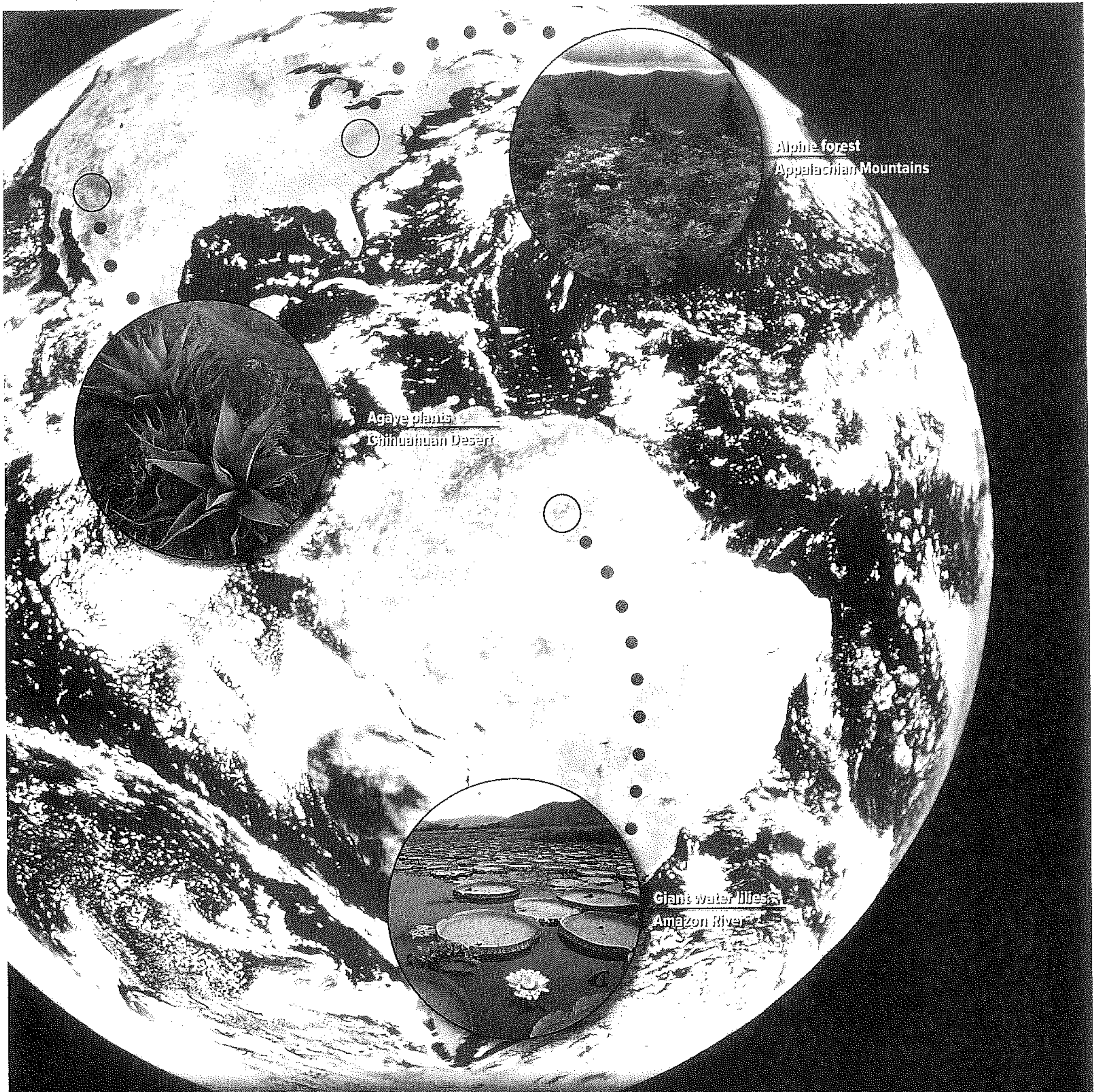


THEME FOCUS Structure and Function

The 300,000 types of plants found all over Earth fill different niches.

BIG Idea Plants have changed over time and are now a diverse group of organisms.

Section 1 • Plant Evolution and Adaptations

Section 2 • Nonvascular Plants

Section 3 • Seedless Vascular Plants

Section 4 • Vascular Seed Plants

Section 1

Reading Preview

Essential Questions

- How do the characteristics of plants and green algae compare?
- What are the adaptations of plants to land environments?
- What is the importance of vascular tissue to plant life on land?
- What is alternation of generations of plants?
- What are the divisions of the plant kingdom?

Review Vocabulary

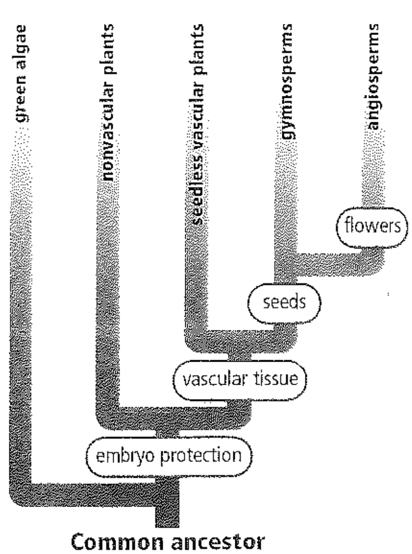
limiting factor: any abiotic or biotic factor that restricts the existence, numbers, reproduction, or distribution of organisms

New Vocabulary

stomata
vascular tissue
vascular plant
nonvascular plant
seed

Multilingual eGlossary

Figure 1 This evolutionary tree shows the relationship of ancient freshwater green algae to present-day plants.



Plant Evolution and Adaptations

MAIN Idea **Adaptations to environmental changes on Earth contributed to the evolution of plants.**

Real-World Reading Link Perhaps you have seen a photo of your ancestors and noticed that some of your living relatives resemble people in the photo. In a similar way, scientists who study evolution notice common characteristics among ancient groups of organisms and present-day groups.

Plant Evolution

Plants are vital to our survival. The oxygen we breathe, the food we eat, and many of the things that make our lives comfortable, such as clothing, furniture, and our homes, come from or are parts of plants. If you were asked to describe a plant, would you describe a tree, a garden flower, or a houseplant? Biologists describe plants as multicellular eukaryotes with tissues and organs that have specialized structures and functions. For example, most plants have photosynthetic tissues, and organs that anchor them in soil or to an object or another plant. However, does this description apply to ancient plants?

Connection to Earth Science Recall that Earth is about 4.6 billion years old. Can you imagine ancient Earth without land plants? That was the case until about 400 million years ago, when primitive land plants appeared. However, fossil evidence from about 500 million years ago indicates that the shallow waters of ancient Earth were filled with a variety of organisms–archaea, bacteria, algae and other protists, and animals, such as sponges, corals, and worms.

There is strong evidence, including biochemical and fossil evidence, that multicellular land plants and present-day green algae share a common ancestor, as diagrammed in the evolutionary tree in **Figure 1.** This common ancestor might have been able to survive periods of drought. Through natural selection, drought-resistant adaptations in that ancestor, such as protected embryos and other survival characteristics, might have passed to future generations. When scientists compare present-day plants and present-day green algae, they find the following common characteristics:

- cell walls composed of cellulose
- cell division that includes the formation of a cell plate
- the same type of chlorophyll used in photosynthesis
- similar genes for ribosomal RNA
- food stored as starch
- the same types of enzymes in cellular vesicles

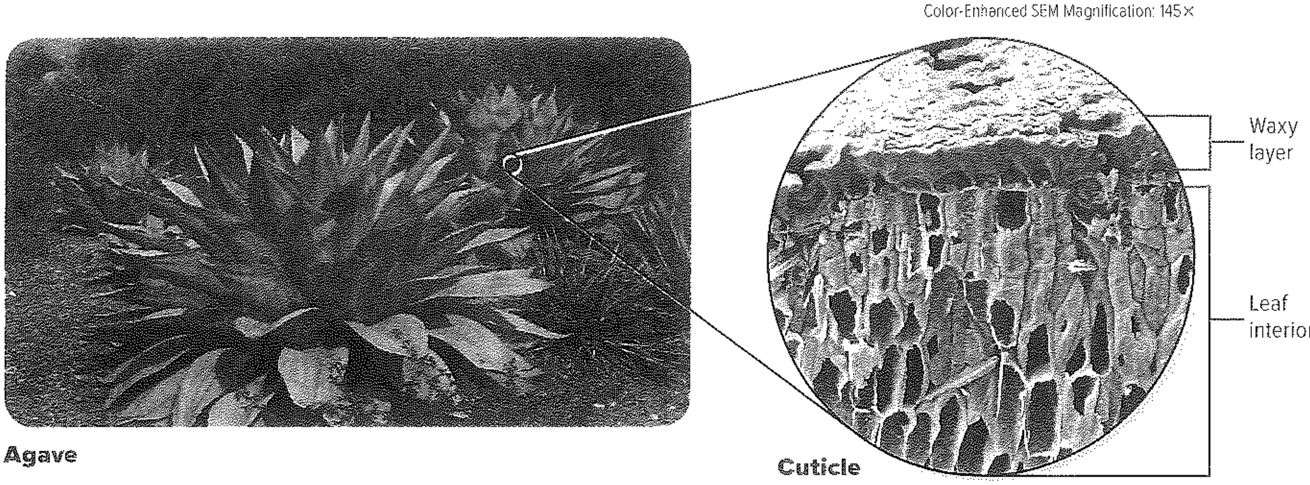


Figure 2 The cuticle is produced by the outer layer of cells. Plants in dry environments often have a thick waxy layer over the cuticle.
Infer ***what advantage this waxy layer provides to plants in dry environments.***

Plant Adaptations to Land Environments

While living on land might seem advantageous for many organisms, there are challenges for land organisms that aquatic organisms do not face. Over time, plants that inhabited land developed adaptations that helped them survive limited water resources as well as other environmental factors.

Cuticle Have you ever noticed that some plant leaves appear shinier than others, or that some leaves have a grayish appearance, such as those of the agave in **Figure 2**? An adaptation found on most aboveground plant parts is a fatty coating called the cuticle on the outer surface of their cells. Wax can also be a component of the cuticle, giving it a grayish appearance. Fats and waxes are lipids and are insoluble in water. Because of this, the cuticle helps prevent the evaporation of water from plant tissues and can also act as a barrier to invading microorganisms.

VOCABULARY

Cuticle
from the Latin diminutive word *cuticula*, meaning *skin*

MiniLab 1

Compare Plant Cuticles

MiniLab

Does the cuticle vary among different types of plants? Plant leaves are covered with a cuticle that reduces water loss. The thickness of cuticle material varies among plants.

Procedure

1. Read and complete the lab safety form.
2. Observe the **plant leaves** provided by your teacher. Write a description of each leaf type.
3. Pile each type of leaf on separate but identical **plastic plates.** Measure the mass and then adjust the number of leaves on each plate until they are of equal mass. Record the masses.
4. The next day, examine each plate of leaves. Record your observations.
5. Measure the mass of each plate of leaves and record the data.

Analysis

1. **Interpret Data** Which leaves appeared to have lost more water? Do the data support your observations?
2. **Infer** which leaves might have a thicker cuticle.

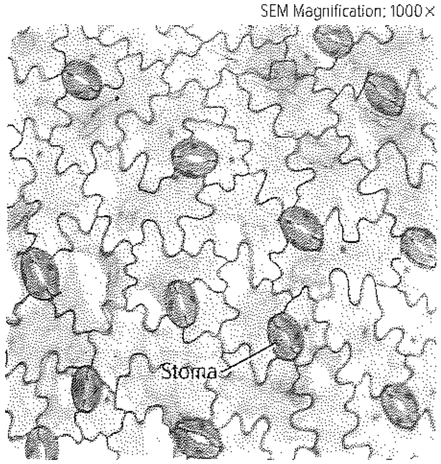


Figure 3 Stomata are common on the lower surfaces of most plants' leaves.

FOLDABLES®
Incorporate information from this section into your Foldable.

Virtual Lab

Stomata Like algae, most plants carry on photosynthesis, which produces glucose and oxygen from carbon dioxide and water. The exchange of gases between plant tissues and the environment is necessary for photosynthesis to occur. If the cuticle reduces water loss, it also might prevent the exchange of gases between a plant and its environment. **Stomata** (singular, stoma) are openings in the outer cell layer of leaves and some stems, as shown in **Figure 3.** They are adaptations that enable the exchange of gases even with the presence of a cuticle on a plant. Although photosynthesis can occur in some green stems, plant leaves usually are the sites of photosynthesis and are where most stomata are found.

Vascular tissues Another plant adaptation to land environments is **vascular tissue**–specialized transport tissue. Recall that many substances slowly move into and out of cells and from cell to cell by osmosis or diffusion. However, vascular tissue enables faster movement of substances than by osmosis and diffusion, and over greater distances. Plants with vascular tissue are called **vascular plants,** like those in **Figure 4.** In some plants, substances slowly move from cell to cell by osmosis and diffusion. These are **nonvascular plants** and lack specialized transport tissues.

Vascular tissues also provide structure and support. The presence of thickened cell walls in some vascular tissue provides additional support. Therefore, vascular plants can grow larger than nonvascular plants can.

Reproductive strategies A spore is a haploid cell capable of producing an organism. Some land plants reproduce by spores that have waterproof protective coverings. However, the gametophytes of those land plants must have a film of water covering them for sperm to swim to eggs. Water is a limiting factor in the environments of these plants. Seed plants have adaptations that enable a sperm to reach an egg without the presence of water.

Reading Check Explain why vascular plants can grow larger than nonvascular plants.

Figure 4 Vascular plants have many shapes and sizes.
Identify ***the plants that you recognize.***

(t)Steven P. Lynch; (b)©Michael Boys/Corbis

Seeds The evolution of the seed was another important adaptation that helped ensure the success of some vascular plants. A **seed**, as shown in **Figure 5**, is a plant structure that contains an embryo, contains nutrients for the embryo, and is covered with a protective coat. These features enable seeds to survive harsh environmental conditions and then sprout when favorable conditions exist. Seeds also can have different structural adaptations that help scatter them.
You will read more about these structural adaptations of seeds in Section 4 of this chapter.

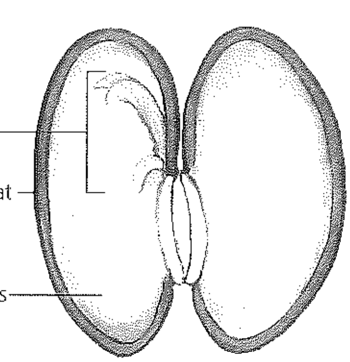


Figure 5 The seed coat protects the embryo—the new sporophyte generation.

Alternation of Generations

Recall that the life cycles of some organisms include an alternation of generations—a haploid gametophyte generation and a diploid sporophyte generation. The gametophyte generation produces gametes—sperm and eggs. Some plants produce sperm and eggs on separate gametophytes, while others produce them on one gametophyte. When a sperm fertilizes an egg, a diploid zygote forms that can undergo countless mitotic cell divisions to form a multicellular sporophyte. The sporophyte generation produces spores that can grow to form the next gametophyte generation.

Depending on the type of plant, one generation is dominant over the other. The dominant generation is usually larger and accounts for more time in the plant's life cycle. Most of the plants you see—houseplants, grasses, garden plants, and trees—are the diploid sporophyte generation for those plants. During plant evolution, the trend was from dominant gametophytes to dominant sporophytes that contain vascular tissue. In land plants, the gametophyte generation of vascular plants is microscopic, as shown in **Figure 6**, but is larger in nonvascular plants and can be observed without a magnifying device. You will see more examples of gametophytes and sporophytes later in this chapter.

VOCABULARY

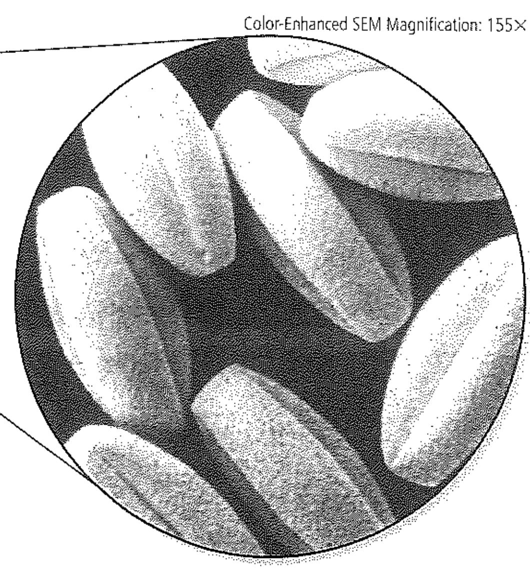
ACADEMIC VOCABULARY

Dominant (DAH muh nunt)
most immediately noticeable
Oaks are the dominant trees in some forests.

Reading Check **Identify** the generation of a plant's life cycle that produces sperm and eggs.

Figure 6 The sporophyte of a maple tree—the roots, trunk, and branches—is larger than the tiny male gametophyte found in its pollen. The maple sporophyte also lives longer than the pollen.

Sporophyte generation—maple tree

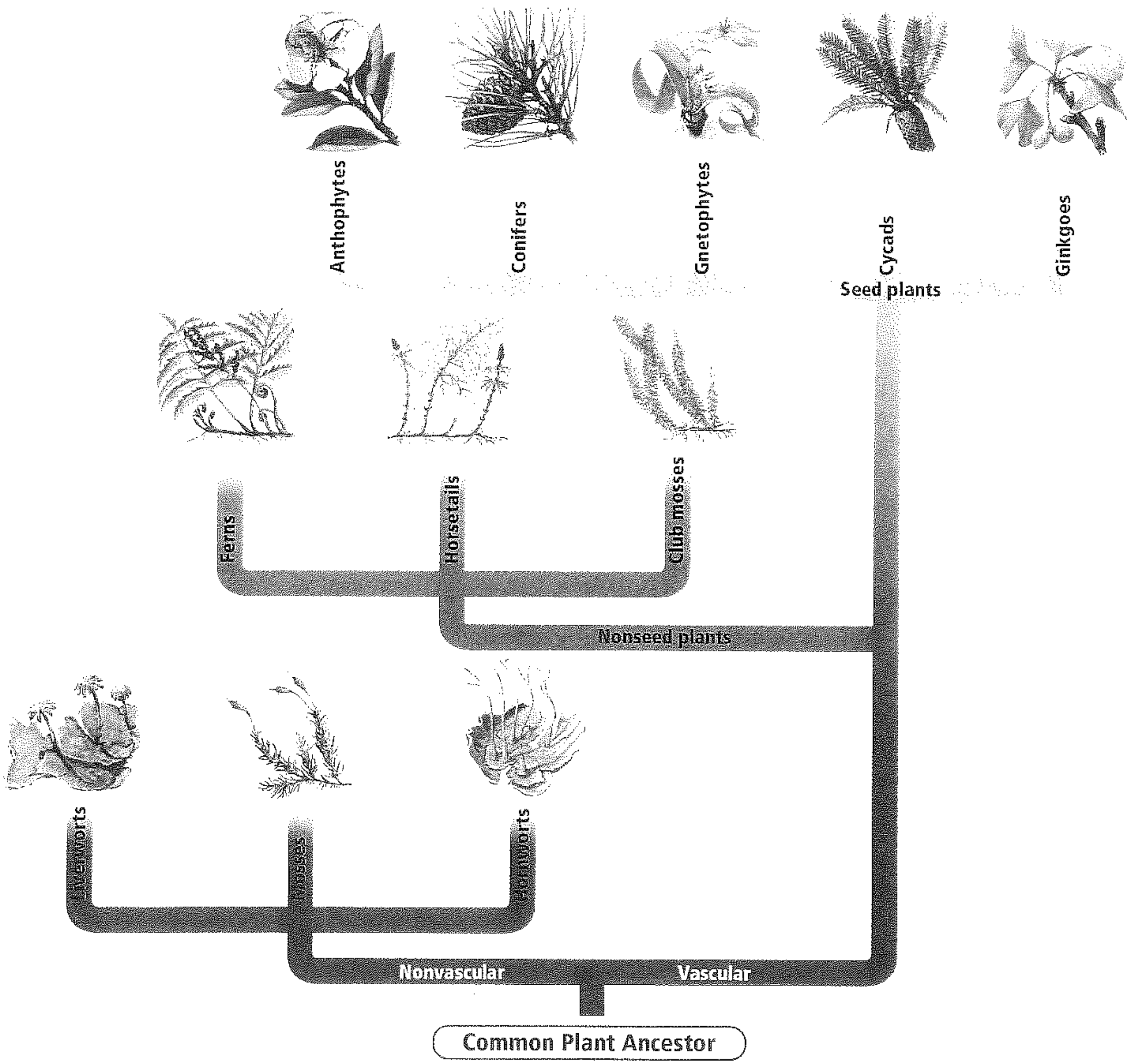


Gametophyte generation—maple pollen

Visualizing the Plant Kingdom

Figure 7

One way to classify the divisions of the plant kingdom is as either nonvascular or vascular plants. In addition, vascular plants can be classified as nonseed or seed plants.



Animation

Plant Classification

Over time, plant adaptations resulted in a diversity of plant characteristics. Botanists use these characteristics to classify all plants of Kingdom Plantae into divisions. Recall that other kingdoms, except for bacteria, are divided into phyla, not divisions. When referring to members of a division, it is common practice to drop the *-a* from the division name and add *-es*. For example, members of Division Bryophyta are called bryophytes (BRI uh fites).

The plant divisions can be placed in two groups–the nonvascular plants and the vascular plants, eleven of which are illustrated in **Figure 7.** As you learned in this section, nonvascular plants lack specialized transport tissues. They include the following:

- bryophytes–mosses;
- anthocerophytes (an tho SAIR uh fites)–hornworts;
- hepaticophytes (hih PA tih koh fites)–liverworts.

You also learned that vascular plants have specialized transport tissues. Vascular plants are divided into two smaller groups–plants that do not produce seeds and plants that produce seeds. Two seedless vascular plants discussed later in this chapter include the following:

- lycophytes (LI kuh fites)–club mosses;
- pterophytes (TER uh fites)–ferns and horsetails.

Also discussed are the following five seed-producing vascular plants:

- cycadophytes (si KAH duh fites)–cycads or sago palms;
- gnetophytes (NEE tuh fites)–joint firs;
- ginkgophytes (GIHN koh fites)–ginkgoes;
- coniferophytes (kuh NIHF uh ruh fites)–pines and similar plants;
- anthophytes (AN thuh fites)–flowering plants.

CAREERS IN BIOLOGY

Botanist Individuals who study plant life are botanists. They study the interactions of plants and the environment, and the structures and functions of plants. They might identify new plant species. A botanist can teach, conduct research, or work at a botanical garden, plant nursery, or greenhouse, or for a governmental agency.

Launch Lab

Review **Based on what you've read about plant characteristics, how would you now answer the analysis questions?**

Section 1 Assessment

Section Summary

- Plants are multicellular organisms, and most are photosynthetic.
- Evidence indicates that ancient, unicellular, freshwater green algae were the ancestors of present-day plants.
- Present-day plants and green algae have many common characteristics.
- Over time, plants developed several adaptations for living on land.
- Plants alternate between a sporophyte and a gametophyte generation.

Understand Main Ideas

1. MAIN Idea **Identify** adaptations that make it possible for plants to survive on land.
2. **Explain** why scientists hypothesize that green algae and plants share a common ancestor.
3. **Name** the plant divisions. Which ones are seedless vascular plants?
4. **Differentiate** between a gametophyte and a sporophyte.

Think Critically

5. **Apply** what you know about lipids to explain why the cuticle helps prevent water loss in plants.
6. **Assess** the importance of a plant's vascular tissue to its ability to live on land.

WRITING in Biology

7. Find a poem about any plant and then analyze its scientific accuracy.

Online Quiz

Section 2

Reading Preview

Essential Questions

- What are the structures of nonvascular plants?
- What are the similarities and differences among the nonvascular plant divisions?

Review Vocabulary

symbiosis: a relationship in which two organisms live together in a close association

New Vocabulary

thallose

Multilingual eGlossary

Nonvascular Plants

MAIN Idea **Nonvascular plants are small and usually grow in damp environments.**

Real-World Reading Link Have you ever used a garden hose to water a lawn or wash a car? Why didn't you carry water from the faucet in a bucket? As you probably realize, using a garden hose to transport water is more efficient than using a bucket. You learned in the previous section that nonvascular plants lack structures that can move water and other substances. However, because of their small size, moving substances by diffusion and osmosis is sufficient for them.

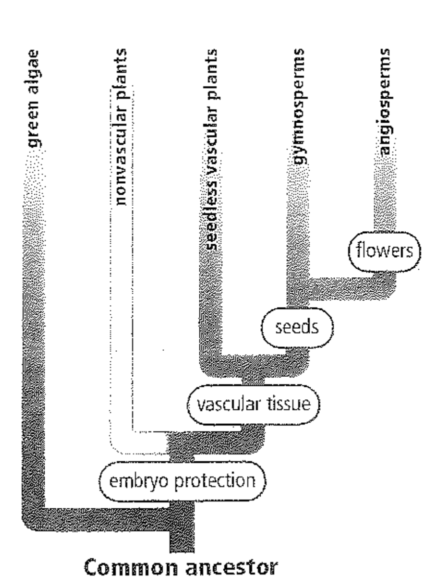
Diversity of Nonvascular Plants

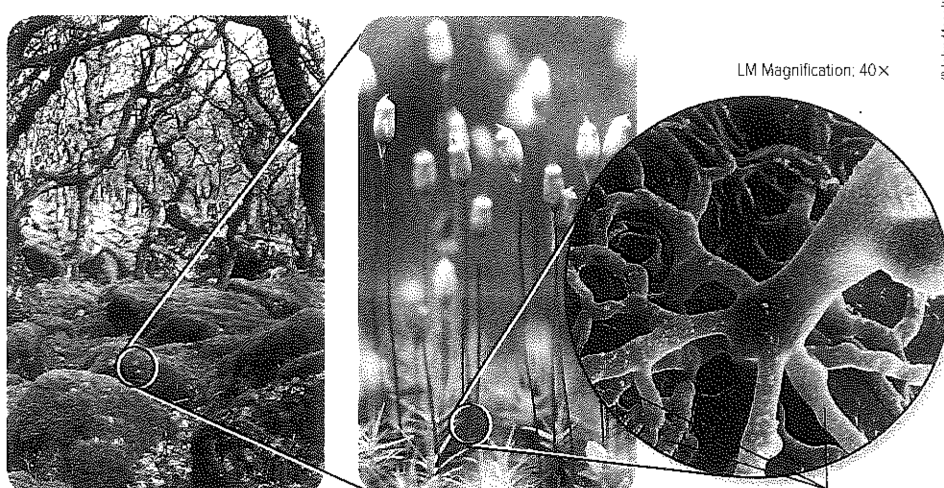
As shown in the evolutionary tree in **Figure 8,** nonvascular plants make up one of the four major groups of plants that evolved along with green algae from a common ancestor. In general, nonvascular plants usually are small, which enables most materials to move within them easily. These plants often are found growing in damp, shady areas—environments that provide the water needed by nonvascular plants for nutrient transport and reproduction.

Division Bryophyta The most familiar bryophytes are the mosses. You might have seen these small, nonvascular plants growing on a damp log or along a stream. Although they do not have true leaves, mosses have structures that are similar to leaves. Their photosynthetic, leaflike structures usually consist of a layer of cells that is only one cell thick.

Mosses produce rootlike, multicellular rhizoids that anchor them to soil or another surface, as shown in **Figure 8.** Water and dissolved minerals can diffuse into a moss's rhizoids. Although mosses have some tissue that transports water and food, these plants do not have true vascular tissues. Water and other substances move throughout moss by osmosis and diffusion.

Figure 8 Embryo protection is a characteristic of nonvascular and vascular plants. The dense carpet of moss—a nonvascular plant—consists of hundreds of moss plants, each with leafy stems and rhizoids.





Carpet of moss

Mosses exhibit variety in structure and growth. Some mosses have stems that grow upright, and others have trailing, vinelike stems. Other mosses form extensive mats that help slow erosion on rocky slopes. Over time, *Sphagnum* (a type of moss) and other plant matter accumulate, decay, and form deep deposits called peat. Peat can be cut into blocks and burned as a fuel. Gardeners and florists often add peat moss to soil to help it retain moisture.

Scientists estimate that as much as one percent of Earth's surface might be covered by bryophytes. Many mosses, like those in **Figure 8,** grow in temperate regions and freeze and thaw without damage. Others can survive an extreme loss of water and then resume growth when moisture returns.

Reading Check **Explain** how peat is formed.

Division Anthocerophyta The smallest division of nonvascular plants is division Anthocerophyta. Anthocerophytes are called hornworts because of their hornlike sporophytes, as shown in **Figure 9.** Water and nutrients move in hornworts by osmosis and diffusion. About 100 hornwort species have been identified.

An identifying feature of these plants is the presence of one large chloroplast in each cell of the gametophyte and sporophyte. This feature can be observed under a microscope. However, the hornwort sporophyte produces much of the food used by its sporophyte and gametophyte generations.

While examining hornwort tissue under a microscope, besides the large chloroplast in each cell, you also might observe that the spaces around cells are filled with mucilage, or slime, rather than air. Cyanobacteria in the genus *Nostoc* often grow in this slime. The cyanobacteria and hornwort exhibit mutualism.

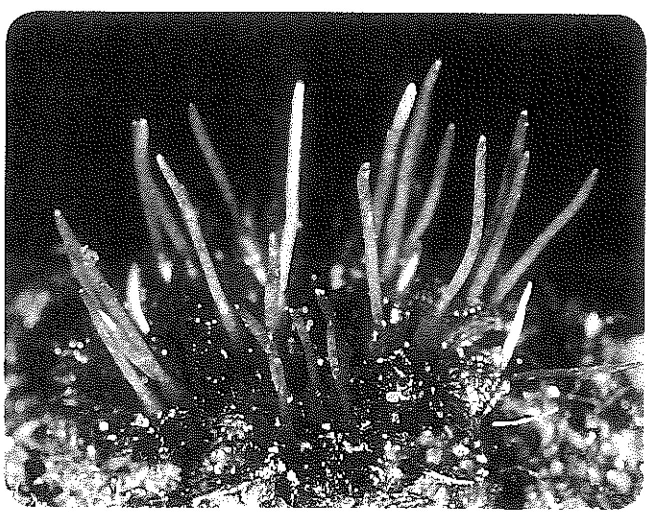


Figure 9 The hornlike sporophyte of a hornwort is anchored to the gametophyte.

DATA ANALYSIS LAB 1

Based on Real Data*

How does *Nostoc* benefit a hornwort?
Cyanobacteria, usually species of *Nostoc,* form mutualistic relationships with a few liverworts and the majority of hornworts.

Data and Observations

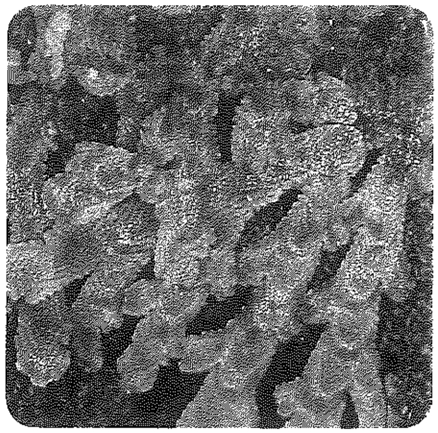
Nostoc colonies appear as dark spots within gametophyte tissue, as shown in the photo.

Think Critically

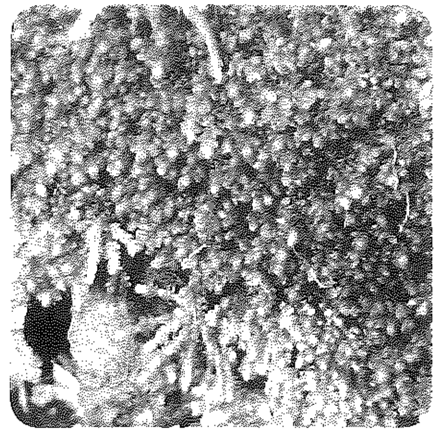
1. **Hypothesize** about the benefit(s) the cyanobacteria receive from the hornwort.
2. **Design** an experiment to test your hypothesis.

*Data obtained from: Costa, J-L., et al. 2001. Genetic diversity of *Nostoc* symbionts endophytically associated with two bryophyte species. *Appl. Envir. Microbiol.* 67: 4393–4396.

Figure 10 A thallose liverwort's shape resembles lobes of a liver. Leafy liverworts have leaflike structures but not true leaves.



Thallose liverwort



Leafy liverwort

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Fleshy

Science usage: having a juicy or pulpy texture

Peaches and plums are fleshy fruits.

Common usage: relating to, consisting of, or resembling flesh

The piece of beef was fleshy, not bony.

Division Hepaticophyta Because of their appearance and use as a medicine to treat liver ailments during medieval times, hepaticophytes are referred to as liverworts. This division of nonvascular plants contains more than 6000 species. They are found in a variety of habitats ranging from the tropics to the arctic. Liverworts tend to grow close to the ground and in areas where moisture is plentiful, such as in damp soil, near water, or on damp, decaying logs. A few species can even survive in relatively dry areas. Like other nonvascular plants, water, nutrients, and other substances are transported throughout liverworts by osmosis and diffusion.

Liverworts are classified as either **thallose** (THAL lohs) or leafy. Both are shown in **Figure 10.** A thallose liverwort has a body that resembles a fleshy, lobed structure. Leafy liverworts have stems with flat, thin leaflike structures arranged in three rows–a row on each side of the stem and a row of smaller leaves on the undersurface. Liverworts have unicellular rhizoids, unlike mosses, which have multicellular rhizoids.

DNA analysis has shown that liverworts lack DNA sequences that most other land plants contain. This suggests that liverworts are the most primitive of land plants.

Section 2 Assessment

Section Summary

- Distribution of nonvascular plants is limited by the plants' ability to transport water and other substances.
- Mosses are small plants that can grow in different environments.
- Like other nonvascular plants, hornworts rely on osmosis and diffusion to transport substances.
- The two types of liverworts are classified as thallose and leafy.

Understand Main Ideas

1. MAIN Idea **Summarize** the characteristics of mosses.
2. **Identify** environmental changes that might have influenced the evolution of nonvascular plant structures.
3. **Distinguish** between a liverwort and a hornwort.
4. **Generalize** the economic value of bryophytes.

Think Critically

5. **Apply** what you know about osmosis and diffusion to suggest why nonvascular plants usually are small.
6. **Predict** the changes that would occur at the cellular level when a moss dries out.
7. **Compare and contrast** the habitats of mosses, hornworts, and liverworts.

Online Quiz

Section 3

Reading Preview

Essential Questions

- What are the characteristics of seedless vascular plants?
- What are the similarities and differences between the characteristics of club mosses and ferns?

Review Vocabulary

spore: a reproductive haploid cell with a hard outer coat that can develop into a new organism without the fusion of gametes

New Vocabulary

strobilus
epiphyte
rhizome
sporangium
sorus

Multilingual eGlossary

Seedless Vascular Plants

MAIN Idea Because they have vascular tissues, seedless vascular plants generally are larger and better adapted to drier environments than nonvascular plants.

Real-World Reading Link Whether it is to brush your teeth, to get a drink of water, or to wash something, when you turn on a faucet, water flows out. The plumbing in your home carries water to and from different places. The vascular tissue in plants can be thought of as a plant's plumbing because it carries water and dissolved substances throughout the plant.

Diversity of Seedless Vascular Plants

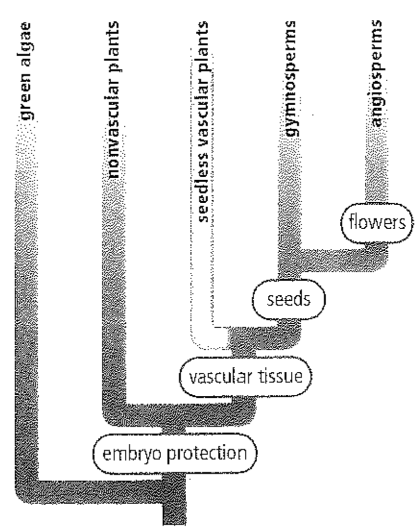
Club mosses, also known as spike mosses, and the fern group make up the seedless vascular plant group. Keep in mind that although the common name for a club moss identifies it as a moss, it is not like the mosses described in the previous section. As indicated in **Figure 11,** this plant group is one of the three plant groups with vascular tissues. Seedless vascular plants exhibit a great diversity of form and size.

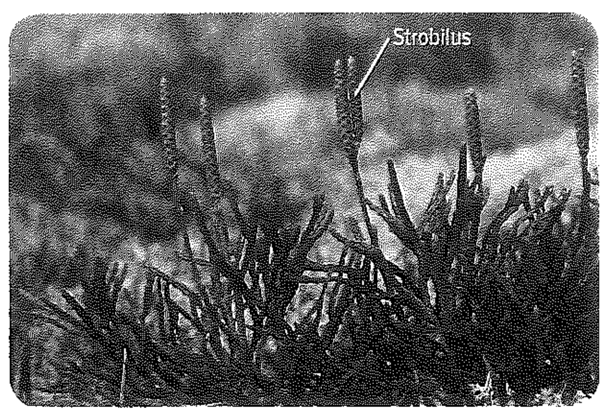
Regardless of their size, an adaptation seen in some seedless vascular plant sporophytes is the strobilus (STROH bih lus) (plural, strobili). A **strobilus** is a compact cluster of spore-bearing structures. The tiny spores produced in the strobilus often are carried by the wind. If a spore lands in a favorable environment, it can grow to form a gametophyte.

Division Lycophyta Present-day lycophytes or club mosses are descendants of the oldest group of vascular plants. Fossil evidence suggests that ancient lycophytes were tree-sized plants–some as tall as 30 m. They formed a large part of the vegetation of Paleozoic forests. After this vegetation died, its remains changed over time and eventually became part of the coal that humans mine for fuel.

Unlike true mosses, the sporophyte generation of lycophytes is dominant. They resemble moss gametophytes, and their reproductive structures that produce spores are club-shaped or spike-shaped, as shown in **Figure 11.**

Figure 11 Seedless vascular plants, such as the club moss called wolf's claw, produce spores in strobili instead of seeds.





Lycopodium **sp.—wolf's claw**

Figure 12 This spike moss belongs to the genus *Selaginella.*

Lycophytes have roots, stems, and small, scaly, leaflike structures. Another name for some lycophytes is ground pines because they resemble miniature pine trees. Their stems are either branched or unbranched and either grow upright or creep along the soil's surface. Roots grow from the base of a stem. Extending down the middle of each scaly leaflike structure is a vein of vascular tissue.

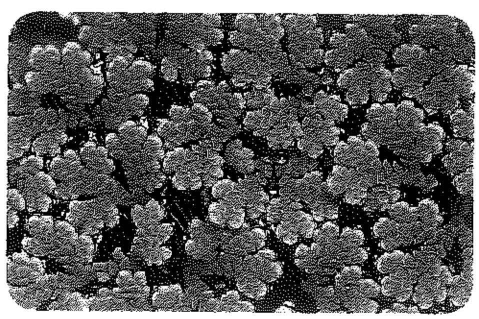
Most of the club mosses belong to two genera—*Lycopodium* and *Selaginella*—like the examples shown in **Figure 11** and **Figure 12.** Many tropical lycophyte species are epiphytes. An **epiphyte** is a plant that lives anchored to an object or another plant. When anchored in treetops, they create another habitat for insects and other small animals in the forest canopy.

Reading Check **Identify** the contribution of ancient lycophytes to present-day economies.

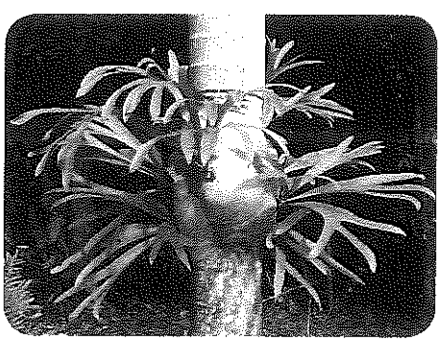
Division Pterophyta This plant division includes ferns and horsetails. The horsetails once were in their own plant division. However, recent biochemical studies reveal that they are closely related to ferns and should be grouped with them.

Connection to Earth Science During the Carboniferous period, about 300–359 million years ago, ferns were the most abundant land plants. Vast forests of treelike ferns existed, and some of them produced seedlike structures. Today, ferns grow in many different environments. Although ferns are most common in moist environments, they can survive dry conditions. When water is scarce, the life processes of some ferns slow so much that the ferns appear to be lifeless. When water becomes available, the ferns resume growth. Examples of ferns growing in diverse habitats are shown in **Figure 13.**

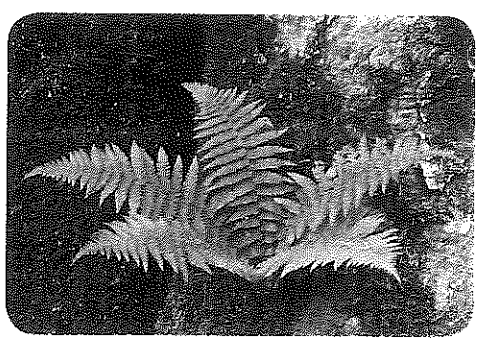
Figure 13 Ferns are a diverse group of plants that occupy a variety of habitats.



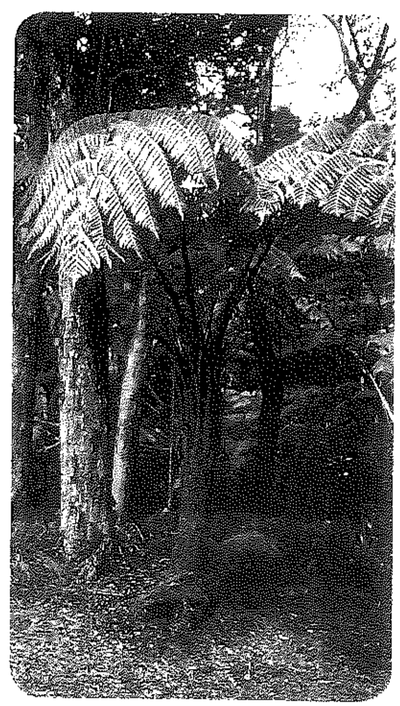
The aquatic fern *Azolla* is mutualistic with a cyanobacterium.



The staghorn fern grows as an epiphyte.

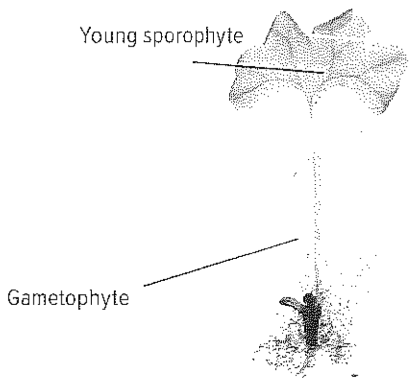


Dryopteris grows best in shady, dry environments.

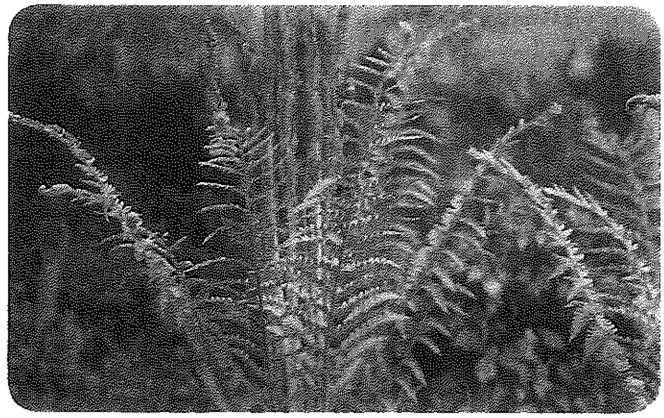


Hawaii is the only U.S. state to which tree ferns are native in tropical forests.

Color-Enhanced Image Magnification: unavailable



Fern gametophyte and sporophyte



Mature fern sporophyte

Figure 14 Fern gametophytes and sporophytes differ greatly in size and appearance. A mature fern sporophyte is many times larger than the gametophyte.

It is unlikely that you have seen a fern gametophyte like the one in **Figure 14.** This tiny, thin structure is smaller than a pin. It grows from a spore and has male and female reproductive structures. Following fertilization, the sporophyte grows from and is briefly dependent on the gametophyte. One adaptation of some ferns that live in dry areas is that they can produce sporophytes without fertilization. Eventually, the sporophyte produces roots and a thick underground stem called a **rhizome.** The rhizome is a food-storage organ. The aboveground structures of some ferns die at the end of a growing season. The breakdown of the rhizome's stored food releases energy when growth resumes.

The familiar parts of a fern are its photosynthetic leafy structures, or fronds, shown in **Figure 14.** The frond is part of the sporophyte generation of ferns. Fronds have branched vascular tissue and vary greatly in size.

DATA ANALYSIS LAB 2

Based on Real Data*

Analyze Models

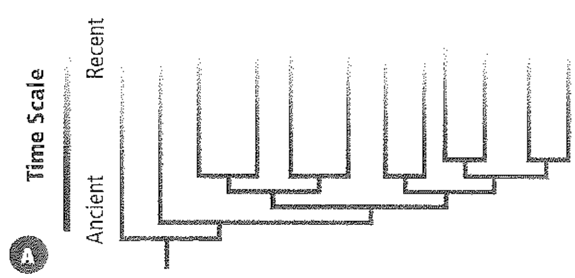
When did the diversity of modern ferns evolve? Researchers analyzed fossil evidence and DNA sequence data of ferns. They found that ferns have shown greater diversity in more recent evolutionary history. They concluded that the diversity of modern ferns evolved after angiosperms dominated terrestrial ecosystems.

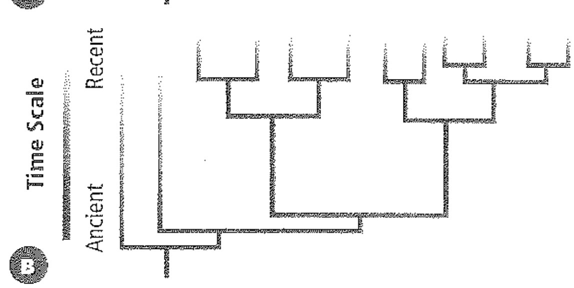
Data and Observations

Observe the two models showing the evolution of the diversity of organisms.

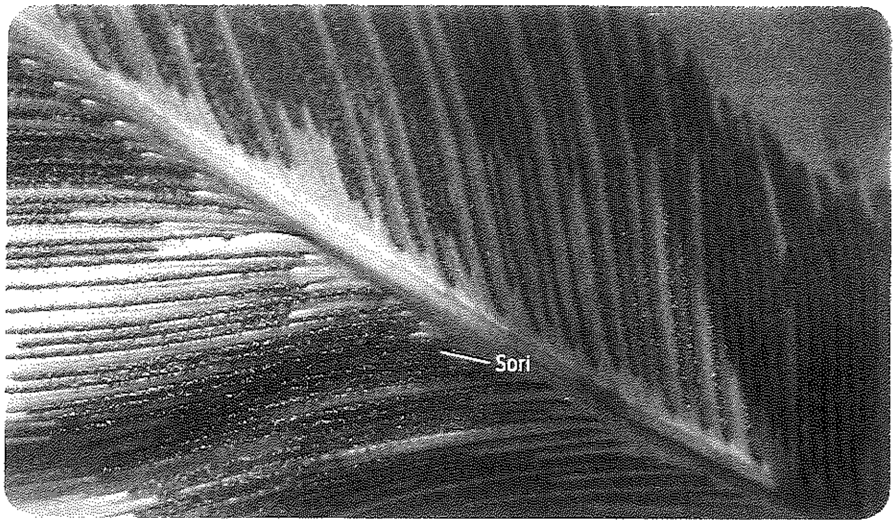
Think Critically

1. **Select** the model that best fits the researchers' conclusion described above.
2. **Infer** Angiosperms are flowering plants. How might angiosperms have influenced fern diversity?





*Data obtained from: Eriksson, Torsten. 2004. Evolutionary biology: Ferns reawakened. *Nature* 428: 480–481.



Bird's nest fern

Horsetails

Figure 15 The sori of the bird's nest fern contain spores and form lines on the underside of a frond. Some horsetails produce two different sporophyte stalks—vegetative and reproductive.

Fern spores form in a structure called a **sporangium** (plural, sporangia), and clusters of sporangia form a **sorus** (plural, sori). Sori usually are located on the undersides of fronds, as shown in **Figure 15.**

Figure 15 also shows the typical structure of horsetails–ribbed, hollow stems with circles of scalelike leaves. Like lycophytes, horsetails produce spores in strobili at the tips of reproductive stems. When they are released into a favorable environment, horsetail spores can develop into gametophytes.

Another common name for horsetails is scouring rushes. In colonial days, they often were used to scrub pots and pans. Horsetails contain a scratchy substance called silica. You can feel it when you rub your finger along a horsetail stem.

Present-day horsetail species are much smaller than their ancient ancestors. Most horsetails grow in wet areas, such as marshes, swamps, and stream banks. Some species grow in the drier soil of fields and roadsides only because their roots grow into underlying, water-saturated soil.

Section 3 Assessment

Section Summary

- Seedless vascular plants have specialized transport tissues and reproduce by spores.
- The sporophyte is the dominant generation in vascular plants.
- Lycophytes and pterophytes are seedless vascular plants.

Understand Main Ideas

1. MAIN Idea **Create** a table that lists the characteristics of seedless vascular plant groups.
2. **Compare** the sporophyte and gametophyte generations of vascular and nonvascular plants.
3. **Infer** the advantages of the fern sporophyte's initial dependency upon the gametophyte.

Think Critically

4. **Design** an experiment that would test the ability of fern gametophytes to grow on different soils.
5. **Evaluate** the advantage of branching vascular tissue in fern fronds.
6. **Construct** a Venn diagram showing characteristics of club mosses and ferns.

Online Quiz

Section 4

Reading Preview

Essential Questions

- What are the similarities and differences among the seed plants?
- What are the divisions of gymnosperms?
- What are the life spans of angiosperms?

Review Vocabulary

adaptation: inherited characteristic that results from response to an environmental factor

New Vocabulary

cotyledon
cone
annual
biennial
perennial

Multilingual eGlossary

Vascular Seed Plants

Main Idea **Vascular seed plants are the most widely distributed plants on Earth.**

Real-World Reading Link You put a letter in an envelope to mail it so that the envelope will protect your letter. In a similar way, a new plant is protected within the seed until environmental conditions are favorable for growth.

Diversity of Seed Plants

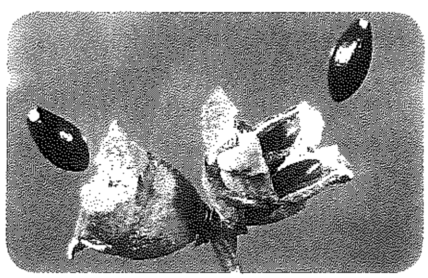
Vascular seed plants produce seeds. Each seed usually contains a tiny sporophyte surrounded by protective tissue. Seeds have one or more **cotyledons** (kah tuh LEE dunz)–structures that either store food or help absorb food for the tiny sporophyte. Plants whose seeds are part of fruits are called angiosperms. Those plants whose seeds are not part of fruits are called gymnosperms. The word *gymnosperm* comes from two Greek words that together mean *naked seed.*

Seed plants have a variety of adaptations for the dispersal or scattering of their seeds throughout their environments, like those shown in **Figure 16.** Dispersal is important because it limits competition between the new plant and its parent and other offspring.

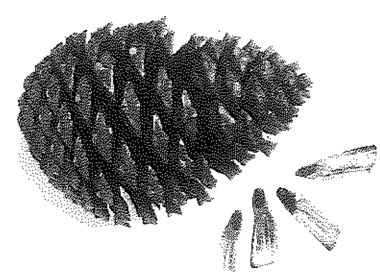
The sporophyte is dominant in seed plants and produces spores. These spores divide by meiosis to form male gametophytes (pollen grains) and female gametophytes. Each female gametophyte consists of one or more eggs surrounded by protective tissues. Both gametophytes are dependent on the sporophyte generation for their survival.

Figure 16 Examine these structural adaptations for seed dispersal.

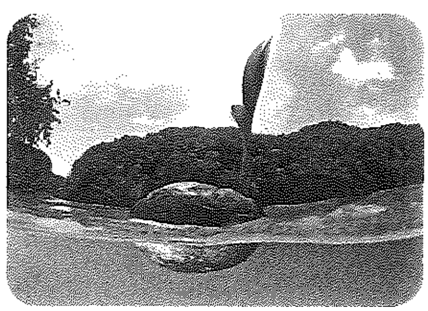
The cocklebur has hooks that can attach to an animal's fur or a human's clothing.



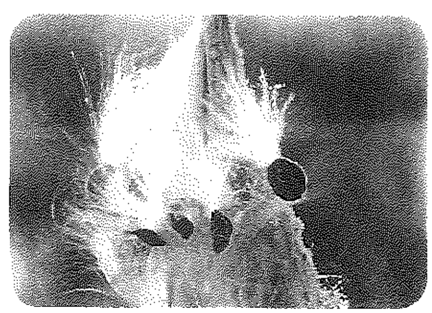
The dry fruit of a witch hazel plant can eject its two seeds more than 12 m from the plant.



These pine seeds have winglike structures that enable them to move with the wind.



The coconut, with its seed inside, can float great distances on ocean currents.



Parachute-like structures help disperse milkweed seeds.

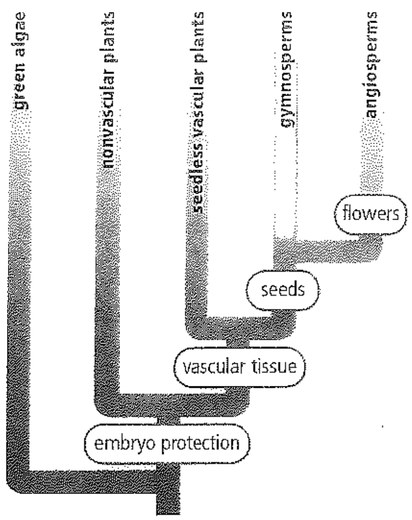


Figure 17 The evolutionary tree above shows that the development of cones was an earlier evolutionary adaptation than flowers.

Earlier in this chapter, you read that water must be present for a sperm to reach an egg in both nonvascular plants and seedless vascular plants. Most seed plants do not require a film of water for this process. This is an important difference between seed plants and other plants. This adaptation enables seed plants to thrive in different environments, including areas where water is scarce.

Division Cycadophyta As shown in the evolutionary tree in **Figure 17,** plants with cones–the gymnosperms–evolved before plants with flowers–the angiosperms. A **cone** is a structure that contains the male or female reproductive structures of cycads and other gymnosperm plants. A male cone produces clouds of pollen grains that produce male gametophytes. Female cones contain female gametophytes. Cycad cones can be as long as 1 m and weigh as much as 35 kg. Male and female cones grow on separate cycad plants.

Because cycads have large divided leaves and some grow more than 18 m tall, people often think that cycads are related to palm trees. However, cycads have structural differences and different reproductive strategies than do palms. While cycads might resemble woody trees, they actually have soft stems or trunks consisting mostly of storage tissue.

The natural habitats of cycads are the tropics or subtropics. There is only one species native to the United States. Its native habitat is southern Florida. Cycads grew in abundance 200 million years ago, but today there are only about 11 genera and 250 species.

Reading Check **Compare** a cone with a strobilus.

Division Gnetophyta Plants in division Gnetophyta can live as long as 1500–2000 years. There are just three genera of gnetophytes, and each exhibits unusual structural adaptations to its environment.

The genus *Ephedra* is the only gnetophyte genus that grows in the United States. The genus *Gnetum* includes about 30 species of tropical trees and climbing vines. The remaining genus, *Welwitschia,* has only one species–a bizarre-looking plant shown in **Figure 18**–found exclusively in the deserts of southwestern Africa. It has a large storage root and two continuously growing leaves that eventually can exceed 6 m in length. *Welwitschia* takes in available moisture from fog, dew, or rain through its two leaves.

CAREERS IN BIOLOGY

Wood Scientist An individual who is involved in one or more aspects of converting wood to wood products is a wood scientist. A wood scientist can conduct research or work in manufacturing as a product or process developer, quality or production controller, engineer, or manager.

Figure 18 *Welwitschia* leaves are blown about by the wind. This causes them to split many times and makes the two leaves appear as many leaves.

Division Ginkgophyta Only one living species, *Ginkgo biloba*, represents division Ginkgophyta. Early in the 19th century, fossil remains of *Ginkgo biloba* were discovered in the state of Washington. The ginkgo disappeared from North America during the last ice age. However, it survived in China, where it was grown for its seeds—a food delicacy eaten only at weddings and during holidays.

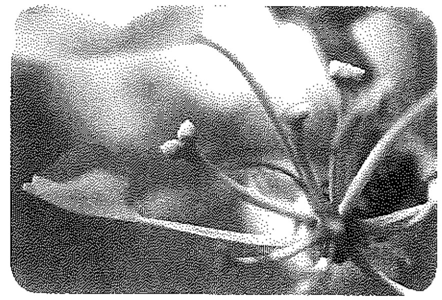
This distinctive tree has small, fan-shaped leaves. Like cycads, male and female reproductive systems are on separate plants. The male tree produces pollen grains in strobiluslike cones growing from the bases of leaf clusters, as shown in **Figure 19.** The female tree produces cones, also shown in **Figure 19,** which, when fertilized, develop foul-smelling, fleshy seed coats. Because they tolerate smog and pollution, ginkgoes are popular with gardeners and urban landscapers. However, male trees usually are favored because they do not produce foul-smelling fleshy cones.

Division Coniferophyta Conifers range in size from low-growing shrubs that are several centimeters tall to towering trees over 50 m in height. Pines, firs, cypresses, and redwoods are examples of conifers. Conifers are the most economically important gymnosperms. They are sources of lumber, paper pulp, and the resins used to make turpentine, rosin, and other products.

Reproductive structures of most conifers develop in cones. Most conifers have male and female cones on different branches of the same tree or shrub. The small male cones produce pollen. Larger female cones remain on the plants until the seeds have matured. The characteristics of female cones, such as those shown in **Figure 20,** can be used to identify conifers.

Conifers, like all plants, exhibit adaptations to their environments. What connection can you make between the facts that most conifers have drooping branches and that many conifers grow in snowy climates? Another adaptation is a waxlike coating called cutin that covers conifers' needlelike or scalelike leaves and reduces water loss.

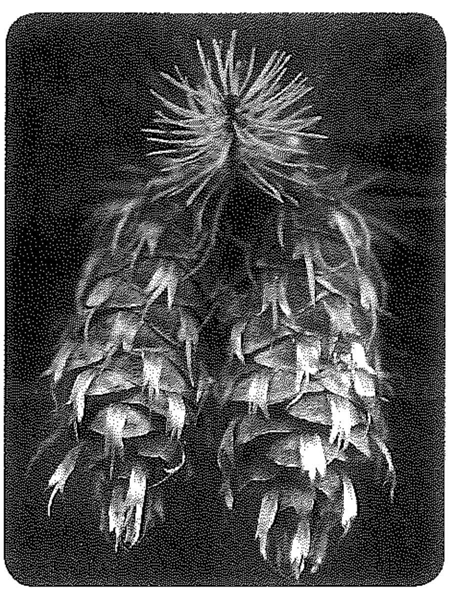
Male reproductive structures



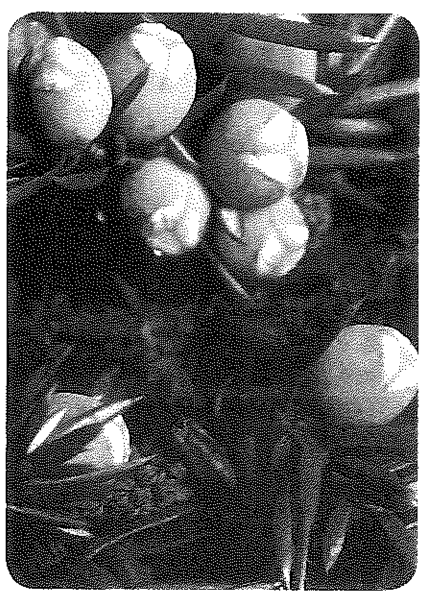
Female reproductive structures

Figure 19 Both male and female ginkgo reproductive structures grow from the bases of leaf clusters, but on separate trees.
Predict ***how pollen travels to the female reproductive structure.***

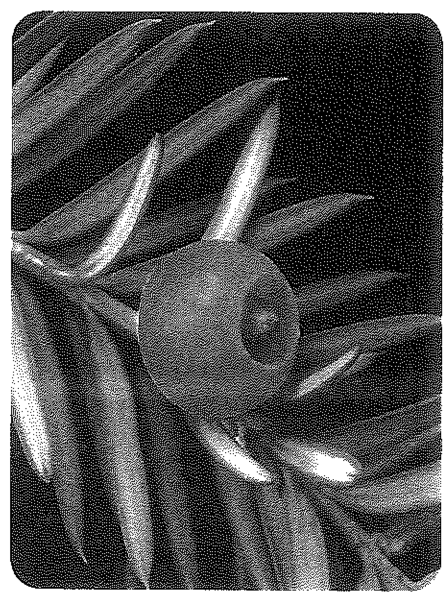
Figure 20 Female cones of conifers can be described as woody, berrylike, or fleshy.



Douglas fir—woody cones



Juniper—berrylike cones



Pacific yew—fleshy cones

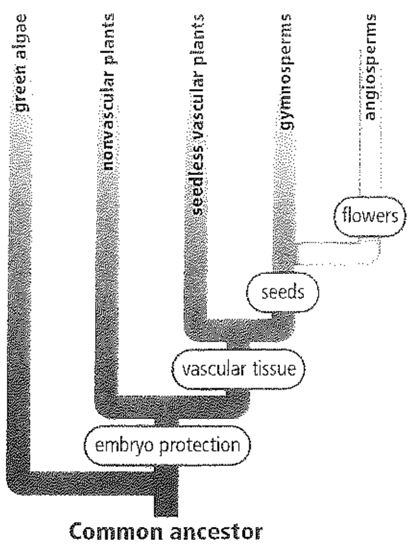


Figure 21 The flowering plants were the most recently evolved of the plant kingdom.

Video Lab

BrainPOP

When you hear the word *evergreen,* do you think of a pine or another conifer? Most plants in northern temperate regions called evergreens are conifers. However, in subtropical and tropical regions, other plants, such as palms, also are evergreen. Botanists define an evergreen plant as one with some green leaves throughout the year. This adaptation enables it to undergo photosynthesis whenever conditions are favorable. A plant that loses its leaves at the end of the growing season or when moisture is scarce is called deciduous. Some conifers are deciduous, such as larches and bald cypresses. Whether deciduous or evergreen, you can identify a conifer species by its leaves, as demonstrated in **MiniLab 2.**

Reading Check **Explain** why some trees are called evergreens.

Division Anthophyta Flowering plants, also known as anthophytes or angiosperms, are the most widely distributed plants because of adaptations that enable them to grow in terrestrial and aquatic environments. Anthophytes first appeared in the fossil record about 130 million years ago after the appearance of gymnosperms, as shown in **Figure 21.** Today, flowering plants make up more than 75 percent of the plant kingdom.

Traditionally, botanists classified anthophytes as monocots or dicots. The names refer to the number of seed leaves, called cotyledons: a monocot has one seed leaf, and a dicot has two seed leaves. However, botanists now classify dicots as eudicots, based on the structure of their pollen.

Life spans A few weeks or years describe the life spans of anthophytes. An **annual** plant completes its life span–sprouts from a seed, grows, produces new seeds, and dies–in one growing season or less. This group includes many garden plants and most weeds.

MiniLab 2

Investigate Conifer Leaves

MiniLab

What similarities and differences exist among conifer leaves? Some conifer trees are among the tallest and oldest organisms on Earth. Most conifers have needlelike leaves that differ in a variety of ways. Leaf characteristics are important in conifer identification.

Procedure

1. Read and complete the lab safety form.
2. Obtain one of each of the **conifer samples** your teacher has identified. Label each sample by name.
3. Design a data table to record your observations.
4. Compare and contrast the leaves. Make a list of characteristics that you determine are important for describing each sample. Record these characteristics for each conifer sample.
5. Develop a system for grouping the conifer samples. Be prepared to justify your system.
6. Wash your hands thoroughly after handling plant samples.

Analysis

1. **Explain** the reasoning for your classification system.
2. **Compare** your classification system to those created by other students. Explain why your system is an efficient way to classify the conifer samples that you studied.

First-year growth

Second-year growth

Figure 22 An evening primrose (a biennial) produces leaves, an underground stem, and roots the first growing season. It flowers in the second year of growth.

A **biennial** plant's life spans two years. During the first year, it produces leaves and a strong root system. Refer to **Figure 22.** Some biennials, such as carrots, beets, and turnips, develop fleshy storage roots that are harvested after the first growing season. If the biennial is not harvested, the aboveground tissues die. However, roots and other underground parts remain alive for biennials that are adapted to their environments. In the second year, stems, leaves, flowers, and seeds grow. The plant's life ends the second year.

Perennial plants can live for several years and usually produce flowers and seeds yearly. Some perennials respond to harsh conditions by dropping leaves, while others completely die back so that only their roots remain alive. They resume growth when favorable growing conditions return. Fruit and shade trees, shrubs, irises, peonies, roses, and many types of berries are perennial plants.

The life spans of all plants are determined genetically and reflect adaptations for surviving harsh conditions. However, all plant life spans are affected by environmental conditions.

What's Biology Got to Do With It?

Section 4 Assessment

Section Summary

- Vascular seed plants produce seeds containing the sporophyte generation.
- Vascular seed plants exhibit numerous adaptations for living in varied environments.
- There are five divisions of vascular seed plants. Each division has distinct characteristics.
- Flowering plants are annuals, biennials, or perennials.

Understand Main Ideas

1. MAIN Idea **Describe** the advantages of a plant that produces seeds.
2. **Compare and contrast** a gymnosperm and an angiosperm.
3. **Distinguish** between male and female cones of gymnosperms.
4. **Identify** the divisions of gymnosperms.
5. **Differentiate** between a monocot and a eudicot.
6. **Compare and contrast** the three types of anthophyte life spans.

Think Critically

7. **Consider** A Christmas tree farmer saw an advertisement that read, "Bald cypresses—the way to quick profits. Plant these fast-growing trees and harvest them in just five years." Would these trees be profitable for the farmer? Explain.

MATH in Biology

8. The smallest flowering plant is 1 mm tall and the largest conifer can be 90 m tall. How many times taller is the largest conifer than the smallest flowering plant?

Online Quiz

In the Field

Career: Forensic Palynology

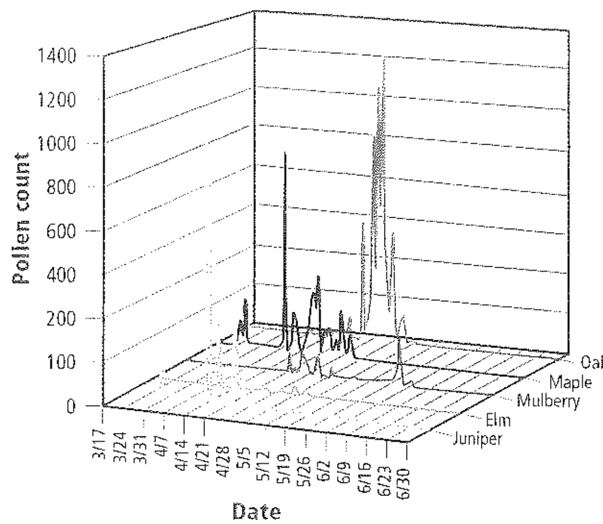
The Proof Is in the Pollen

Forensic palynology (pah luh NAW luh gee), a relatively new science, uses pollen and spore evidence in legal cases to help police solve crimes. A jogger was attacked, dragged to a nearby wooded area, and murdered. The police questioned a key suspect who admitted that he was in the area, but he claimed that he did not see the jogger. He also said that he never had been in the wooded area where the body was found. Was he telling the truth?

Incriminating evidence Soil from the crime scene contained large amounts of pine pollen and fern spores. A survey revealed that no other nearby locations contained both pine trees and ferns. When police searched the suspect's apartment, they found a sweater and pants that they believed he was wearing during the attack. When a forensic palynologist examined the clothes, she found the same pine pollen and fern spores that were at the crime scene. The suspect eventually was tried and convicted of the murder.

Palynologists at a crime scene Detectives collect many types of evidence from a crime scene, including fingerprints. Can palynologists collect fingerprints? In a way, yes. Each seed-plant species produces unique pollen grains. They can be thought of as a species' "fingerprint" and can be used for identification. Also, dirt and dust often contain large amounts of pollen and spores. Fibers in woven fabrics can act as filters and trap pollen and spores. Blown by the wind, pollen can become trapped between strands of hair.

Pollen Count at Crime Scene



This graph shows the pollen count at a crime scene. It indicates which pollen types were most abundant at a given date.

Forensic palynology A pollen study can help investigators narrow the list of suspects, making this a valuable investigative tool. Because it requires extensive background knowledge and training in collecting and preserving samples without contamination, forensic palynology is a specialized science.

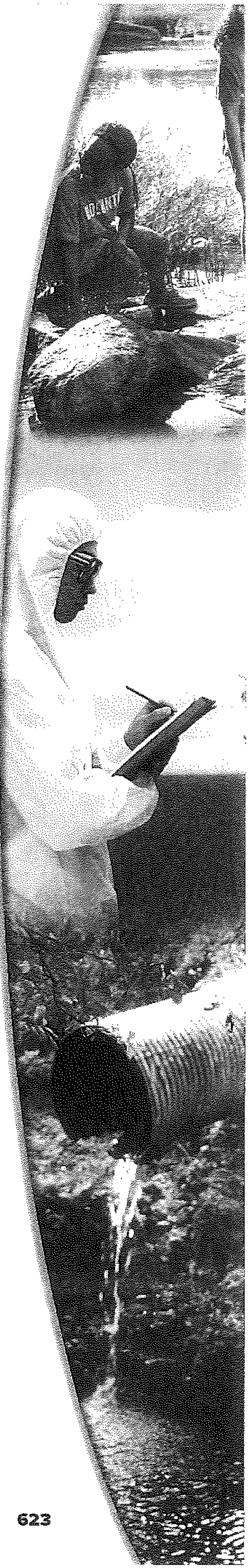
MATH in Biology

Interpret the Graph Examine the graph of tree-pollen counts. What types of pollen might you expect to find if the crime occurred on April 14, May 12, or June 2? Conduct research to find out more about the types of pollen found in your community.

WebQuest

BIOLAB

FIELD INVESTIGATION: HOW CAN YOU IDENTIFY AND CLASSIFY TREES?



Background: Botanists and others interested in plants often use field guides and dichotomous keys to identify plants. In this BioLab, you will use a field guide to identify trees in a given area. Then, you will create your own dichotomous key to identify the trees in your area.

Question: *What characteristics can be used to identify trees and to create a dichotomous key for them?*

Materials

field guide of trees (for your area)
metric ruler
magnifying lens

Safety Precautions

WARNING: ***Stay within the area of study and be alert for plants, insects, or other organisms that might pose a hazard.***

Procedure

1. Read and complete the lab safety form.
2. Study the field guide provided by your teacher to determine how it is organized.
3. Based on your examination of the field guide and what you learned about plant characteristics in this chapter, make a list of characteristics that will help you identify the trees in your area.
4. Create a data table based on the list you made in Step 3.
5. Use a field guide to identify a tree in the area designated by your teacher. Confirm your identification with your teacher.
6. Record in your data table the characteristics of your identified tree.
7. Repeat Steps 5 and 6 until you have identified all trees required for this lab.
8. Review your data table. Choose the characteristics most helpful in identifying trees. These characteristics will form the basis of your dichotomous key.
9. Determine in what rank the characteristics should appear in the dichotomous key. Create a written description for each characteristic.
10. Create your dichotomous key. The traits described at each step of a dichotomous key usually are pairs of contrasting characteristics. For example, the first step might compare needlelike or scalelike leaves to broad leaves.

Analyze and Conclude

1. **Interpret Data** Based on the data you collected, describe plant diversity in the area you studied.
2. **Critique** Exchange your dichotomous key with a classmate's dichotomous key. Use the key to identify trees in the study area. Give your classmate suggestions to improve his or her key.
3. **Predict** How effective would your dichotomous key be for someone trying to identify trees in the study area? Explain.
4. **Error Analysis** What changes could you make to improve the effectiveness of your dichotomous key?

SHARE YOUR DATA

Compare and Contrast Share your data with the rest of the class and compare it to the data your classmates collected. What plants are common to all of the posted dichotomous keys?

Chapter 21 Study Guide

THEME FOCUS Structure and Function The 300,000 types of plants found all over Earth have different types of tissues and reproductive methods that allow them to fill different niches.

BIG Idea Plants have changed over time and are now a diverse group of organisms.

Section 1 Plant Evolution and Adaptations

stomata (p. 606)
vascular tissue (p. 606)
vascular plant (p. 606)
nonvascular plant (p. 606)
seed (p. 607)

MAIN Idea Adaptations to environmental changes on Earth contributed to the evolution of plants.

- Plants are multicellular organisms, and most are photosynthetic.
- Evidence indicates that ancient, unicellular, freshwater green algae were the ancestors of present-day plants.
- Present-day plants and green algae have many common characteristics.
- Over time, plants developed several adaptations for living on land.
- Plants alternate between a sporophyte and a gametophyte generation.

Section 2 Nonvascular Plants

thallose (p. 612)

MAIN Idea Nonvascular plants are small and usually grow in damp environments.

- Distribution of nonvascular plants is limited by the plants' ability to transport water and other substances.
- Mosses are small plants that can grow in different environments.
- Like other nonvascular plants, hornworts rely on osmosis and diffusion to transport substances.
- The two types of liverworts are classified as thallose and leafy.

Section 3 Seedless Vascular Plants

strobilus (p. 613)
epiphyte (p. 614)
rhizome (p. 615)
sporangium (p. 616)
sorus (p. 616)

MAIN Idea Because they have vascular tissues, seedless vascular plants generally are larger and better adapted to drier environments than nonvascular plants.

- Seedless vascular plants have specialized transport tissues and reproduce by spores.
- The sporophyte is the dominant generation in vascular plants.
- Lycophytes and pterophytes are seedless vascular plants.

Section 4 Vascular Seed Plants

cotyledon (p. 617)
cone (p. 618)
annual (p. 620)
biennial (p. 621)
perennial (p. 621)

MAIN Idea Vascular seed plants are the most widely distributed plants on Earth.

- Vascular seed plants produce seeds containing the sporophyte generation.
- Vascular seed plants exhibit numerous adaptations for living in varied environments.
- There are five divisions of vascular seed plants. Each division has distinct characteristics.
- Flowering plants are annuals, biennials, or perennials.

Vocabulary eGames

Chapter 21 Assessment

Section 1

Vocabulary Review

For questions 1–3, match each phrase with a vocabulary term from the Study Guide page.

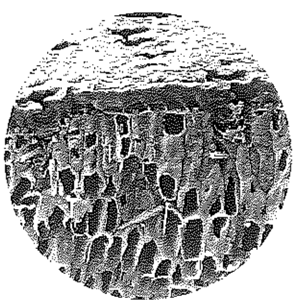
1. plant structure that contains the embryo
2. transport tissue
3. enable exchange of gases

Understand Main Ideas

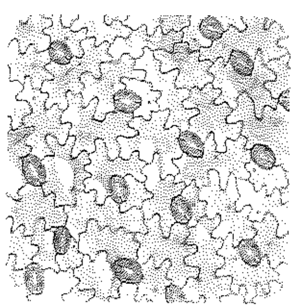
4. Approximately when did primitive land plants appear?
   A. 30 mya
   B. 400 mya
   C. 500 mya
   D. 2000 mya

5. Which is not a trait shared by freshwater green algae and plants?
   A. cellulose cell walls
   B. chlorophyll
   C. food stored as starch
   D. contain vascular tissue

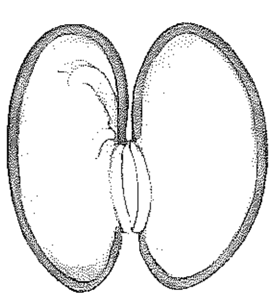
6. Which is likely to ensure the survival of the embryo?



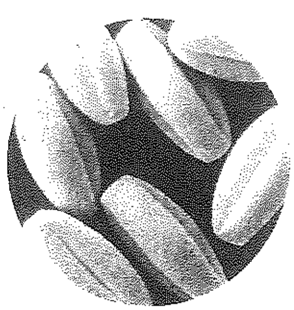
A.



C.



B.



D.

7. Which was a major obstacle for plants to live on land?
   A. obtaining enough light
   B. obtaining enough soil
   C. obtaining enough water
   D. obtaining enough oxygen

Constructed Response

8. **Short Answer** Describe the adaptations that you would expect to find in an aquatic plant.
9. Idea Of the adaptations discussed in Section 1, which one do you predict would be most important to a plant living in the desert?

Think Critically

10. **THEME FOCUS Structure and Function** Organize the adaptations to life on land from the most important to the least important. Defend your decisions.

Section 2

Vocabulary Review

Write a sentence using the following vocabulary term correctly.

11. thallose

Understand Main Ideas

Use the photo below to answer question 12.

12. Which word does not describe the plant shown above?
   A. multicellular
   B. nonvascular
   C. seedless
   D. thallose

Online Test Practice

13. Which is a characteristic of mosses?
   A. vascular tissue C. seeds
   B. flowers D. rhizoids

Constructed Response

14. **Short Answer** Refer to **Figure 9** and analyze the need for a nonvascular sporophyte to remain dependent on the gametophyte generation.

15. MAIN Idea Describe a habitat in your community that would support nonvascular plants.

Think Critically

16. **Research** nonvascular plants online and make a list of those that grow in your state.

Section 3

Vocabulary Review

For questions 17–19, match each definition with a vocabulary term from the Study Guide page.

17. spore-bearing structures that form a compact cluster

18. thick, underground stem

19. plant that lives anchored to another plant or object

Understand Main Ideas

Use the concept map below to answer question 20.

seedless plants — ? — mosses, liverworts, and hornworts

20. Which term correctly completes the concept map shown above?
   A. nonvascular C. vascular
   B. flowering D. seed-producing

21. What structure contains clusters of sporangia?
   A. sorus C. stem
   B. frond D. blade

22. Which is not part of the fern sporophyte generation?
   A. rhizome C. frond
   B. sorus D. rhizoid

23. Which photo shows sori?

A.

C.

B.

D.

Constructed Response

24. **Short Answer** Summarize the characteristics of ferns.

25. MAIN Idea Differentiate between division Pterophyta and division Lycophyta.

Think Critically

26. **Infer** the advantage of fern sori being on the undersurfaces of fronds rather than on the upper surfaces.

Section 4

Vocabulary Review

For questions 27–29, replace each underlined word with the correct vocabulary term from the Study Guide page.

27. A root of a seed provide nutrients when it sprouts.

28. A plant that lives for several growing seasons is a rhizome.

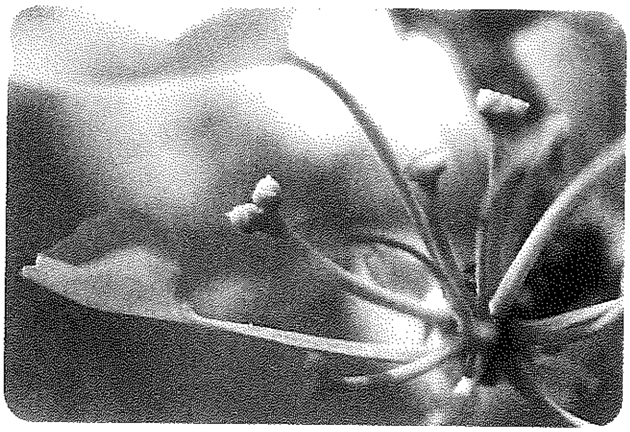
29. A flower contains the male or female reproduction structures of gymnosperms.

Online Test Practice

Understand Main Ideas

30. Which plant division has plants with needlelike or scaly leaves?
 A. Gnetophyta C. Coniferophyta
 B. Anthophyta D. Cycadophyta

Use the photo below to answer question 31.



31. Which plant division has plants that produce female reproductive structures like those shown above?
 A. Coniferophyta C. Gnetophyta
 B. Anthophyta D. Ginkgophyta
32. Which describes the importance of seed dispersal?
 A. ensures more favorable environments for growth
 B. creates greater biodiversity
 C. limits competition with parent plants and other offspring
 D. provides greater resources

Constructed Response

33. **Open Ended** What might be the adaptive advantage of having a gametophyte dependent on a sporophyte?
34. **Open Ended** Make a list of the traits that you would use to differentiate between coniferophytes and anthophytes.

Think Critically

35. **Compare and contrast** cones and strobili.
36. BIG Idea Infer why there are more conifers than flowering plants in colder environments such as those in northern Canada and Alaska.

Online Test Practice

Summative Assessment

37. BIG Idea Pick three adaptations described in this chapter and explain why plants needed them to populate land successfully. Then identify one plant division that has each adaptation.
38. WRITING in Biology Imagine that you are one of the first plants that survived living on land. What stories could you tell your grand children about the difficulties you faced?
39. Explain the meaning of alternation of generations as it applies to plants.
40. Distinguish between vascular and nonvascular plants.

DBQ Document-Based Questions

Data obtained from: Qiu, Yin-Long, et al. 1998. The gain of three mitochondrial introns identifies liverworts as the earliest land plants. *Nature* 394: 671.

Here we survey 352 diverse land plants and find that three mitochondrial Group II introns are present . . . in mosses, hornworts and all major lineages of vascular plants, but are entirely absent from liverworts, green algae and all other eukaryotes. These results indicate that liverworts are the earliest land plants, with the three introns having been acquired in a common ancestor of all other land plants, and have important implications concerning early plant evolution.

41. Evaluate the research above by making a cladogram.
42. Explain how this research led scientists to suggest that liverworts are the ancestors of all other plants.
43. Apply what you know about polymerase chain reactions to predict how the scientists determined which plants contained these introns.
44. Imagine that a fellow classmate is having trouble understanding the document above. Summarize the main points of the document in your own words, making an effort to clarify any concepts that may be confusing.

Standardized Test Practice

Cumulative

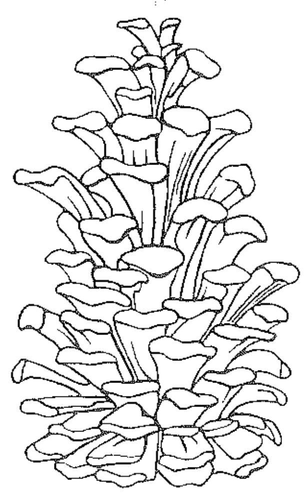
Multiple Choice

1. Which substance do yeasts produce that causes bread to rise?
   A. carbon dioxide
   B. ethanol
   C. oxygen
   D. simple sugars

2. Which must a virus have to attack a host cell?
   A. a DNA or RNA sequence that is recognized by the ribosomes of the host cell
   B. the enzymes to burst the host cell so that the host cell can be used as raw materials
   C. a particular shape that matches the proteins on the surface of the host cell
   D. the proper enzyme to puncture the membrane of the host cell

3. Which group of protists is characterized by parasitic behavior?
   A. chrysophytes
   B. dinoflagellates
   C. sarcodines
   D. sporozoans

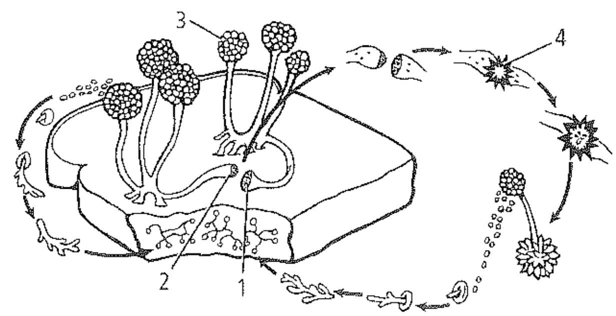
Use the following illustration to answer question 4.



4. In which division of seed plants would you expect to find the structure in the above illustration?
   A. Anthophyta
   B. Coniferophyta
   C. Cycadophyta
   D. Ginkgophyta

5. Suppose a cell from the frond of a fern contains 24 chromosomes. How many chromosomes would you expect to find in the spores?
   A. 6
   B. 12
   C. 24
   D. 48

Use the diagram below to answer questions 6 and 7.



6. Which phylum of fungi has these kinds of reproductive structures?
   A. Ascomycota
   B. Basidiomycota
   C. Deuteromycota
   D. Zygomycota

7. Which of these structures is involved in asexual reproduction?
   A. 1
   B. 2
   C. 3
   D. 4

8. Why is conjugation important for protists?
   A. It expands the habitat.
   B. It improves locomotion speed.
   C. It increases genetic variation.
   D. It restores injured parts.

Short Answer

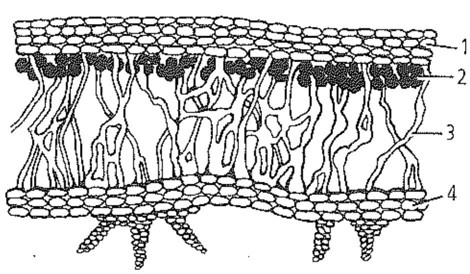
9. Compare the sporophyte generation in nonvascular plants to the sporophyte generation in seedless vascular plants.

10. Describe the cell membrane and ectoplasm of an amoeba and suggest why it is beneficial for the amoeba to have both structures.

11. What is the relationship between bat wings and monkey arms? Explain the importance of this relationship for the classification of organisms.

12. Describe how a multicellular fungus obtains nutrients from its environment and assess how that affects its role in the environment.

Use the diagram of the lichen below to answer questions 13 and 14.



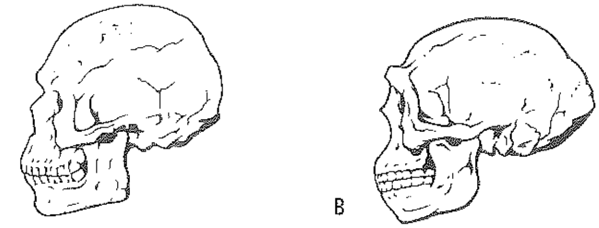
13. Identify and evaluate the importance of the layer of the lichen where photosynthesis takes place.

14. Analyze how the photosynthesizer and fungus benefit from being part of a lichen.

15. Evaluate how spore production gives fungi an advantage in an ecosystem.

Extended Response

Use the diagram below to answer question 16.



16. Look at the two skulls in the diagram. Infer which one you think is more closely related to *Homo sapiens*. Explain your inference.

17. Compare and contrast reproduction in paramecia and amoebas.

Essay Question

During the 1840s, the potato was an extremely popular crop plant in Ireland. Many people in rural Ireland were completely dependent on potatoes for food. From 1845 to 1847, the potato blight–a funguslike disease–wiped out potato crops. The blight produces spores on the leaves of the potato plant. The spores can be transmitted by water or wind. They are carried into the soil by water, where they infect the potato tubers, and they can survive through winter on the potatoes left buried in the fields. Close to one million people died from starvation and nearly as many left Ireland for America and other countries.

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

18. Write an essay that indicates why potato blight spread so quickly through Ireland and how the spread of the fungus might have been slowed by different farming practices.

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
Review Section . . .	20.1	18.2	19.1	21.4	21.3	20.2	20.3	19.2	21.3	19.2	15.2	20.1	20.3	20.3	20.2	16.3	19.2	20.1