stamen
pistil
photoperiodism
short-day plant
long-day plant
intermediate-day plant
day-neutral plant

Multilingual eGlossary

Flowers

Main Idea **Flowers are the reproductive structures of anthophytes.**

Real-World Reading Link Have you ever worn a corsage or boutonniere to a dance? Perhaps you have given a flower to someone to let him or her know that he or she is special to you. You probably can think of many other instances when flowers were important to you. However, from a scientific viewpoint, the most important role of flowers is in anthophyte sexual reproduction.

Flower Organs

Vivid orange, deep purple, ghostly white, fragrant, rancid, spectacular, and inconspicuous–these all are terms that can be used to describe flowers. The colors, shapes, and sizes of flowers are determined by each species' genetic makeup. It is important to remember that flowers can vary in structure and form from species to species.

Flowers have several organs. Some organs provide support or protection, while others can be involved directly in reproduction. In general, flowers have four organs–sepals, petals, stamens, and one or more pistils, illustrated in **Figure 7.** **Sepals** protect the flower bud and can look like small leaves or even resemble the flower's petals. **Petals** usually are colorful structures that can both attract pollina-tors and provide them with a landing platform. Sepals and petals, if present, are attached to a flower stalk, called a peduncle.

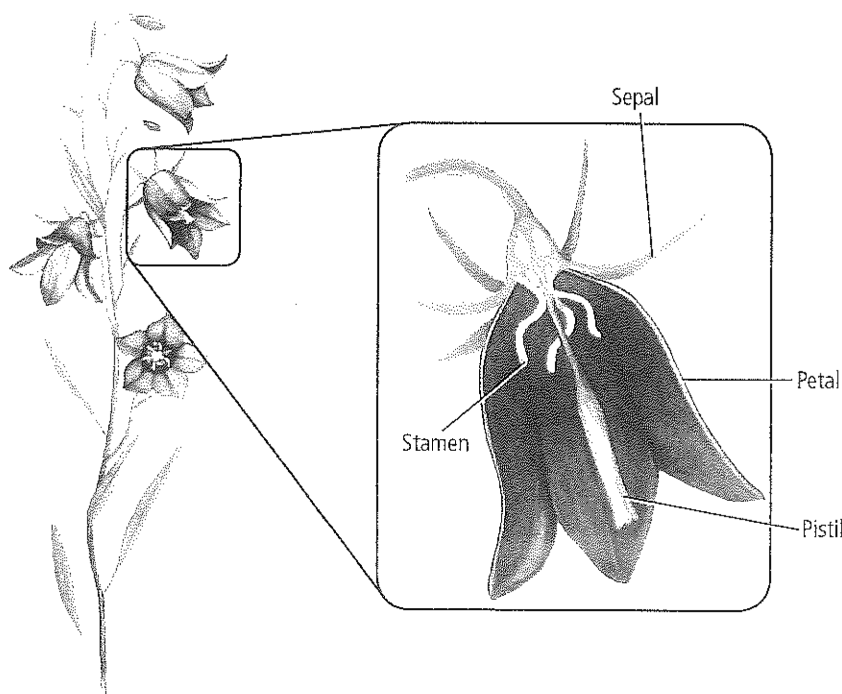


Figure 7 The typical flower has four organs—sepals, petals, stamens, and one or more pistils.

Animation

Most flowers have several **stamens**—the male reproductive organs. A stamen is composed of two parts—the filament and the anther. The filament, or stalk, supports the anther. Inside the anther are cells that undergo meiosis and then mitotic cell divisions, forming pollen grains. Two sperm eventually form inside each pollen grain.

The female reproductive organ of a flower is the **pistil**. In the center of a flower is one or more pistils. A pistil usually has three parts—the stigma, the style, and the ovary. The stigma is the tip of the pistil and is where pollination occurs. The style is the part that connects the stigma to the ovary that contains one or more ovules. A female gametophyte develops in each ovule, and an egg forms inside each female gametophyte.

VOCABULARY

Science usage v. Common usage

Stigma

Science usage: the tip of a flower's pistil where pollination occurs

The stigma of an iris's pistil has three parts.

Common usage: a mark of shame or discredit

A criminal record often is a stigma for an individual trying to reenter society.

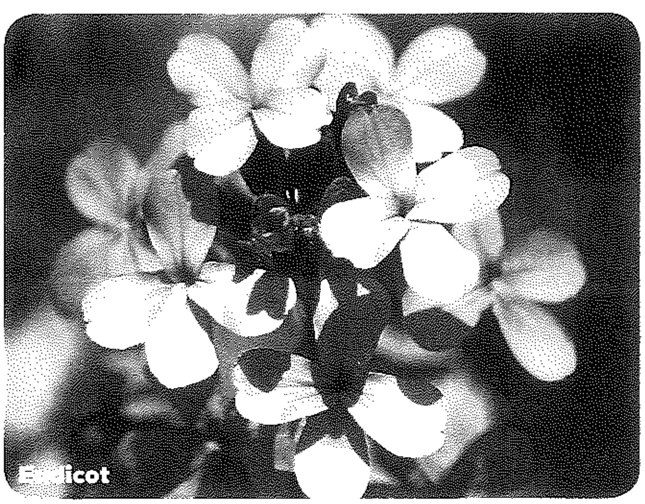
Flower Adaptations

The flower organs described in the previous paragraphs are typical of most flowers. However, many flowers can have modifications to one or more organs. Scientists categorize flowers using these modifications.

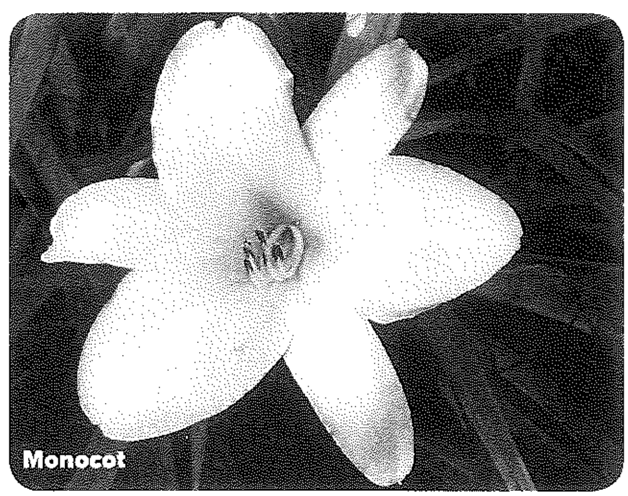
Structural differences Flowers that have sepals, petals, stamens, and one or more pistils are called complete flowers. If a flower is missing one or more of these organs, it is an incomplete flower. For example, wild ginger flowers are called incomplete because they have no petals. Other descriptive terms relating to flower organs are perfect and imperfect. Flowers that have both stamens and pistils are called perfect flowers. Some plants, such as cucumbers and squash, have imperfect flowers. An imperfect flower has either functional stamens or pistils, not both. The stamen-containing, or male, flowers release pollen grains. Following fertilization, a fruit forms from the pistil-containing, or female, flowers.

The number of each flower organ varies from species to species. However, the number of flower organs distinguishes eudicots from monocots. When the petal number for a flower is a multiple of four or five, the plant usually is a eudicot. The number of other organs—the sepals, pistils, and stamens—is often the same multiple of four or five. For example, the members of the mustard family of plants have flowers with four sepals and four petals, as shown in **Figure 8.** Monocots generally have flower organs in multiples of three. The daylily, also shown in **Figure 8,** has three sepals and three petals and six stamens.

Figure 8 Some plants can be identified as either a monocot or a eudicot by their flowers.



This plant is related to those whose seeds are used to make canola oil.

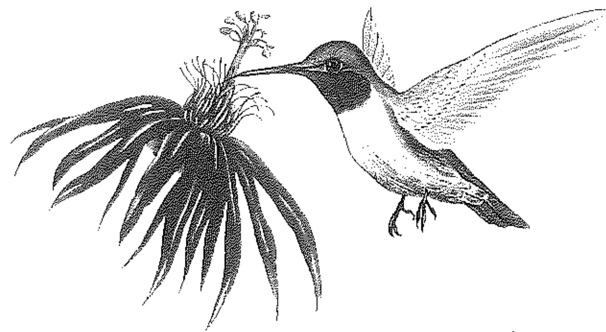


At a glance, this daylily's petals and sepals are indistinguishable.

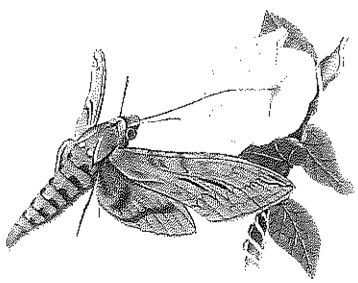
Visualizing Pollination

Figure 9
Flowers have several adaptations that ensure pollination. Pollen might be carried by the wind or by animals. While feeding, an animal can become covered with pollen and can transfer the pollen to the next flower it visits.

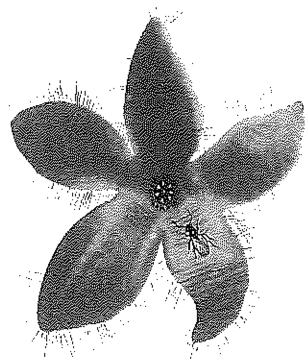
Wind disperses lightweight oak pollen that can cause allergic reactions for many people. Tassels hang down and can wave in the wind.



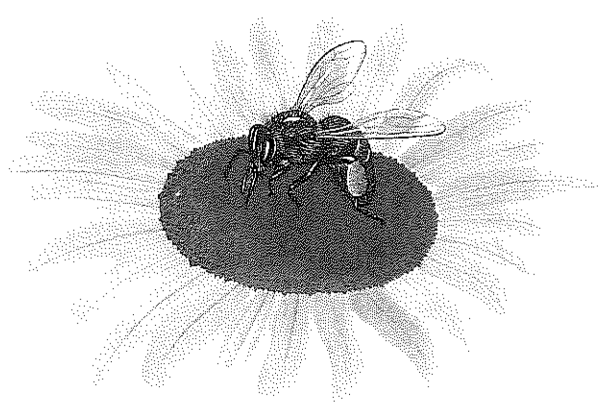
Hummingbirds are attracted to red flowers. The hummingbird's long beak reaches nectar at the base of this flower. Some yellow and orange pigments reflect light in ranges invisible to the human eye. Even so, the markings are highly visible to bees and other insects.



As night falls, heavy scents and pale colors make it easier for moths to locate certain flowers.



The carrion flower has a rancid odor that attracts fly and beetle pollinators.



Nectar producing flowers often attract insect pollinators as they seek food.

Animation

Pollination mechanisms Different anthophyte species have flowers of distinctive sizes, shapes, colors, and petal arrangements. Many of these adaptations relate to pollination. Some of these adaptations are shown in **Figure 9.**

Self pollination and cross pollination Connection to

Recall that Mendel knew that pea flowers tend to self-pollinate, but also can be cross-pollinated. Self-pollinating flowers can pollinate themselves or another flower on the same plant. Cross-pollinated flowers receive pollen from another plant. Some flowers must be cross-pollinated. This is one reason that pollinators play important roles in anthophyte reproduction. Pollinators provide a way to transfer pollen for flowers that must be cross-pollinated. Pollinators also ensure that reproduction can occur for imperfect flowers, like squash blossoms, as shown in **Figure 10.**

Animal pollination As shown in **Figure 9,** many animal-pollinated flowers are brightly colored, have strong scents, or produce a sweet liquid called nectar. When insects and other small animals move from flower to flower searching for nectar, they can carry pollen from one flower to another flower. Other insects collect pollen for food. The bright colors and sweet scents of peonies, roses, and lilacs attract insects such as bees, butterflies, beetles, and wasps. White or pale yellow flowers are more visible at dusk and at night, and attract nocturnal animals, such as moths and bats. Bird-pollinated flowers often give off little or no aroma. A bird generally has a poor sense of smell, so it usually locates flowers by sight.

Wind pollination Flowers that generally lack showy or fragrant floral parts, also shown in **Figure 9,** usually are wind-pollinated. They produce huge amounts of lightweight pollen. This helps to ensure that some pollen grains will land on the stigma of a flower of the same species. Also, the stamens of wind-pollinated flowers often hang below the petals, exposing them to the wind. The stigma of a wind-pollinated flower is often large, which helps to ensure that a pollen grain might land on it. Wind-pollinated plants include most trees and grasses.

Reading Check **Compare and contrast** pollination mechanisms.

CAREERS IN BIOLOGY

Plant Breeder Knowledge of flower structures, pollination mechanisms, and genetics are essential for a plant breeder. A plant breeder conducts selective breeding by choosing plants with desirable traits, breeding them together, and then recording results.

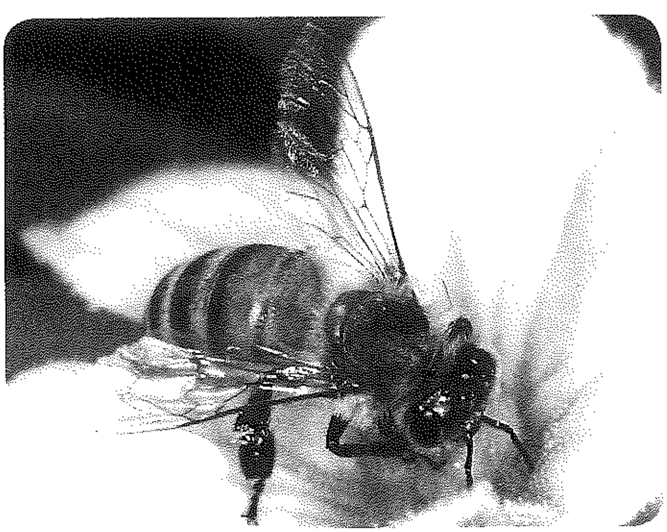


Figure 10 Honeybees or other insects must transfer pollen from the male squash flower to the female squash flower for the fruit—a squash—to form.

Determine ***whether squash flowers are perfect or imperfect. Explain.***

Launch Lab

Review Based on what you have read about plant reproduction, how would you now answer the analysis questions?

Photoperiodism After noticing that certain plants only flowered at certain times of the year, plant biologists conducted experiments to explain this observation. The research initially focused on the number of hours of daylight to which the plants were exposed. However, researchers discovered that the critical factor that influenced flowering was the number of hours of uninterrupted darkness, not the number of hours of daylight. This flowering response is known as **photoperiodism** (foh toh PIHR ee uh dih zum). Scientists also learned that the beginning of flower development for each plant species was a response to a range in the number of hours of darkness. This range of hours is called the plant's critical period.

Botanists classify flowering plants into one of four different groups--short-day plants, long-day plants, intermediate-day plants, or day-neutral plants. This classification is based on the critical period. The names reflect the researchers' original focus, which is the number of hours of daylight. It is important to remember that a more accurate term for a short-day plant, for example, would be a long-night plant. As you read the descriptions of these plants, refer to **Figure 11.**

Short-day photoperiodism A **short-day plant** flowers when exposed daily to a number of hours of darkness that is greater than its critical period. For example, a short-day plant could flower when exposed to 16 hours of darkness. Short-day plants flower during the winter, spring, or fall, when the number of hours of darkness is greater than the number of hours of light. Some short-day plants you might recognize are pansies, poinsettias, tulips, and chrysanthemums.

Long-day photoperiodism A **long-day plant** flowers when the number of hours of darkness is less than its critical period. These plants flower during the summer. Examples of long-day plants are lettuce, asters, coneflowers, spinach, and potatoes.

MiniLab 2

Compare Flower Structures

MiniLab

How do the structures of flowers vary? Just a quick browse through a flower garden or florist's shop reveals that there is great diversity among flowers. Investigate how flowers differ from species to species.

Procedure

1. Read and complete the lab safety form.
2. Create a data table to record your observations and measurements.
3. Obtain the **flowers** for this lab from your teacher.
4. Observe the differences in structure, color, size, and odor of the flowers. Do not damage the flowers in any way.
5. Make a sketch of each flower and record other observations in your data table.
6. Return the flowers to your teacher.

Analysis

1. **Compare and contrast** the flower structures you observed.
2. **Infer** why the flower petals that you observed were different colors.
3. **Propose** an explanation for the different sizes and shapes of flower structures.

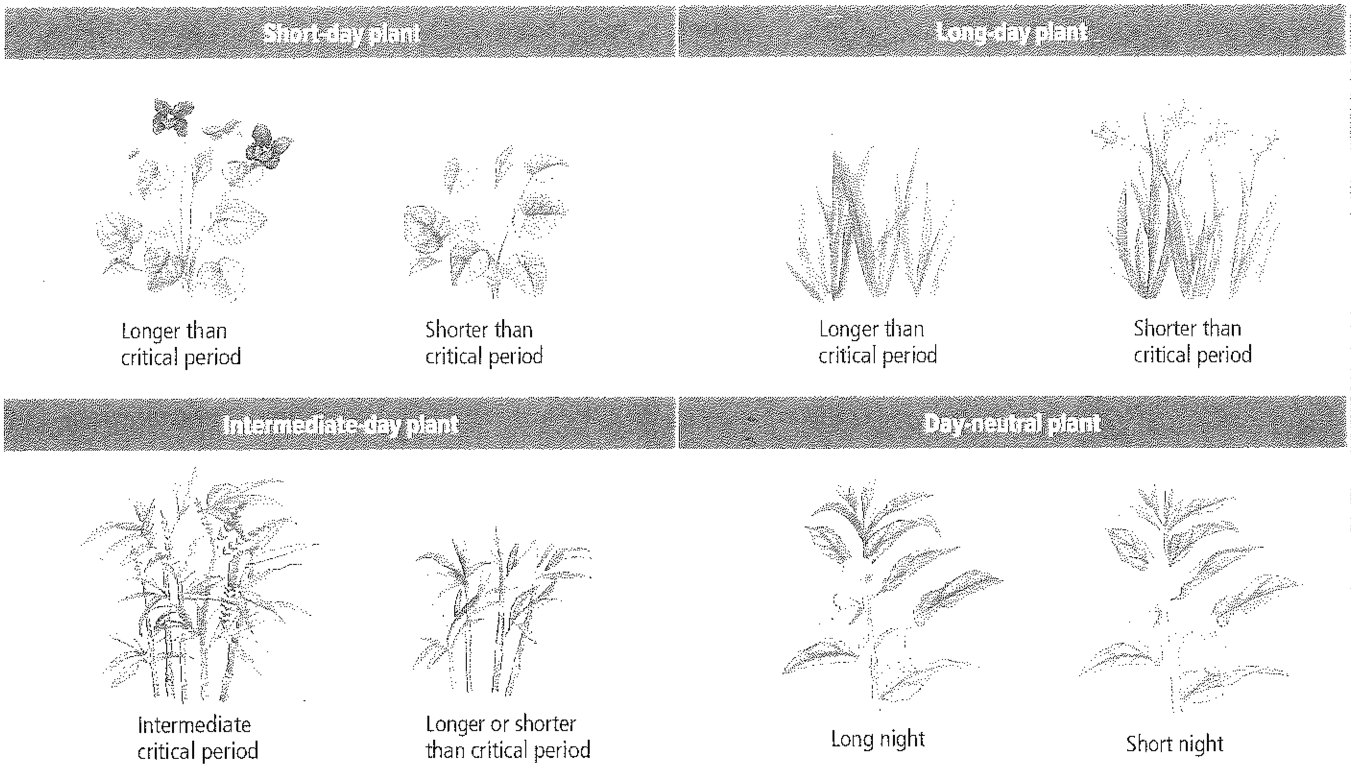


Figure 11 A plant's critical period determines when the plant will flower.

Intermediate-day photoperiodism Many plants that are native to tropical regions are **intermediate-day plants.** This means that they will flower as long as the number of hours of darkness is neither too great nor too few. Sugarcane and some grasses are examples of intermediate-day plants.

Day-neutral photoperiodism Some plants will flower regardless of the number of hours of darkness as long as they receive enough light for photosynthesis that supports growth. A plant that flowers over a range in the number of hours of darkness is a **day-neutral plant.** Buckwheat, corn, cotton, tomatoes, and roses are examples of day-neutral plants.

Section 2 Assessment

Section Summary

- A typical flower has sepals, petals, stamens, and one or more pistils.
- Flowers can be perfect or imperfect, and complete or incomplete.
- Some flower modifications distinguish monocots from eudicots.
- Modifications make flowers more attractive to pollinators.
- Photoperiodism can influence when a plant flowers.

Understand Main Ideas

1. MAIN Idea **Compare and contrast** the function of each of the four organs of a typical flower.
2. **Describe** traits of a typical monocot flower and a typical eudicot flower.
3. **Compare and contrast** complete and incomplete flowers.
4. **Predict** which type of photoperiodism should produce blooms in the spring.

Think Critically

5. **Design** a plan to develop flowers on long-day plants during the winter.
6. **Assess** the importance of pollinators for imperfect flowers.

WRITING in Biology

7. Write a description, from the point of view of a pollinator, of a visit to a flower.

Online Quiz

Reading Preview

Essential Questions

- How can the life cycle of a flowering plant be described?
- What is the process of fertilization and seed formation in flowering plants?
- What are the different methods of seed dispersal?
- What is seed germination?

Review Vocabulary

cytoskeleton: the long, thin protein fibers that form a cell's framework

New Vocabulary

polar nuclei
endosperm
seed coat
germination
radicle
hypocotyl
dormancy

Multilingual eGlossary

Flowering Plants

MAIN Idea In anthophytes, seeds and fruits can develop from flowers after fertilization.

Real-World Reading Link In 1893, the U.S. Supreme Court ruled that a tomato is legally a vegetable and not a fruit. The justices argued that a tomato is not a fruit because it is not sweet. As you read this section, decide whether this ruling is scientifically accurate.

Life Cycle

Anthophytes are the most diverse and widespread group of plants. They are unique because they have flowers. Anthophytes have distinctive life cycles and, like all plants, exhibit an alternation of generations. Like conifers, the sporophyte generation of anthophytes is dominant and supports the gametophyte generation. However, there are many variations of the anthophyte reproductive process.

Gametophyte development In anthophytes, the development of male and female gametophytes begins in an undeveloped flower. Anthophytes are heterosporous–pistils produce megaspores, and stamens produce microspores. A specialized cell in the ovule of a pistil's ovary undergoes meiosis, producing four megaspores. Usually, three of these megaspores disintegrate and disappear. The nucleus of the functional megaspore undergoes mitosis. Mitotic division continues and the megaspore grows until there is one large cell with eight nuclei. As shown in **Figure 12**, two nuclei migrate toward the center and membranes form around the other six nuclei. The result is three nuclei at each end of the cell and two nuclei in the center called **polar nuclei.** One of the three nuclei at the end closest to the micropyle becomes the egg. The cell that contains the egg and seven nuclei is the female gametophyte.

The development of the female gametophyte and the male gametophyte might or might not occur at the same time. Within the anther, specialized cells undergo meiosis and produce microspores. As shown in **Figure 13**, the nucleus in each microspore undergoes mitosis that forms two nuclei called the tube nucleus and the generative nucleus. A thick, protective cell wall forms around a microspore. At this point, the microspore is an immature male gametophyte, or pollen grain.

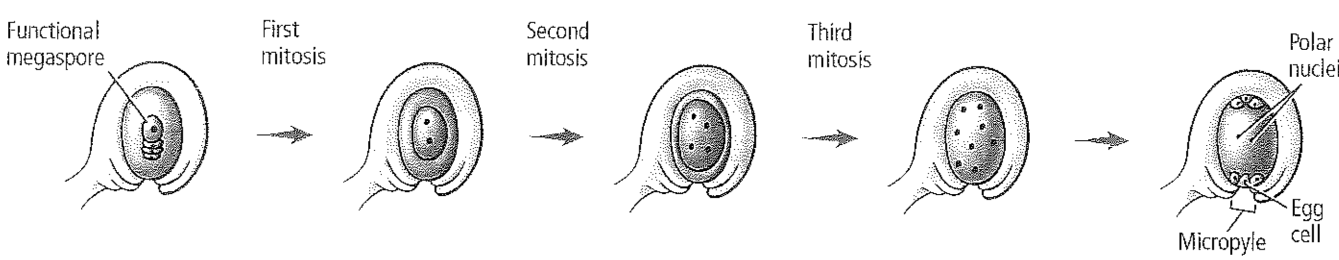


Figure 12 The megaspore results from meiosis, and the egg results from mitosis. This plant has 12 chromosomes.
Infer *the chromosome number of the egg.*

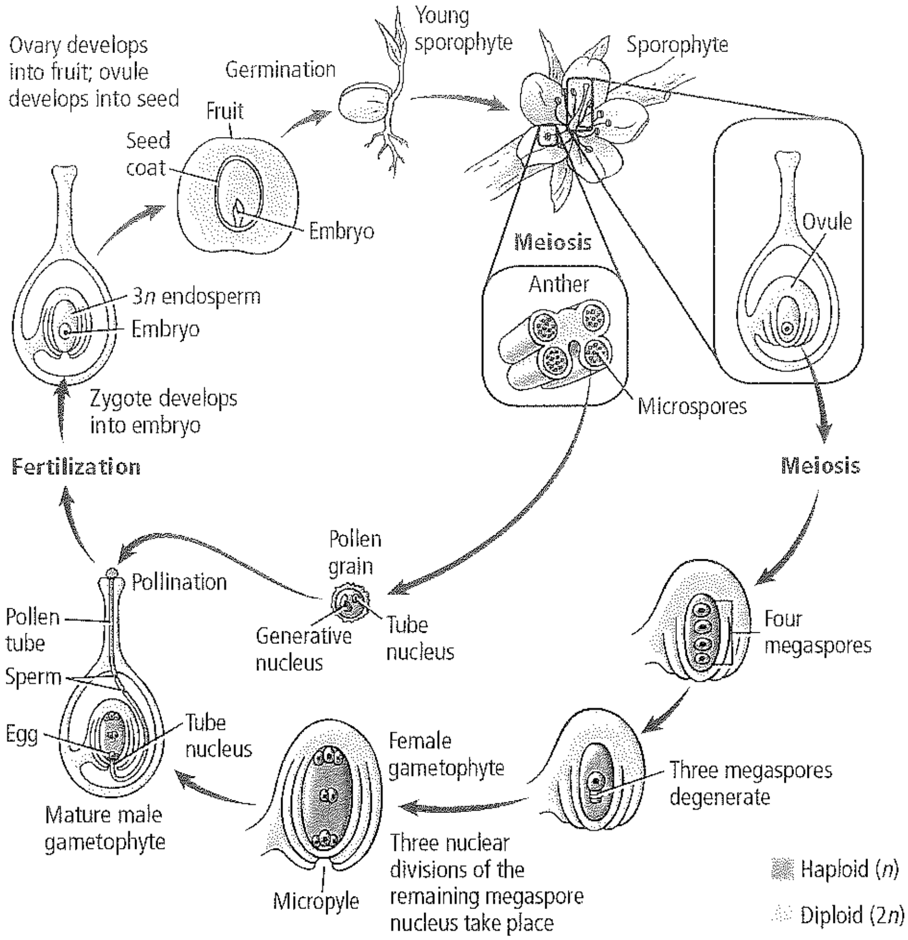


Figure 13 The life cycle of a flowering plant, like a peach, includes gametophyte and sporophyte generations. The male and female gametophytes are surrounded by sporophyte tissue.

Scientists can identify the family or genus of a pollen grain by the distinctive outer layer of its cell wall called the exine. This characteristic is useful to paleontologists and forensic investigators. Paleontologists can trace the agricultural history of certain regions using pollen fossils. For over 50 years, forensic scientists have used pollen evidence to help determine where and when some crimes were committed.

Pollination and fertilization Earlier in this chapter, you learned that various flower adaptations help to ensure the successful transfer of pollen from the anther to the stigma of the pistil. Once pollination occurs, the pollen grain can form a pollen tube, which is an extension of the pollen grain. Usually, the pollen tube grows down through the style to the ovary and the two nuclei travel in the pollen tube toward the ovule.

Connection to Chemistry The pollen grain's exine can contain compounds that react with compounds of the pistil's stigma. These reactions can stimulate or inhibit the growth of the pollen tube. For example, in some poppies, when an incompatible pollen grain lands on the stigma, a chemical reaction disrupts the formation of the pollen grain's cytoskeleton. This inhibits the pollen tube's growth. Different mechanisms prevent the incompatible pollen from producing a functional pollen tube.

When a compatible pollen grain lands on a stigma, the pollen grain absorbs substances from the stigma and a pollen tube starts to form, also shown in **Figure 13.** The tube nucleus directs the growth of the pollen tube. However, recent research suggests that the growth of the pollen tube toward the ovule is a chemotaxic response. In some plants, it has been found that calcium affects the direction of the pollen tube's growth.

FOLDABLES®
Incorporate information from this section into your Foldable.

BrainPOP

VOCABULARY
ACADEMIC VOCABULARY

Compatible
capable of functioning together
Because agricultural corn's pollen is compatible with sweet corn's pollen, the two crops must be planted some distance apart to prevent contamination of the sweet corn.

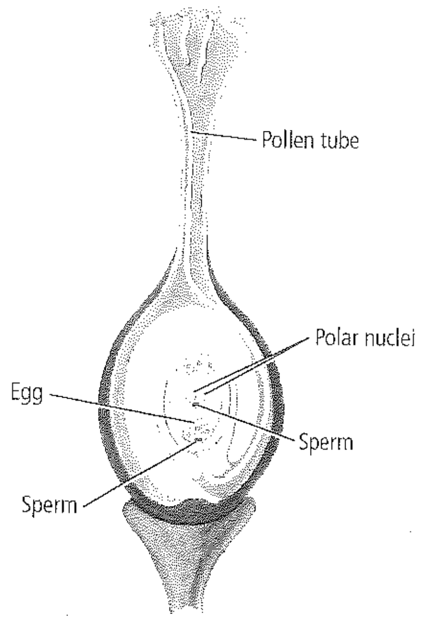


Figure 14 Double fertilization results in the formation of diploid and triploid tissues.

Animation

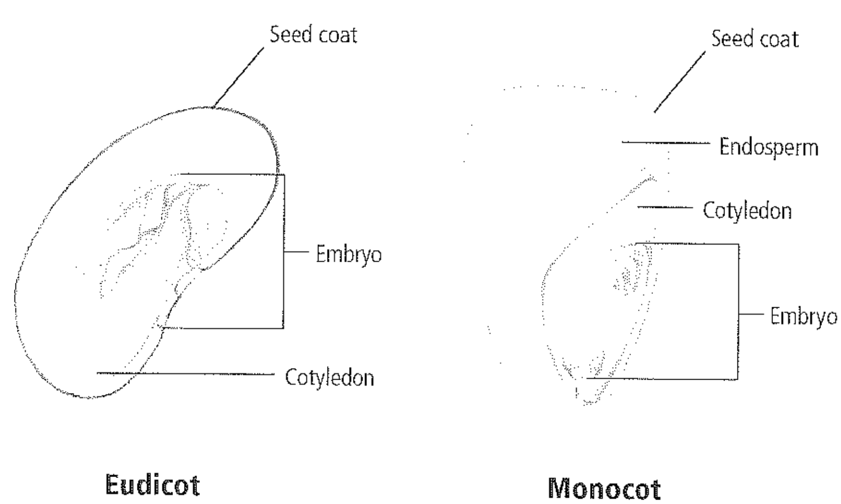
The length of a pollen tube depends on the length of the pistil, and can vary from a few centimeters or less to more than 50 cm in some corn plants. As the pollen tube grows, the generative nucleus undergoes mitosis, forming two nonflagellated sperm nuclei. The pollen grain is now a mature male gametophyte. When the pollen tube reaches the ovule, it grows through the micropyle and releases the two sperm nuclei. One sperm nucleus fuses with the egg, forming the zygote–the new sporophyte. The other sperm nucleus and the two polar nuclei in the center of the ovule fuse, forming a triploid or $3n$ cell.

Because two fertilizations occur in an anthophyte egg, this is called double fertilization, shown in **Figure 14.** Double ferilization occurs only in anthophytes. After fertilization, the ovule and the ovary begin to develop into the seed and fruit, respectively.

Results of Reproduction

Fertilization is only the beginning of a long process that finally ends with the formation of a seed. In anthophytes, a seed is part of a fruit that develops from the ovary and sometimes other flower organs.

Seed and fruit development The sporophyte begins as a zygote, or a $2n$ cell. Numerous cell divisions produce a cluster of cells that eventually develops into an elongated embryo with one cotyledon in monocots or two cotyledons in eudicots. The $3n$ cell formed as a result of double fertilization undergoes cell divisions. A tissue called the **endosperm** (EN duh spurm) forms as a result of these divisions and provides nourishment for the embryo. Initially, these cell divisions occur rapidly without cell wall formation. As the endosperm matures, cell walls form. In some monocots, the endosperm is the major component of the seed and makes up most of the seed's mass. For example, the coconut palm is a monocot. The liquid inside a fresh coconut is liquid endosperm–cells without cell walls. In eudicots, the cotyledons absorb most of the endosperm tissue as the seed matures. Therefore, the cotyledons of eudicot seeds provide much of the nourishment for the embryo. Examples of eudicot and monocot seeds are shown in **Figure 15.**



Personal Tutor

Figure 15 Seeds of monocots differ from those of eudicots.

***Identify** the embryo's food source in each seed.*

As the endosperm matures, the outside layers of the ovule harden and form a protective tissue called the **seed coat**. You might notice the seed coats of beans or peas when you eat them. The seed coat is the thin, outer covering that often comes off or loosens as seeds are cooked.

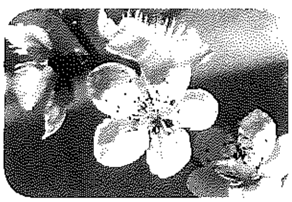
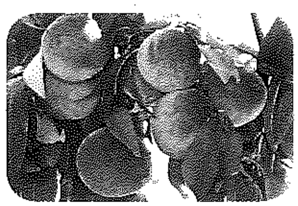
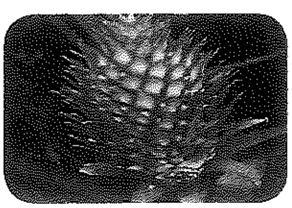
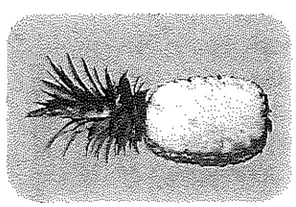
Have you ever eaten a tomato or cucumber and noticed the number of seeds inside? Depending on the plant, the ovary can contain one ovule or hundreds. As the ovule develops into a seed, changes occur in the ovary that lead to the formation of a fruit.

Fruits form primarily from the ovary wall. In some cases, the fruit consists of the ovary wall and other flower organs. For example, the seeds of the apple are within the core that develops from the ovary. The juicy tissue that we eat develops from other flower parts.

Besides the apple, other fruits, such as peaches and oranges, are fleshy, while some are dry and hard, such as walnuts and grains. Study **Table 1** to learn about types of fruit.

Reading Check **Compare and contrast** the formation of a seed and a fruit.

Table 1 Types of Fruit — Interactive Table

Fruit Type	Example of Flower and Fruit	Description
Simple fleshy fruits	  **Peach**	Simple fleshy fruits can contain one or more seeds. Apples, peaches, grapes, oranges, tomatoes, and pumpkins are simple fleshy fruits.
Aggregate fruits	  **Raspberry**	Aggregate fruits form from flowers with multiple female organs that fuse as the fruits ripen. Strawberries, raspberries, and blackberries are examples of aggregate fruits.
Multiple fruits	  **Pineapple**	Multiple fruits form from many flowers that fuse as the fruits ripen. Figs, pineapples, mulberries, and osage oranges are examples of multiple fruits.
Dry fruits	  **Redbud**	When mature, these fruits are dry. Examples of dry fruits include pods, nuts, and grains.

Seed dispersal In addition to providing some protection for seeds, fruits also help disperse seeds. Dispersal of seeds away from the parent plant increases the survival rate of offspring. For example, when many plants are growing in one area, there is competition for light, water, and soil nutrients. Seeds sprouting next to parent plants and with other offspring compete for these resources.

Fruits that are attractive to animals can be transported great distances away from the parent plant. Animals that gather and bury or store fruits usually do not recover all of them, so the seeds might sprout. Some of the animals, such as deer, bears, and birds, consume fruits. The seeds pass through their digestive tracts undamaged and then are deposited on the ground along with the animals' wastes. Some seeds have structural modifications that enable them to be transported by water, animals, or wind.

Seed germination When the embryo in a seed starts to grow, the process is called **germination.** There are a number of factors that affect germination, including the presence of either water or oxygen (or both), temperature, and those described in **Data Analysis Lab 1.** Most seeds have an optimum temperature for germination. For example, some seeds can germinate when soil is cool, but others need warmer soils.

Germination begins when a seed absorbs water, either as a liquid or gas. As cells take in water, the seed swells; this can break the seed coat. Water also transports materials to the growing regions of the seed.

Within the seed, digestive enzymes help start the breakdown of stored food. This broken-down food and oxygen are the raw materials for cellular respiration, which results in the release of energy for growth.

DATA ANALYSIS LAB 1

Based on Real Data*

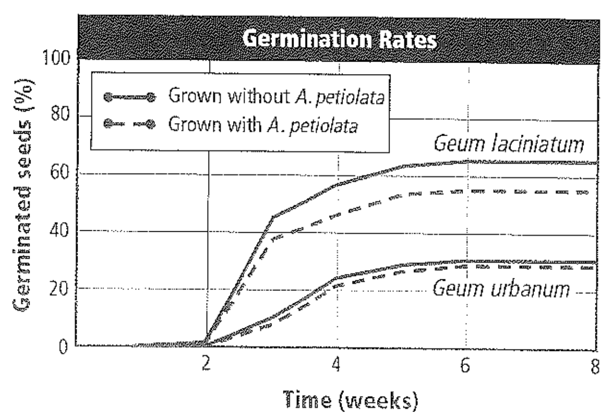
Recognize Cause and Effect

What is allelopathy? In nature, some plants produce chemicals that affect nearby plants. This is called allelopathy (uh LEEL luh pa thee). Some scientists studied the connection between allelopathy and the spread of nonnative plants, such as garlic mustard *Alliaria petiolata*. They investigated the effect of garlic mustard on the seed germination of native plants *Geum urbanum* and *Geum laciniatum*.

Think Critically

1. **Describe** the effect of garlic mustard on seed germination.
2. **Design an experiment** Alfalfa is known to allelopathically inhibit germination of some seeds. Use alfalfa sprouts to investigate their effect on seeds of your choice.

Data and Observations



*Data obtained from: Prati, D. and O Bossdorf. 2004. Allelopathic inhibition of germination by *Alliaria petiolata* (Brassicaceae). *Amer. Journal of Bot.* 91(2): 285–288.

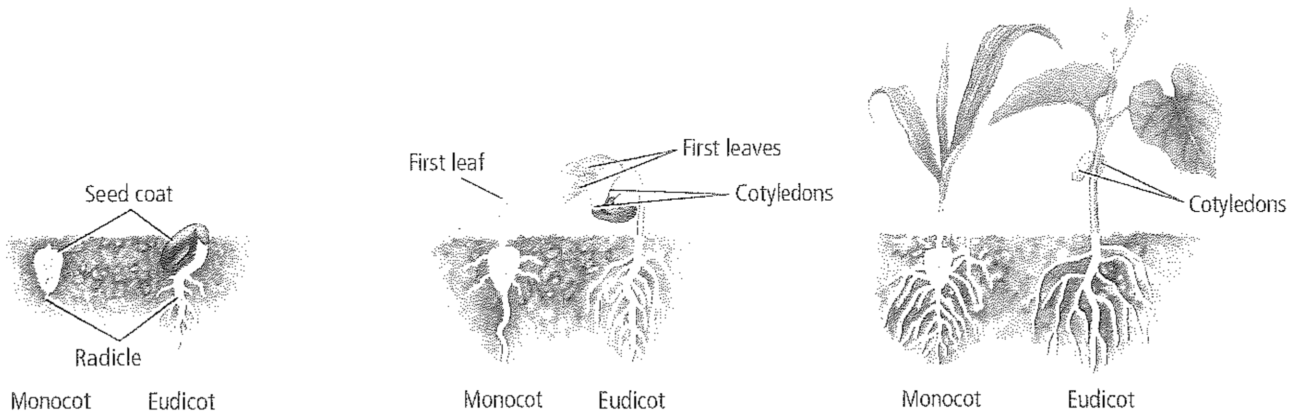


Figure 16 Seed germination differs in monocots and eudicots.

Animation

The first part of the embryo to appear outside the seed is a structure called the **radicle** that starts absorbing water and nutrients from its environment. The radicle, as shown in **Figure 16**, will develop into the plant's root. The **hypocotyl** is the region of the stem nearest the seed and, in many plants, it is the first part of the seedling to appear above the soil. In some eudicots, as the hypocotyl grows, it pulls the cotyledons and the embryonic leaves out of the soil. Photosynthesis begins as soon as the seedling's cells that contain chloroplasts are above ground and exposed to light. In monocots, seedling growth is slightly different because the cotyledon usually stays in the ground when the stem emerges from the soil.

Some seeds can survive harsh environmental conditions, such as drought and cold. Other seeds germinate soon after dispersal and still others can germinate after long periods. Some maple seeds must germinate within two weeks after dispersal or they will not germinate at all. Most seeds produced at the end of a growing season enter **dormancy,** a period of little or no growth. Dormancy is an adaptation that increases the survival rate of seeds exposed to harsh conditions. The length of dormancy varies from species to species.

Section 3 Assessment

Section Summary

- The life cycle of anthophytes includes alternation of generations.
- The development of gametophytes occurs in the flower.
- Double fertilization is unique to anthophytes.
- Seeds provide nutrition and protection for the embryonic sporophyte.
- Fruits help protect and disperse seeds.
- Environmental conditions affect seed germination.

Understand Main Ideas

1. MAIN Idea **Diagram** the steps of the flowering-plant life cycle.
2. **Summarize** the development of the male gametophyte.
3. **Illustrate** the internal structure of a eudicot seed.
4. **Discuss** the importance of double fertilization.
5. **Construct** a graphic organizer that shows the different ways in which seeds can be dispersed.

Think Critically

6. **Evaluate** the mechanism that prevents incompatible pollen from producing a pollen tube.
7. **Compare and contrast** the germination of monocot and eudicot seeds.

MATH in Biology

8. As many as three million seeds can form inside an orchid pod. What is the percentage of germination, if all three million seeds are planted and 1,860,000 germinate?

Online Quiz

Biology & Society

Genetically Modified Plants

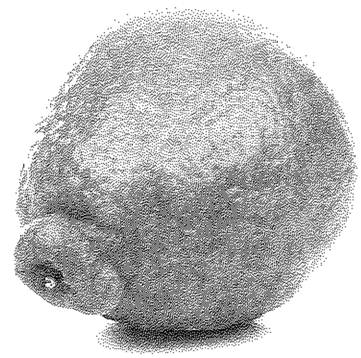
Did you have cornflakes, orange juice, or wheat toast for breakfast? If they were purchased from a large grocery store, then there is a good chance you ate genetically modified foods. People have been altering the genetics of plants for centuries through selective breeding. Only recently have scientists modified the genetic makeup of plants through genetic engineering.

What are genetically modified plants? Before genetic engineering, there was selective breeding. For example, if a fungus infected a corn crop, then a farmer would collect seeds from those plants with little or no signs of infection. If the farmer continued to select seeds from fungus-free plants, fungus-resistant corn could be developed over time.

In recent years, scientists have performed intra-species gene transfers to alter plants. Genes for resistance to insects or disease are transferred from one variety of plant into another variety of the same species. Generally, plants that result from intraspecies gene transfer are considered safe to eat. In 1994, the first genetically modified food became available to the public. It was a tomato that would not soften prematurely.

Other genetically modified plants include corn, soybeans, cotton, wheat, rice, grapples, a cross between an apple and a grape, and pluots, a cross between a plum and an apricot. These products are available in your local grocery stores.

What are the benefits and risks? There are both benefits and risks to creating and using genetically modified plants. Some of the benefits include improved nutritional quality, better crop yields, longer shelf lives, and resistance to herbicides, viruses, and fungi. One negative aspect of genetically modified crops involves determining the risks and the probability that the



Genetically modified minneolas are harvested and sold in grocery stores around the country. Minneolas are a cross between a mandarin orange and a grapefruit.

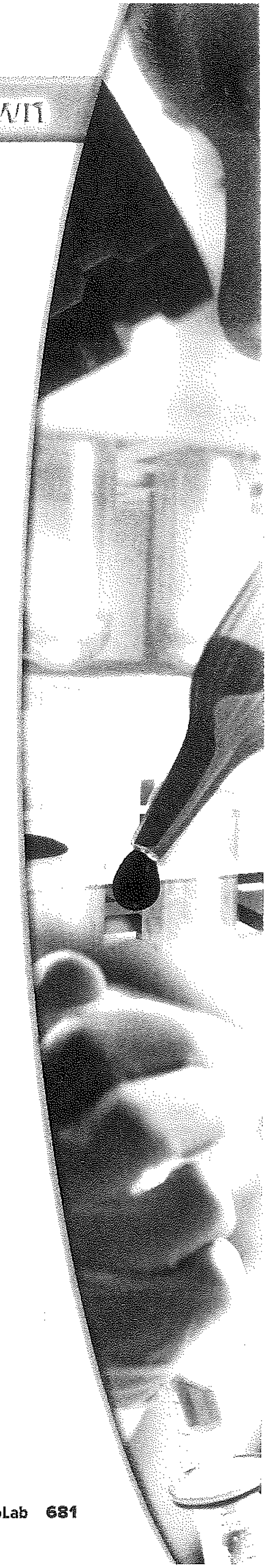
modified plants could easily cross-pollinate with wild varieties of plants. Another potentially negative aspect is a controversial modification called the terminator gene. The terminator gene causes plants to produce seeds that cannot germinate. This way, farmers must buy seeds each growing season. Plants with this gene are not currently being sold, but there is no law prohibiting it.

While genetically modified plants provide many benefits, there are also political, social, and economic concerns that impact how we grow our food. Careful consideration of all areas of this issue is important.

DEBATE in Biology

Debate Should interspecies genetic modification of plants continue without any controls? Conduct additional research and prepare arguments that support your side and refute the other side.

WebQuest



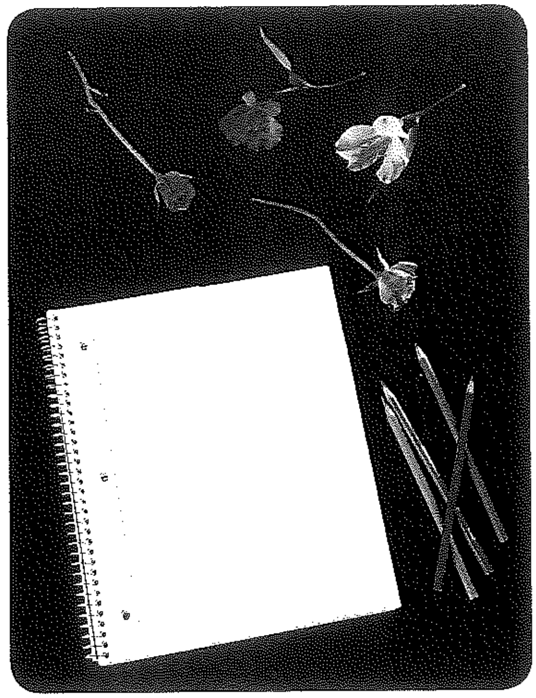
Design Your Own

BIOLAB

HOW DO MONOCOT AND EUDICOT FLOWERS COMPARE?

Background: Flowers are the reproductive structures of flowering plants, and there is great diversity in flower form. Botanists classify flowering plants into two groups—monocots and eudicots—based on the structure of their seeds. However, their flower structures also differ. Explore the differences between these two groups of plants by completing this lab.

Question: *What are the structural differences between monocot and eudicot flowers?*



Materials

monocot flowers
eudicot flowers
colored pencils
Choose other materials that would be appropriate for this lab.

Safety Precautions

WARNING: ***Use dissecting tools with extreme caution.***

Plan and Perform the Experiment

1. Read and complete the lab safety form.
2. Choose several features of monocot and eudicot flowers to observe and compare.
3. Create a data table to record your observations of flowers–monocots and eudicots. Include sketches of each flower type.
4. Make sure your teacher approves your plan before you proceed.
5. Make observations as you planned.
6. Label and color-code the female and male reproductive structures and other flower parts of one of your monocot flower sketches.
7. Repeat Step 6 using one of the eudicot flower sketches.
8. **Cleanup and Disposal** Properly dispose of the flower parts. Clean all equipment as instructed by your teacher and return everything to its proper storage location.

Analyze and Conclude

1. **Compare and contrast** the characteristics of monocot and eudicot flowers.
2. **Conclude** Which of the flowers that you examined were monocots? Eudicots?
3. **Error Analysis** Compare your data with the data collected by your classmates. Explain any differences.

APPLY YOUR SKILL

Field Investigation Visit a local florist, greenhouse, or plant conservatory on your own or with a friend. Make a list of monocot and eudicot plants, based on their flower structures, that you observe at the location. Ask permission before touching any plants.

(t, b) Ryan McVay/Getty Images; (cl) Laura Sifferlin; (cr) Chad Baker/Getty Images

Chapter 23 Study Guide

THEME FOCUS Stability and Change The alternation of generations provides stability and structure in plant reproduction.

BIG Idea The life cycles of plants include various methods of reproduction.

Section 1 Introduction to Plant Reproduction

vegetative reproduction (p. 662)
chemotaxis (p. 664)
protonema (p. 664)
prothallus (p. 665)
heterosporous (p. 665)
megaspore (p. 665)
microspore (p. 666)
micropyle (p. 666)

MAIN Idea Like all plants, the life cycles of mosses, ferns, and conifers include alternation of generations.

- Vegetative reproduction produces new plants without sexual reproduction.
- The life cycles of plants involve the alternation of generations.
- A fern sporophyte can live independently of the gametophyte.
- Conifer gametophytes develop within sporophyte tissues.

Section 2 Flowers

sepal (p. 668)
petal (p. 668)
stamen (p. 669)
pistil (p. 669)
photoperiodism (p. 672)
short-day plant (p. 672)
long-day plant (p. 672)
intermediate-day plant (p. 673)
day-neutral plant (p. 673)

MAIN Idea Flowers are the reproductive structures of anthophytes.

- A typical flower has sepals, petals, stamens, and one or more pistils.
- Flowers can be perfect or imperfect, and complete or incomplete.
- Some flower modifications distinguish monocots from eudicots.
- Modifications make flowers more attractive to pollinators.
- Photoperiodism can influence when a plant flowers.

Section 3 Flowering Plants

polar nuclei (p. 674)
endosperm (p. 676)
seed coat (p. 677)
germination (p. 678)
radicle (p. 679)
hypocotyl (p. 679)
dormancy (p. 679)

MAIN Idea In anthophytes, seeds and fruits can develop from flowers after fertilization.

- The life cycle of anthophytes includes alternation of generations.
- The development of gametophytes occurs in the flower.
- Double fertilization is unique to anthophytes.
- Seeds provide nutrition and protection for the embryonic sporophyte.
- Fruits help protect and disperse seeds.
- Environmental conditions affect seed germination.

Vocabulary eGames

Chapter 23 Assessment

Section 1

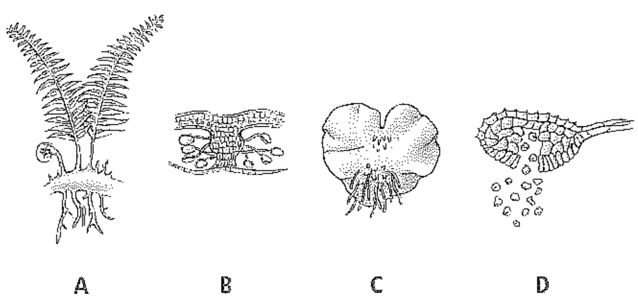
Vocabulary Review

The sentences below are incorrect. Make each sentence correct by replacing the italicized word with a vocabulary term on the Study Guide page.

1. The *megaspore* of a conifer develops into the pollen grain.
2. A *protonema* is the gametophyte of a fern.
3. *Chemotaxis* is the growth of a new plant from a piece of the old plant.

Understand Main Ideas

4. Which is a fern prothallus?

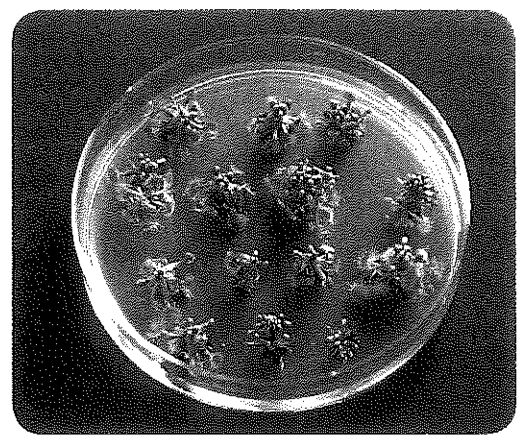


5. Which phrase accurately compares a fern sporophyte to the fern gametophyte?
   - **A.** smaller than
   - **B.** larger than
   - **C.** always independent of
   - **D.** always dependent on
6. From which structure does a conifer female gametophyte develop?
   - **A.** prothallus
   - **B.** fertilized egg
   - **C.** microspore
   - **D.** megaspore
7. Which is not an advantage of vegetative reproduction?
   - **A.** uniform plant features
   - **B.** genetically identical plants
   - **C.** faster reproduction
   - **D.** greater genetic variation

Constructed Response

8. Create a flowchart showing the reproductive cycle of moss.
9. **Short Answer** What are some advantages and disadvantages of the moss sporophyte growing on the gametophyte?

Use the image below to answer question 10.



10. **Short Answer** Explain the genetic relationship among the offspring shown above.

Think Critically

11. **Discuss** the advantages or disadvantages of heterosporous plants.
12. **THEME FOCUS Stability and Change** Suggest a possible mechanism for the development of independent sporophyte generations as seen in conifers.

Section 2

Vocabulary Review

Distinguish between the vocabulary terms in each set.

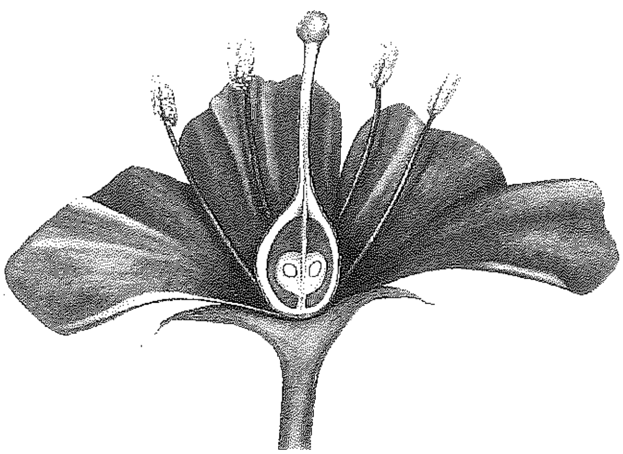
13. pistil, stamen
14. long-day plant, short-day plant
15. petal, sepal

Understand Main Ideas

16. Which flower organ produces pollen?
    - **A.** stamen
    - **B.** pistil
    - **C.** petal
    - **D.** sepal

17. What dark/light conditions produce flowers in a short-day plant?
   A. hours of darkness are greater than the hours of light
   B. hours of darkness are less than hours of light
   C. hours of darkness are equal to hours of light
   D. hours of darkness and light are not factors

Use the image below to answer question 18.



18. Which terms describe the flower above?
   A. perfect, complete
   B. perfect, incomplete
   C. imperfect, incomplete
   D. imperfect, complete

19. Which best describes pollen production in wind-pollinated flowers?
   A. small amounts of pollen
   B. larger pollen grains
   C. large amounts of pollen
   D. large quantities of nectar

20. Which terms could describe a monocot flower?
   A. four sepals, four petals
   B. five sepals, ten petals
   C. twelve sepals, twelve petals
   D. four sepals, eight petals

Constructed Response

21. **Short Answer** Explain why *short-day* and *long-day* are not the best descriptive terms for these types of flowering plants.

22. **Open Ended** Suggest a flower modification that would make water necessary for pollination. Justify your suggestion.

23. Explain how modifications in flower structure make pollination more successful.

Think Critically

24. **Design** an experiment to test the ability of butterflies to distinguish between a real flower and an artificial flower.

25. **Assess** the benefits of photoperiodism.

Section 3

Vocabulary Review

Explain the relationship between the vocabulary terms in each pair below.

26. dormancy, germination

27. hypocotyl, radicle

28. polar nuclei, endosperm

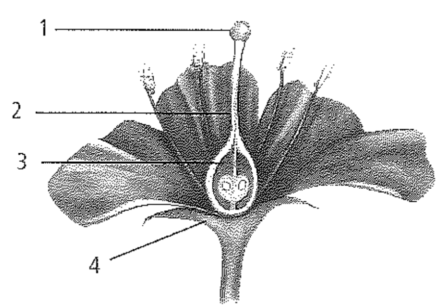
Understand Main Ideas

29. Which is not part of a seed?
   A. cotyledon
   B. embryo
   C. endosperm
   D. pollen

30. Which describes the embryo of an anthophyte?
   A. diploid
   B. haploid
   C. monoploid
   D. triploid

31. From what structure does a pollen grain develop?
   A. egg
   B. embryo
   C. endosperm
   D. microspore

Use the image below to answer question 32.



32. From which structure is a fruit usually formed?
   A. 1
   B. 2
   C. 3
   D. 4

33. What is the inactive period of a seed?
   A. alternation of generations
   B. dormancy
   C. fertilization
   D. photoperiodism

Constructed Response

34. MAIN Idea Describe the process of the fertilizing of a flowering plant.

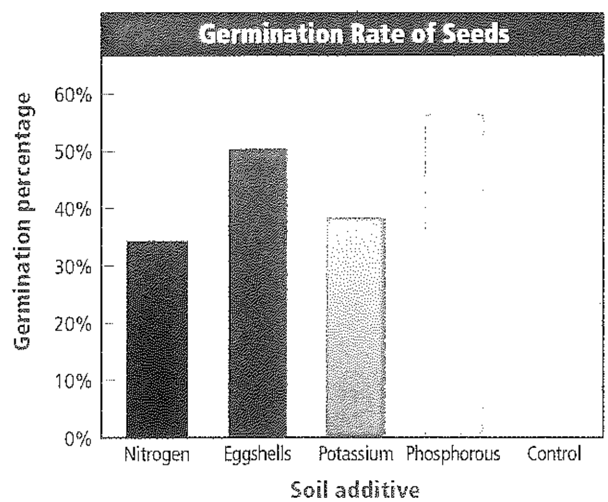
35. **Short Answer** Explain why fruit and/or seed dispersal is so important.

36. **Open Ended** Hypothesize why an anthophyte's female gametophyte produces so many nuclei when only two are involved in fertilization.

37. **Open Ended** When a seed germinates, as shown in **Figure 16,** the radicle usually is the first structure to break through the seed coat. Why is this beneficial for the embryo?

Think Critically

Use the graph below to answer questions 38–39.



38. **Compare** the effects of each soil additive on the rate of germination to the control's rate of germination.

39. **Design** an experiment to test the effect on the rate of germination for various amounts of a soil additive. Choose one of the soil additives listed in the graph above.

Summative Assessment

40. BIG Idea Life cycles, whether in plants or animals, include reproduction. Results of reproduction in plants are seeds and fruits. What else do the various methods of plant reproduction have in common?

41. WRITING in Biology Write a short story about the life of a pollen grain.

DBQ Document-Based Questions

Data obtained from: Lang, A. et al. 1977. Promotion and inhibition of flower formation in a day-neutral plant in grafts with a short-day plant and a long-day plant. *Proc. Natl. Acad. Sci.* 74 (6): 2412-2416.

The day-neutral plant flowered sooner when it was grafted to the short-day plant that was exposed to its critical period. The flowering of another day-neutral plant also was accelerated when it was grafted to a long-day plant that was exposed to its critical period.

42. Examine the drawings above. Form a hypothesis about why the grafted day-neutral plants flowered before the day-neutral plant that was not grafted.

43. Predict what might happen if a long-day plant was grafted to a short-day plant and they were exposed to the critical period of the short-day plant.

44. Design an experiment to determine the "longest day" under which a long-day plant flowers.

Online Test Practice

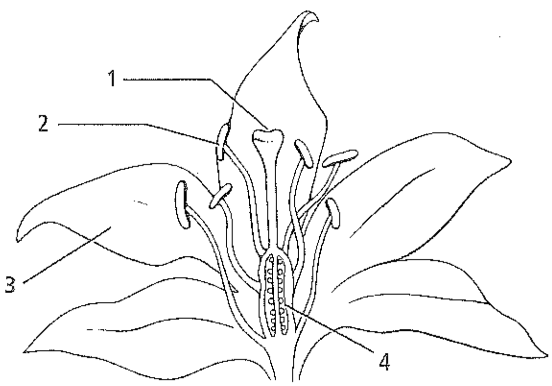
Standardized Test Practice

Cumulative

Multiple Choice

1. Which vascular tissue is composed of living tubular cells that carry sugars from the leaves to other parts of the plant?
   A. cambium
   B. parenchyma
   C. phloem
   D. xylem

Use the diagram below to answer question 2.



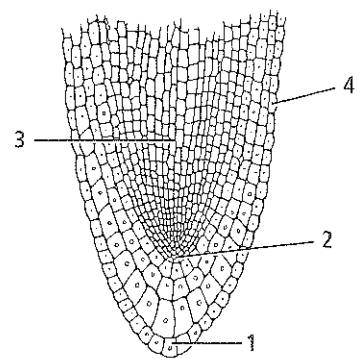
2. Which labeled structure is part of a flower's male reproductive organ?
   A. 1
   B. 2
   C. 3
   D. 4

3. Which statement provides evidence that anthophytes evolved after other seed plants?
   A. About 75 percent of all plants are anthophytes.
   B. Anthophytes do not require water to facilitate the fertilization of an egg.
   C. Prehistoric tree-like ferns were the main coal-forming plants.
   D. The seeds of anthophytes are more advanced than those of other seed plants.

4. Which precedes the haploid generation in seedless vascular plants?
   A. epiphytes
   B. gametophytes
   C. rhizomes
   D. spores

5. Which is the primary pollinator for conifers?
   A. birds
   B. insects
   C. water
   D. wind

Use the diagram below to answer question 6.



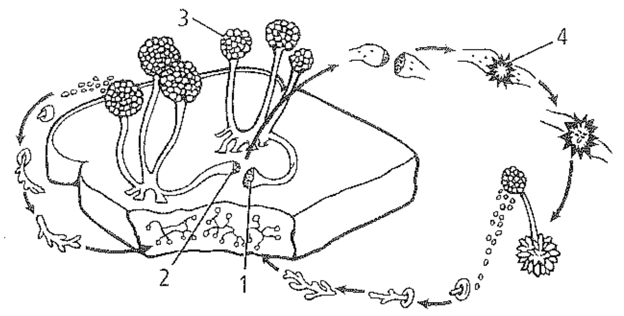
6. Which structure produces cells that result in an increase in length of the root?
   A. 1
   B. 2
   C. 3
   D. 4

7. Which statement is true of an aseptate fungus?
   A. Cell walls are made of cellulose.
   B. Cell walls are made of thin membranes.
   C. Hyphae are not divided by cross walls.
   D. Hyphae are not present except during reproduction.

8. A tuber is an adaptation of which structure?
   A. cell
   B. leaf
   C. root
   D. stem

Short Answer

Use the diagram below to answer question 9.



9. Describe two ways that bread mold could spread in a kitchen.

10. List two characteristics of nonvascular plants that compensate for their lack of transport tissues.

11. A certain type of fern has a chromosome number of 14. What would be the chromosome number of the prothallus? Explain why.

12. Explain the benefit to nonvascular plants of having very thin rhizoids and leaflike structures.

13. Name and describe the three types of plant cells and their functions.

14. Interpret how the actions of plate tectonics affected the evolution of primates.

15. Imagine that a friend who lives in Montana gives you some seeds from a plant. You plant the seeds in Florida but they do not grow. Predict why the seeds do not germinate in Florida.

Extended Response

16. Infer how collenchyma cells support surrounding plant tissues.

17. Critique the idea that roots in the ground do not need oxygen to survive.

18. A forest near a city provides drainage for rainfall runoff. A group of citizens is protesting new housing developments in the forest because they believe flooding and property destruction will result. Analyze the value of biodiversity that describes their concern.

19. Suppose that a couple wants to have children and neither the man nor the woman has cystic fibrosis. However, some distant family members have cystic fibrosis. Could their child have the disease? Write an explanation summarizing the risk for this couple.

Essay Question

Water is important for functions in plants. For example, it is one of the reactants in the chemical reactions of photosynthesis. Water enters a plant by diffusion. Most of the water that enters a plant diffuses into roots. Therefore, water must be in a higher concentration in the soil than in the roots. After water enters the roots, it moves through vascular tissue to tissues that contain chloroplasts. The water also diffuses into the plants' cells, making them rigid.

Using the information in the paragraph above, answer the following question in essay format.

20. When more water leaves a plant than enters it, the plant begins to wilt. Explain the role of guard cells in regulating the amount of water in a plant.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Review Section . . .	22.1	23.2	21.4	21.3	23.1	22.1	20.1	22.2	20.3	21.2	23.1	21.2	22.1	16.1	23.3	22.1	22.2	5.1	11.1	22.2