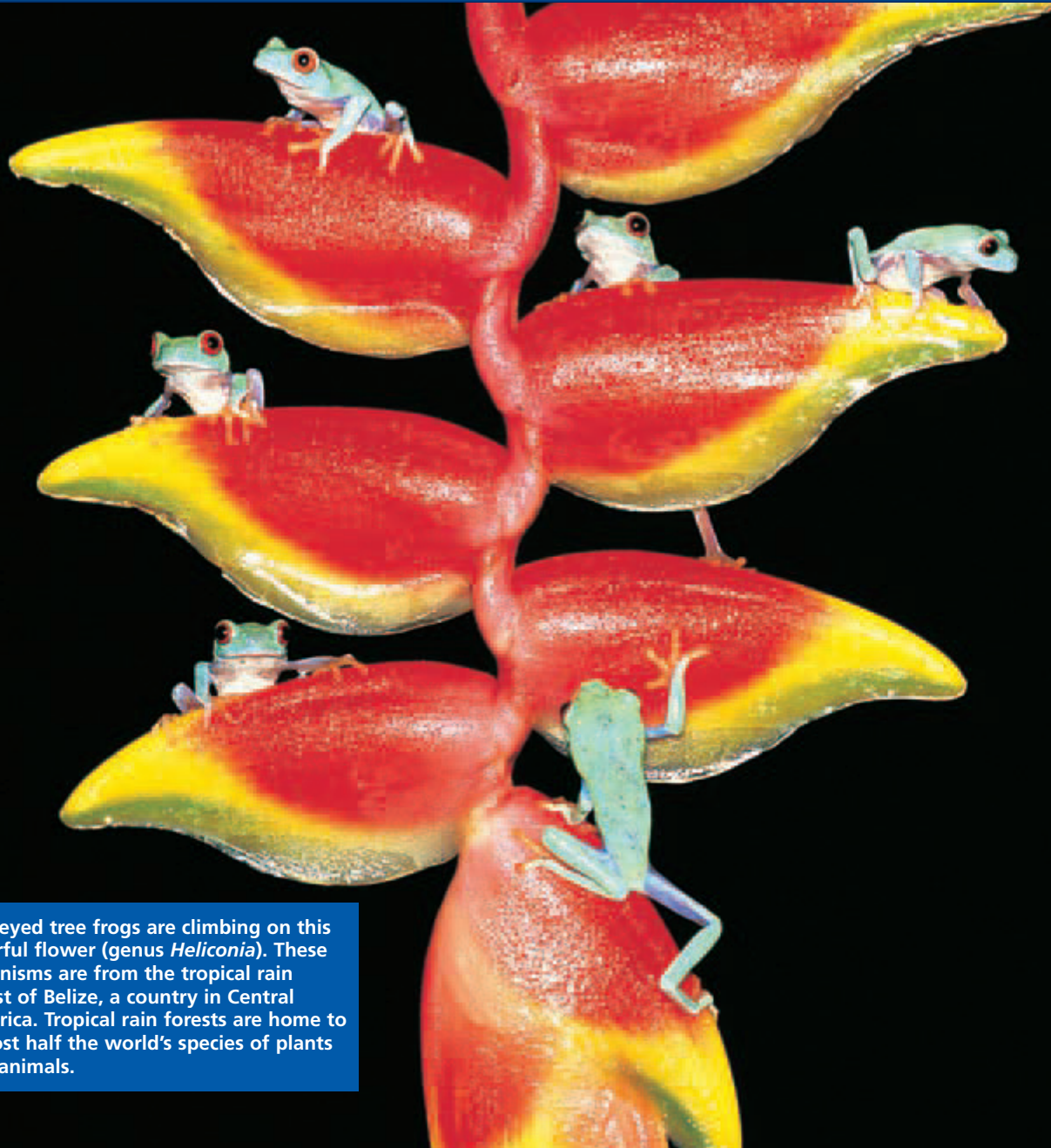


PLANT EVOLUTION AND CLASSIFICATION



Red-eyed tree frogs are climbing on this colorful flower (genus *Heliconia*). These organisms are from the tropical rain forest of Belize, a country in Central America. Tropical rain forests are home to almost half the world's species of plants and animals.

SECTION 1 *Overview of Plants*

SECTION 2 *Nonvascular Plants*

SECTION 3 *Vascular Plants*

OVERVIEW OF PLANTS

Plants dominate the land and many bodies of water. Plants exhibit tremendous diversity. Some plants are less than 1 mm (0.04 in.) in width, and some plants grow to more than 100 m (328 ft) in height. The 12 phyla, or divisions, of kingdom Plantae include more than 270,000 species. Some plants complete their life cycle in a few weeks, but others may live nearly 5,000 years.

ADAPTING TO LAND

Although life had flourished in the oceans for more than 3 billion years, no organisms lived on land until about 475 million years ago, when a layer of ozone formed. The ozone protected organisms from the sun's ultraviolet radiation. Eventually, small club-shaped plants began to grow in the mud at the water's edge. Three adaptations allowed plants to thrive on land: the ability to prevent water loss, the ability to reproduce in the absence of water, and the ability to absorb and transport nutrients.

Preventing Water Loss

The move to land offered plants distinct advantages, including more exposure to sunlight for photosynthesis, increased carbon dioxide levels, and a greater supply of inorganic nutrients. However, the land environment also presented challenges. Plants on land are susceptible to drying out through evaporation.

The **cuticle** (KYOOT-i-kuhl), a waxy protective covering on plant surfaces that prevents water loss, was one early adaptation to life on land. Although it protects a plant by keeping water in the plant, the cuticle also keeps out carbon dioxide. Plants that had small openings in their surfaces, called *stomata*, were able to survive. Stomata allow the exchange of carbon dioxide and oxygen.

Reproducing by Spores and Seeds

Successful land plants also developed structures that helped protect reproductive cells from drying out. A **spore** is a haploid reproductive cell surrounded by a hard outer wall. Spores allowed the widespread dispersal of plant species. Eventually, most plants developed seeds. A **seed** is an embryo surrounded by a protective coat. Some seeds also contain *endosperm*, a tissue that provides nourishment for the developing plant. Figure 28-1 shows the unusual adaptation of the sugar maple tree for seed dispersal. Seeds are more effective at dispersal than spores are.

OBJECTIVES

- **Name** three adaptations plants have made to life on land.
- **Summarize** the classification of plants.
- **Describe** alternation of generations.

VOCABULARY

cuticle
spore
seed
vascular tissue
xylem
phloem
nonvascular plant
vascular plant
seed plant
gymnosperm
angiosperm
sporophyte
gametophyte
alternation of generations



FIGURE 28-1

The seeds of a sugar maple tree are found inside a winged fruit. Wind can carry the winged fruit away from the tree, thus helping the seeds to disperse away from the parent plant.

Word Roots and Origins

vascular

from the Latin *vasculum*, meaning
"small vessel"

Absorbing and Transporting Materials

Aquatic plants take nutrients from the water around them. On land, most plants absorb nutrients from the soil with their roots. Although the first plants had no roots, fossils show that fungi lived on or within the underground parts of many early plants.

Certain species of plants evolved a type of tissue known as **vascular** (VAS-kyuh-luhr) **tissue**, which transports water and dissolved substances from one part of the plant to another. Two types of specialized tissue make up vascular tissue. **Xylem** (ZIE-luhm) carries absorbed water and inorganic nutrients in one direction, from the roots to the stems and leaves. **Phloem** (FLOH-EM) carries organic compounds, such as carbohydrates, and some inorganic nutrients in any direction, depending on the plant's needs. In addition to transporting absorbed materials, vascular tissue also helps support the plant, which is an important function for land plants.

CLASSIFYING PLANTS

Study the classification of plants in Table 28-1. The 12 phyla of plants, formerly referred to as divisions, can be divided into two groups based on the presence of vascular tissue. The three phyla of **nonvascular plants** have neither true vascular tissue nor true roots, stems, or leaves. The nine phyla of **vascular plants** have vascular tissue and true roots, stems, and leaves.

TABLE 28-1 The 12 Phyla of the Plant Kingdom

Type of plant	Phylum	Common name	Approximate number of existing species
Nonvascular	Bryophyta	mosses	10,000
	Hepatophyta	liverworts	8,000
	Anthocerophyta	hornworts	100
Vascular, seedless	Psilophyta	whisk ferns	10–13
	Lycophyta	club mosses	1,000
	Sphenophyta	horsetails	15
	Pteridophyta	ferns	12,000
Vascular, seed Gymnosperms	Cycadophyta	cycads	100
	Ginkgophyta	ginkgoes	1
	Coniferophyta	conifers	550
	Gnetophyta	gnetophytes	70
Angiosperms	Anthophyta	flowering plants	240,000
	class Monocotyledones	monocots	70,000
	class Dicotyledones	dicots	170,000

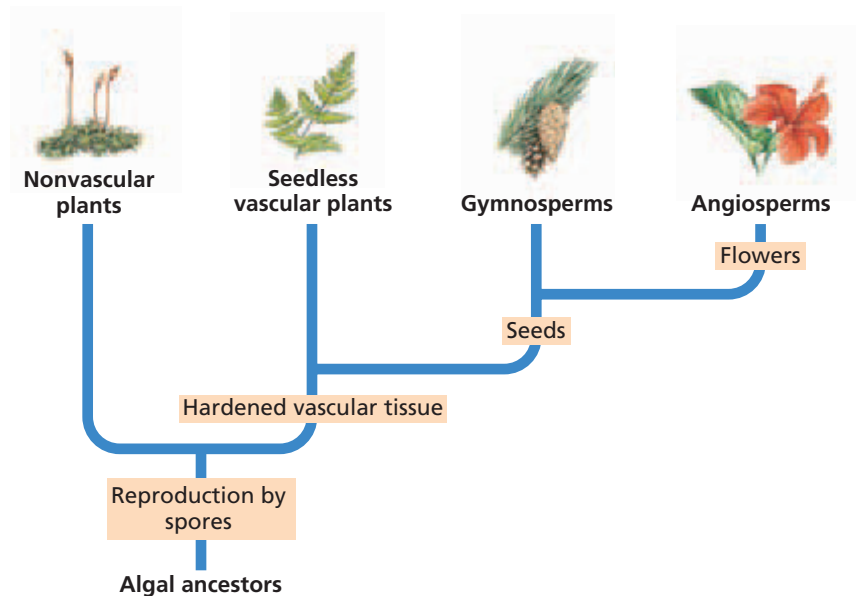


FIGURE 28-2

This phylogenetic diagram represents a hypothesis for the evolutionary relationships between plants and green algae. The earliest plants were nonvascular. These plants evolved into more-complex forms of plants, the vascular plants. For updates on phylogenetic diagrams, visit go.hrw.com. Enter the keyword **HM6 Phylo**.

Notice in Table 28-1 that vascular plants can be further divided into two groups, seedless plants and seed plants. Seedless plants include the phylum of ferns and three phyla made up of plants closely associated with ferns. **Seed plants**—plants that produce seeds for reproduction—include four phyla of gymnosperms (JIM-noh-SPUHRMZ) and one phylum of angiosperms (AN-jee-oh-SPUHRMZ). **Gymnosperms**, which include pine trees, are seed plants that produce seeds that are not enclosed in fruits. **Angiosperms**, also known as flowering plants, are seed plants that produce seeds within a protective fruit. Examples are apple and orange trees.

The Fossil Record of Plants

Figure 28-2 shows the possible origin of major plant groups. Much of what is now known about plant phylogeny comes from the fossil record. The fossil record is incomplete, but scientists hypothesize that plants evolved from algal ancestors. The strongest evidence lies in the similarities between modern green algae and plants. Both have the same photosynthetic pigments—chlorophylls *a* and *b*, both store energy as starch, and both have cell walls made of cellulose.

ALTERNATING LIFE CYCLES

All plants have a life cycle that involves two phases, which are named for the type of reproductive cells they produce. Recall that cells having two sets of chromosomes are referred to as *diploid*, and cells having only one set of chromosomes are referred to as *haploid*. The first phase of a plant's life cycle consists of a diploid ($2n$) **sporophyte** (SPOH-ruh-FIET) plant that produces spores. The second phase consists of a haploid ($1n$) **gametophyte** (guh-MEET-uh-FIET) plant that produces eggs and sperm. A life cycle that alternates between the gametophyte phase and sporophyte phase is called **alternation of generations**.

Eco Connection

Reforestation Efforts

The process of replacing trees that have died or been cut down is called *reforestation*. Natural reforestation occurs when seeds grow into new seedlings. Throughout the world, many governments and private landowners do not replace trees after land has been cleared to produce timber, build roads, and construct buildings.

Such *deforestation* is occurring at a rate of several hundred thousand square miles per year. Although this rate seems overwhelming, people can help reforestation efforts in once naturally forested areas by planting seeds or seedlings. It's best to choose trees that are well adapted to your area. For more information, call your local or state parks department, the U.S. Forest Service, a county extension agent, or a nearby college forestry department.

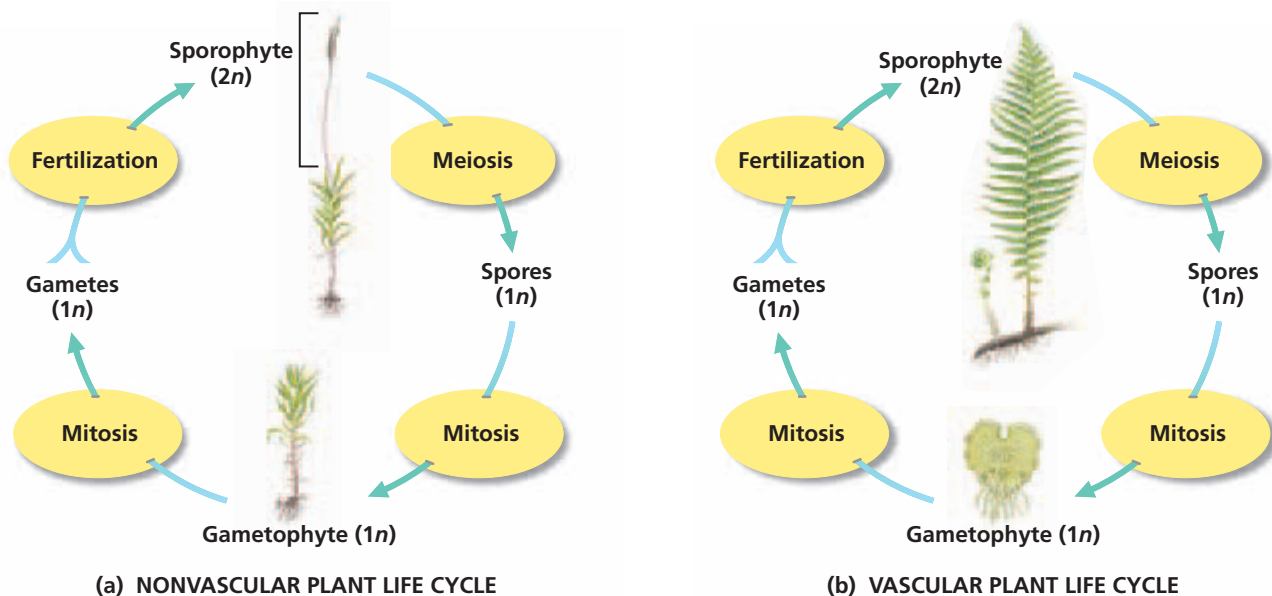


FIGURE 28-3

In the life cycle of a plant, there is an alternation of the haploid gametophyte generation and the diploid sporophyte generation. (a) The life cycle of a nonvascular plant, such as a moss, is characterized by a long, thin sporophyte growing up from the top of the more prominent gametophyte. (b) The life cycle of a vascular plant, such as a fern, is characterized by a large sporophyte and a very small gametophyte.

Figure 28-3 shows the life cycles of a nonvascular plant and a vascular plant. In alternation of generations, the gametophyte ($1n$) undergoes mitosis to form gametes—eggs and sperm. Once an egg is fertilized by a sperm and produces a zygote, the plant begins the diploid phase of its life cycle. The zygote divides by mitosis to form a sporophyte plant. The sporophyte ($2n$) produces cells that undergo meiosis to form haploid spores. These spores are released by most seedless plants but are retained by seed plants. The life cycle begins again when spores divide by mitosis to form new gametophytes.

In nonvascular plants, the gametophyte is the dominant phase. In contrast, the sporophyte is the dominant phase of vascular plants. Oak trees are large sporophytes that dominate some landscapes. In seedless vascular plants, the gametophyte is usually a separate small organism quite different from the sporophyte. In seed plants, the gametophyte is a very small parasite of the sporophyte. For example, gametophytes of flowering plants are microscopic parts of their flowers that are not photosynthetic.

SECTION 1 REVIEW

1. How does the cuticle represent an adaptive advantage for early land plants?
2. Compare the structure of a spore with that of a seed.
3. What is the main difference between the nine phyla of vascular plants and the three phyla of nonvascular plants?
4. Explain how alternation of generations between the gametophyte phase and the sporophyte phase differs in vascular plants and nonvascular plants.

CRITICAL THINKING

5. **Justifying Conclusions** Why are vascular plants more successful than nonvascular plants as land plants?
6. **Inferring Relationships** How have a vascular system and a dominant sporophyte contributed to the success of plants on land?
7. **Organizing Information** For each of the following pairs, identify the most recently evolved characteristic: spore/seed; vascular tissue/no vascular tissue; and cuticle/no cuticle.

NONVASCULAR PLANTS

*The three phyla of nonvascular plants are collectively called **bryophytes**. Botanists have identified about 16,600 species of bryophytes. They lack vascular tissue and do not form true roots, stems, and leaves. These plants usually grow on land near streams and rivers.*

CHARACTERISTICS OF BRYOPHYTES

Bryophytes are the most primitive type of plants. Overall, their characteristics are more like those of plants than of algae. Bryophytes are mostly terrestrial and have an alternation-of-generations life cycle. Bryophytes are seedless, and they produce spores. Because they do not have vascular tissue, they are very small, usually 1–2 cm (0.4–0.8 in.) in height.

Bryophytes need water to reproduce sexually because the sperm must swim through water to an egg. In dry areas, bryophytes can reproduce sexually only when adequate moisture is available. The asexual production of haploid spores does not require water.

PHYLUM BRYOPHYTA

Almost every land environment is home to at least one species of moss in the phylum Bryophyta (brie-AHF-uh-tuh). The thick green carpets of moss on shady forest floors actually consist of thousands of moss gametophytes. Each gametophyte is attached to the soil by rootlike structures called *rhizoids* (RIE-ZOYDZ). Unlike roots, rhizoids do not have vascular tissue. But rhizoids do function like roots by anchoring the moss and by absorbing water and inorganic nutrients.

Moss gametophytes are usually less than 3 cm (1.2 in.) tall. The moss sporophyte grows up from the top of the gametophyte, as shown in Figure 28-4. Gametophytes may be male, may be female, or may contain both male and female reproductive parts.

Mosses are called *pioneer plants* because they are often the first species to inhabit a barren area. Mosses gradually accumulate inorganic and organic matter on rock surfaces, creating a layer of soil in which other plants can grow. In areas devastated by fire, volcanic action, or human activity, pioneering mosses can help trigger the development of new biological communities. They also help prevent soil erosion by covering the soil surface and absorbing water.

OBJECTIVES

- **Identify** the characteristics of bryophytes.
- **Describe** plants in the phylum Bryophyta.
- **Describe** plants in the phylum Hepatophyta.
- **Describe** plants in the phylum Anthoceroophyta.

VOCABULARY

bryophyte
liverwort
hornwort



FIGURE 28-4

Moss sporophytes (thin, brown stalks) depend on the gametophytes (green, “mossy” parts) to which they are attached, because sporophytes do not undergo photosynthesis.

FIGURE 28-5

A peat farmer cuts blocks of peat, produced from moss of the genus *Sphagnum*, to heat his farmhouse in County Clare, Ireland.



Peat moss (of the genus *Sphagnum*) is a major component of bogs in northern parts of the world. Peat moss produces an acid that slows down decomposition in the swamplike bogs. Compression and chemical breakdown in peat bogs produces *peat*, which consists of partially decomposed plant matter. In many northern European and Asian countries, peat is mined and dried for use as fuel, as shown in Figure 28-5. Dried peat moss is widely used to enhance the water-retaining ability of potting and gardening soils. Dried peat moss is also used by florists to pack bulbs and flowers for shipping.

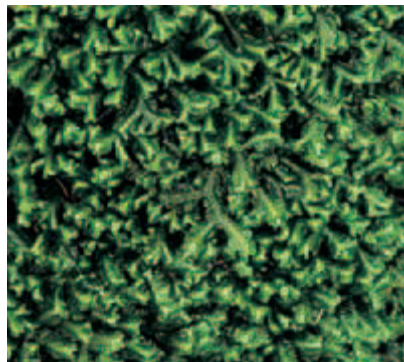
Word Roots and Origins

liverwort

from the familiar *liver* (body organ) and the Old English *wort*, meaning “herb”

PHYLUM HEPATOPHYTA

Phylum Hepatophyta (HEP-uh-TAHF-uh-tuh) includes the **liverworts**, unusual-looking plants that grow in moist, shady areas. Most liverworts have thin, transparent leaflike structures arranged along a stemlike axis, as shown on the left side of Figure 28-6. Some liverworts have a *thalloid* (THAL-oyd) form—that is, a flat body with distinguishable upper and lower surfaces, as shown on the right side of Figure 28-6. All liverworts lie close to the ground. This adaptation allows them to absorb water readily. In some species, the gametophyte is topped by an umbrella-shaped structure that holds the reproductive cells.



(a)



(b)

FIGURE 28-6

A leafy liverwort (a) has two rows of leaflike structures growing on a stem. A thalloid liverwort (b) has very flat, thin lobes.



FIGURE 28-7

Hornworts grow in warm, moist habitats, such as along roads or near streams.

PHYLUM ANTHOCEROPHYTA

Phylum Anthocerophyta (AN-thoh-suh-RAHF-uh-tuh) includes the **hornworts**, which also grow in moist, shaded areas. The name “hornwort” refers to the long, thin, hornlike sporophytes that grow out from the top of the plant, as shown in Figure 28-7. When the sporophytes are not present, hornworts look very similar to thalloid liverworts. Hornworts do not have a stem or leaves; the gametophyte of a hornwort is anchored to the ground by rhizoids. Hornworts share an unusual characteristic with algae: Each cell usually has a single large chloroplast rather than numerous small chloroplasts.

The sporophytes of hornworts are different from the sporophytes of mosses and liverworts in that they are green and carry out photosynthesis. The sporophytes continue to grow throughout the plant’s life. They also are covered with a cuticle and have stomata. Tubelike cells at the center of the sporophytes resemble cells of vascular tissue and may transport materials in these plants. These characteristics indicate that the hornworts are closely related to vascular plants.

SECTION 2 REVIEW

1. List two characteristics shared by all nonvascular plants.
2. Describe the role that mosses play in the early development of biological communities.
3. Explain why liverworts lie close to the ground.
4. Describe how the sporophytes of hornworts differ from the sporophytes of mosses or liverworts.

CRITICAL THINKING

5. **Making Comparisons** What advantage do gametophytes that are either male or female have over gametophytes with both male and female structures?
6. **Evaluating Information** Why can’t mosses grow as large as maple or oak trees?
7. **Applying Information** How is a moss’s ability to absorb water advantageous?

SECTION 3

OBJECTIVES

- **Describe** the adaptive advantages that vascular plants have over nonvascular plants.
- **Summarize** the characteristics of the four phyla of seedless vascular plants.
- **State** the major differences between gymnosperms and angiosperms.
- **Determine** why angiosperms have been so successful.
- **Compare** monocots and dicots.

VOCABULARY

strobilus
rhizome
fiddlehead
frond
germinate
seedling
cone
deciduous
ovary
cotyledon
monocot
dicot
vein
parallel venation
net venation

VASCULAR PLANTS

Vascular plants contain specialized conducting tissues (xylem and phloem) that transport water and dissolved substances from one part of the plant to another. Vascular plants can grow larger and live in more environments than nonvascular plants. The strong stems of vascular plants allow the plants to grow tall, enabling them to rise above other plants and receive more sunlight than shorter plants do.

SEEDLESS VASCULAR PLANTS

Seedless vascular plants dominated the Earth until about 200 million years ago. Characteristics of the four phyla of seedless vascular plants are summarized in Table 28-2. The first three phyla are called *fern allies*, while members of the last phylum are *ferns*. Spores are the mobile sexual reproductive parts of all seedless plants.

Phylum Psilophyta

The phylum Psilophyta (sie-LAHF-uh-tuh) is represented by whisk ferns, illustrated in Figure 28-8. Despite their name, whisk ferns are not ferns at all. They have no roots or leaves and produce spores on the ends of short branches. These features suggest that whisk ferns resemble early land plants. Some species of the phylum Psilophyta are *epiphytes*, which means they grow on other plants. But they are not parasites because they do not harm their host plant.



FIGURE 28-8

The whisk fern produces spores at the ends of branched stem tips. These plants are found in tropical and subtropical regions.

TABLE 28-2 Seedless Vascular Plants

Example plant	Phylum	Features	Size	Location
Whisk ferns	Psilophyta	<ul style="list-style-type: none"> produce reproductive structures on the ends of forked branches no roots or leaves 	<ul style="list-style-type: none"> about 30 cm (1 ft) tall 	<ul style="list-style-type: none"> tropical and temperate regions, as far north as South Carolina
Club mosses	Lycophyta	<ul style="list-style-type: none"> evergreens that produce spores in cones have roots 	<ul style="list-style-type: none"> about 5 cm (2 in.) tall 	<ul style="list-style-type: none"> tropical and temperate regions, on forest floors, in swamps, or as epiphytes
Horsetails	Sphenophyta	<ul style="list-style-type: none"> jointed stems outer cells of stems contain silica, the major component of sand 	<ul style="list-style-type: none"> about 60–90 cm (2–3 ft) tall 	<ul style="list-style-type: none"> tropical and temperate regions, usually in moist soil
Ferns	Pteridophyta	<ul style="list-style-type: none"> leaves most have an underground stem most produce spores on the underside of their leaves 	<ul style="list-style-type: none"> range from less than 1 cm (0.4 in.) to 25 m (82 ft) tall 	<ul style="list-style-type: none"> all climates, on forest floors, as epiphytes, some in full sun, some aquatic

Phylum Lycophyta

The phylum Lycophyta (lie-KAHF-uh-tuh) contains the club mosses, an example of which is shown in Figure 28-9. Because they look like miniature pine trees, club mosses are also called ground pines. They produce a **strobilus** (stroh-BIE-luhs), or cone, which is a cluster of sporangia-bearing modified leaves. Club mosses were once widely collected as Christmas decorations.

Another member of phylum Lycophyta is a spike moss called *Selaginella lepidophylla*, native to the American Southwest. *Selaginella* turns brown and curls up in a ball during drought. However, when moistened, the plant uncurls and turns green again after a few hours.

SCILINKS

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Topic: Vascular Plants
Keyword: HM61595



FIGURE 28-9

The club mosses, sometimes known as ground pines, are members of the phylum Lycophyta. The tips of the aerial stems contain conelike structures.



FIGURE 28-10

This horsetail, of the genus *Equisetum*, has hollow, jointed stems that contain silica. About 300 million years ago, some species of the genus *Equisetum* were large trees, growing with large club moss trees and ferns in steaming swamps. Over millions of years, the trees and other plants died, became buried, and turned into coal.



FIGURE 28-11

Tree ferns, such as the *Dicksonia antarctica* shown here, look like palm trees but are actually the largest living ferns. Sometimes, epiphytic ferns grow on the trunk of tree ferns.

Phylum Sphenophyta

The phylum Sphenophyta (sfee-NAHF-uh-tuh) includes horsetails of the genus *Equisetum*. Horsetails have jointed photosynthetic stems that contain silica, with scalelike leaves at each joint. The vertical stems of horsetails, which grow from a rhizome, are hollow and have joints. Spores form in cones located at the tips of stems.

American pioneers used horsetails to scrub pots and pans; hence, they are frequently called *scouring rushes*. As you can see in Figure 28-10, the shoots are often highly branched and remind some people of a horsetail.

Phylum Pteridophyta

Ferns probably originated over 350 million years ago. Ferns belong to the phylum Pteridophyta (tuhr-uh-DAHf-uh-tuh) and represent a diverse group. Some are floating plants that are less than 1 cm (0.4 in.) across. Ferns also grow above the Arctic Circle and in desert regions. The largest living ferns are tree ferns, shown in Figure 28-11. These ferns can reach 25 m (82 ft) in height, and some have leaves 5 m (16 ft) long. Tree ferns live in tropical and subtropical areas.

Most ferns have an underground stem called a **rhizome** (RIE-ZOHM). The fibrous rhizomes of a few species of ferns are used as a growing medium for orchids. The tightly coiled new leaves of ferns are called **fiddleheads**. The young fiddleheads of some species are eaten by humans as a vegetable. Fiddleheads uncoil and develop into mature leaves called **fronds**.

VASCULAR SEED PLANTS

The mobile sexual reproductive part of seed plants is the multicellular seed. Seeds are an evolutionary success story. Plants with seeds have a greater chance of reproductive success than seedless plants. Inside the tough, protective outer coat of a seed is an embryo and a nutrient supply. When conditions are too hot or too cold, or too wet or too dry, the seed remains inactive. When conditions favor growth, the seed sprouts, or **germinates**—that is, the embryo begins to grow into a young plant, called a **seedling**.

There are two main groups of seed-bearing vascular plants, gymnosperms and angiosperms. The four phyla of gymnosperms produce naked seeds, which means the seeds are not enclosed and protected in fruits. Most gymnosperms are evergreen and bear their seeds in cones. A **cone** is a reproductive structure composed of hard scales. The seeds lie open on the surface of the scales. The one phylum of angiosperms produces seeds that are enclosed and protected in fruits. Angiosperms are commonly referred to as flowering plants. Cones serve some of the same functions for gymnosperms that flowers serve for angiosperms.



Phylum Cycadophyta

Cycads (SIE-KADZ), such as the one shown in Figure 28-12, are gymnosperms of the phylum Cycadophyta (sie-kad-AHF-uh-tuh). Although cycads flourished during the age of the dinosaurs, only about 100 species survive today. Most are native to the Tropics and grow slowly. Some cycads live for almost a thousand years. Many are endangered because of habitat loss, overcollection, and their slow growth. Most cycads have fernlike, leathery leaves at the top of a short, thick trunk. Cycad plants are either male or female, and they bear large cones. Cycads are mostly used as ornamental plants.

Phylum Ginkgophyta

Like cycads, ginkgoes (GING-kohz) flourished during the time of the dinosaurs. The only species existing today is *Ginkgo biloba*, which is native to China. It is called a living fossil because it closely resembles fossil ginkgoes that are 125 million years old. The ginkgo tree has fan-shaped leaves that fall from the tree at the end of each growing season—an unusual characteristic for a gymnosperm. Trees that lose their leaves at the end of the growing season, like the ginkgo, are called **deciduous**. Most gymnosperms are evergreens and retain their leaves year-round.

Ginkgoes are tolerant of air pollution, making them good plants for urban settings. Ginkgo seeds are considered a delicacy in China and Japan. Notice the plum-shaped, fleshy seeds on the ginkgo shown in Figure 28-13. They are often mistakenly called berries or fruits.

Phylum Coniferophyta

The conifers (KAHN-uh-fuhrz), which are gymnosperms of the phylum Coniferophyta (kahn-uh-fuhr-AHF-uh-tuh), include pine, cedar, redwood, fir, spruce, juniper, cypress, and bald cypress trees. They are important sources of wood, paper, turpentine, ornamental plants, and Christmas trees. Juniper seeds can be used to flavor food. Amber is yellow or brownish yellow fossilized resin that once flowed from ancient conifers. Prehistoric insects are often preserved in amber.

FIGURE 28-12

The cycad is a gymnosperm that looks like a palm or fern. Cycads can sometimes grow to 18 m (60 ft) in height.



Quick Lab

Examining Ferns

Materials potted fern, hand lens, water



Procedure

1. Put on your disposable gloves and lab apron.
2. Choose a frond of the fern, and examine its underside for the structures that contain spores.
3. Wash the soil from the underground structures. Examine the fern's horizontal stems and rhizome.

Analysis How do ferns differ from nonvascular plants? What enables ferns to surpass nonvascular plants in height and size? From what part of the fern do the fronds grow?



FIGURE 28-13

The ginkgo, *Ginkgo biloba*, has large seeds and unusual fan-shaped leaves. This gymnosperm tree can reach heights of 24 m (80 ft).



(a) Fir needles and cones



(b) Pine needles and cones



(c) Yew needles and seeds

FIGURE 28-14

The needles and cones of conifers come in many shapes and sizes. (a) The fir tree displays its female cones. Its needle-shaped leaves grow evenly all around the branch. (b) The pine tree shows its small male and larger female cones. Some pines reach heights of 60 m (200 ft). (c) The seed of the yew tree is surrounded by a red covering that looks like a berry. Its leaves are flat, pointed needles that are dark green on top and pale green underneath.

Conifers are woody plants, and most have needle or scalelike leaves, as shown in Figure 28-14. A conifer usually bears both male and female cones. Small male cones typically grow in clusters. Male cones release clouds of dustlike pollen, and then the cones fall from the branches. The pollen falls or blows into the larger female cones, where the egg cells are attached to the scales of the cone. After pollination, the female cone closes up tightly. This protects the developing seeds, which mature after one or two years. The mature seeds are released when the female cone opens.

Redwoods and giant sequoia trees provide a majestic forest setting along the West Coast of the United States. These conifers are the Earth's tallest and most massive living organisms. The tallest living coastal redwood, *Sequoia sempervirens*, is about 110 m (360 ft) tall, the height of a 30-story building. The most massive tree is a giant sequoia, *Sequoiadendron giganteum*, estimated to weigh 5,600 megagrams (6,200 tons).

Phylum Gnetophyta

Gnetophytes (NEE-tuh-FIETS), an odd group of cone-bearing gymnosperms, have vascular systems that more closely resemble those of angiosperms. As Figure 28-15 shows, *Ephedra* (ih-FED-ruh) is a genus of desert shrubs with jointed stems that look like horsetails. It is the source of the drug *ephedrine*, which can be used as a decongestant.



FIGURE 28-15

Ephedra viridis, called Mormon tea, grows on the rim of the Grand Canyon. This highly branched shrub has small, scalelike leaves. It is the source of the drug ephedrine and can be brewed to make a tea.

Figure 28-16 shows the unique *Welwitschia mirabilis* plant. The plant's stem is only a few centimeters tall but can grow to 1 m (3.3 ft) in diameter. Two leaves elongate from their base on the stem and then become tattered and split lengthwise by the wind. A mature leaf may be nearly 1 m (3.3 ft) wide and 3 m (10 ft) long. *Welwitschia* grows in the Namib Desert of southwestern Africa. The Namib Desert lies near the Atlantic Ocean, so a thick night fog often rolls in over the desert. *Welwitschia* apparently gets most of its water from the dew that condenses from the fog.

Phylum Anthophyta

Anthophyta (an-THAHF-uh-tuh), the largest phylum of plants, includes over 240,000 species of flowering plants. Angiosperms, or the flowering plants, are seed plants characterized by the presence of a flower and fruit. Botanists define a *fruit* as a ripened ovary that surrounds the seeds of angiosperms. The **ovary** is the female part of the flower that encloses the egg(s).

Angiosperms grow in many forms and occupy diverse habitats. Some are herbaceous plants with showy flowers, such as violets and impatiens. Others, such as rose bushes, are shrubs. Some angiosperms are vines, such as grape plants. Oak, aspen, and birch trees are all flowering plants that have woody stems, although you may never have noticed their small flowers. Grasses are also angiosperms, but you must look closely to see their small, highly modified flowers. The world's largest flower, which can grow to 1 m (3.3 ft) in diameter, is shown in Figure 28-17.

THE EVOLUTION OF ANGIOSPERMS

Angiosperms first appeared in the fossil record about 135 million years ago. By about 90 million years ago, angiosperms had probably begun to outnumber gymnosperms. Several factors probably led to the success of this new kind of plant. In many angiosperms, seeds germinate and produce mature plants, which in turn produce new seeds, all in one growing season. This is a tremendous advantage over gymnosperms, which often take 10 or more years to reach maturity and produce seeds. Also, the fruits of flowering plants protect seeds and aid in their dispersal. Angiosperms also have a more efficient vascular system and are more likely to be associated with mycorrhizae than gymnosperms are. Angiosperms also may gain an advantage by using animal pollination rather than the less-efficient wind pollination method used by gymnosperms. However, wind pollination is used by many successful angiosperms, including many deciduous trees. Finally, angiosperms are more diverse than gymnosperms, so they occupy more niches, such as in aquatic, epiphytic, and parasitic environments.



FIGURE 28-16



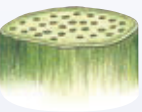





Welwitschia mirabilis has a short, wide stem and twisting leaves. The female plants of this unusual gymnosperm bear large seed cones that are reddish in color.

FIGURE 28-17

The stinking-corpse lily, *Rafflesia arnoldii*, has the world's largest flowers but no leaves or stems. The flowers can be male or female, and they are pollinated by flies. The plant lacks chlorophyll and is parasitic on a woody vine native to Southeast Asia.



TABLE 28-3 Comparing Monocots and Dicots

Plant type	Embryos	Leaves	Stems	Flower parts	Examples
Monocots	One cotyledon 	Parallel venation 	Scattered vascular bundles 	Usually occur in threes 	lilies, irises, orchids, palms, tulips, bananas, pineapples, onions, bamboo, coconut, grasses (including wheat, corn, rice, and oats)
Dicots	Two cotyledons 	Net venation 	Radially arranged vascular bundles 	Usually occur in fours or fives 	beans, lettuce, oaks, maples, elms, roses, carnations, cactuses, most broad-leaved forest trees

MONOCOTS AND DICOTS



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Topic: Monocots/Dicots

Keyword: HM60989

The flowering plants are divided into Monocotyledones (monocots) and Dicotyledones (dicots). The primary feature that distinguishes these two classes is the number of **cotyledons** (KAHT-uh-LEED'nz), or seed leaves, in a plant embryo. **Monocots** (MAHN-oh-KAHTS) usually have one cotyledon, while **dicots** (DIE-KAHTS) typically have two. By comparison, gymnosperms usually have two or more cotyledons.

Several characteristics can be used to identify monocots and dicots, as shown in Table 28-3. For example, most mature monocot leaves have several main **veins**, or bundles of vascular tissue, running parallel to each other. This vein arrangement is called **parallel venation**. Most dicots have one or more nonparallel veins that branch repeatedly, forming a network. This vein arrangement is called **net venation**. More than one characteristic should be used to determine whether a species is a monocot or a dicot.

SECTION 3 REVIEW

1. Identify the reproductive advantages seed plants have over seedless vascular plants and nonvascular plants.
2. Name the reproductive characteristic that all seedless vascular plants share.
3. Describe the main differences between gymnosperms and angiosperms.
4. Explain why angiosperms have been more successful than gymnosperms.
5. List three characteristics that distinguish monocots from dicots.

CRITICAL THINKING

6. **Making Comparisons** Compare the vascular tissue of vascular plants with the circulatory system of vertebrate animals.
7. **Analyzing Information** Explain how the evolutionary advancements present in both seed plants and seedless vascular plants benefit land plants.
8. **Inferring Relationships** Conifers, which typically have needles or scalelike leaves, are the dominant plants in areas with cold winter climates. Identify the adaptive advantage of having narrow or small leaves.

CHAPTER HIGHLIGHTS

SECTION 1 Overview of Plants

- Three adaptations have allowed plants to be successful on land: a cuticle to prevent water loss, spores and seeds to protect reproductive cells, and special tissues for absorbing and transporting materials within the plant.
- The 12 phyla of plants are divided into two groups based on the presence of vascular tissue. The three phyla of nonvascular plants have neither true vascular tissue nor roots, stems, or leaves. Most members of the nine phyla of vascular plants have vascular tissue and true roots, stems, and leaves.
- Vascular plants can be further divided into two groups, seedless plants and seed plants. Seed plants include four phyla of gymnosperms and one phylum of angiosperms.
- All plants have a life cycle known as alternation of generations. In alternation of generations, a haploid gametophyte produces gametes. Gametes unite and give rise to a diploid sporophyte. Through meiosis, the sporophyte produces haploid spores, which develop into gametophytes.

Vocabulary

cuticle (p. 563)

spore (p. 563)

seed (p. 563)

vascular tissue (p. 564)

xylem (p. 564)

phloem (p. 564)

nonvascular plant (p. 564)

vascular plant (p. 564)

seed plant (p. 565)

gymnosperm (p. 565)

angiosperm (p. 565)

sporophyte (p. 565)

gametophyte (p. 565)

alternation of generations
(p. 565)

SECTION 2 Nonvascular Plants

- The three phyla of nonvascular plants are collectively called bryophytes. These plants do not have true roots, stems, or leaves. They are very small and are usually found in moist areas.
- Bryophytes in the phylum Bryophyta are mosses. Mosses are attached to the soil by structures called rhizoids. Peat moss is a moss that has many uses.
- Bryophytes in the phylum Hepatophyta are liverworts. Liverworts lie close to the ground, which allows them to absorb water readily.
- Bryophytes in the phylum Anthocerophyta are hornworts. Hornworts do not have a stem or leaves. Hornworts have long, thin, hornlike sporophytes that grow out of the top of the plant.

Vocabulary

bryophyte (p. 567)

liverwort (p. 568)

hornwort (p. 569)

SECTION 3 Vascular Plants

- Vascular plants have several adaptive advantages over nonvascular plants, including specialized conducting tissues, the ability to grow large and live in many environments, and strong stems that allow them to grow tall and receive more sunlight.
- Seedless vascular plants include the four phyla Psilophyta, Lycophyta, Sphenophyta, and Pteridophyta. Seedless vascular plants include ferns and fernlike plants. Ferns are the dominant phylum of seedless plants. Most ferns have a rhizome, an underground stem.
- There are two main groups of seed-bearing vascular plants, gymnosperms and angiosperms. Gymnosperms are characterized by naked seeds and no flowers. Angiosperms have flowers and seeds enclosed by a fruit.
- Angiosperms have been successful for many reasons, including the production of fruit that protects seeds, quick germination, and an efficient vascular system.
- Dicots are distinguished from monocots on the basis of several characteristics: cotyledon number, leaf venation, arrangement of stem vascular tissue, and number of flower parts.

Vocabulary

strobilus (p. 571)

rhizome (p. 572)

fiddlehead (p. 572)

frond (p. 572)

germinate (p. 572)

seedling (p. 572)

cone (p. 572)

deciduous (p. 573)

ovary (p. 575)

cotyledon (p. 576)

monocot (p. 576)

dicot (p. 576)

vein (p. 576)

parallel venation (p. 576)

net venation (p. 576)


CHAPTER REVIEW

USING VOCABULARY

- For each pair of terms, explain the relationship between the terms.
 - seed* and *spore*
 - vascular plant* and *nonvascular plant*
 - phloem* and *xylem*
- Choose the term that does not belong in the following group, and explain why it does not belong: *cuticle*, *spore*, *seed*, and *strobilus*.
- For each pair of terms, explain how the meanings of the terms differ.
 - gymnosperm* and *angiosperm*
 - gametophyte* and *sporophyte*
 - monocot* and *dicot*
- Use the following terms in the same sentence: *cotyledon*, *germinate*, and *seedling*.
- Word Roots and Origins** The word *deciduous* is derived from the Latin *de*, which means “down,” and *cadere*, which means “to fall.” Using this information, explain why the term *deciduous* is a good name for the plants that this term describes.

UNDERSTANDING KEY CONCEPTS

- Summarize** how plants are adapted to living successfully on land.
- Name** two basic differences between nonvascular plants and vascular plants.
- Describe** how alternation of generations in nonvascular plants differs from that in vascular plants.
- Explain** why bryophytes are the most primitive type of plant.
- Describe** why plants in the phylum Bryophyta are sometimes called pioneer plants.
- Differentiate** between leafy liverworts and thaloid liverworts.
- State** the characteristic that hornworts do not share with other bryophytes.
- Explain** how specialized conducting tissues give vascular plants an adaptive advantage over nonvascular plants.
- Relate** how ferns and fern allies are able to reproduce without seeds.
- Differentiate** between a cone and a fruit.
- Explain** how the diversity of angiosperms has helped them be more successful than gymnosperms.
- State** the primary basis used for classifying angiosperms.

- 
CONCEPT MAPPING Use the following terms to create a concept map that describes the possible evolutionary relationships of plants: *angiosperm*, *cone*, *flower*, *dicot*, *gymnosperm*, *monocot*, *ovary*, and *seed plant*.

CRITICAL THINKING

- Analyzing Information** Fossil trees are easier to find than fossils of small plants. Give two possible explanations.
- Interpreting Graphics** Look at the plants in the photo below. Do you think the cuticles of these plants are thicker on the upper surface of the leaf or on the lower surface? Explain.



- Organizing Information** Copy the chart below into your notebook. Indicate with a check mark (✓) which groups of plants have vascular tissue. Also, indicate which groups of plants have a dominant sporophyte as part of their life cycle.

Plant Evolution

Phylum	Has vascular tissue	Has dominant sporophyte
Anthophyta		
Bryophyta		
Coniferophyta		
Hepatophyta		
Pteridophyta		

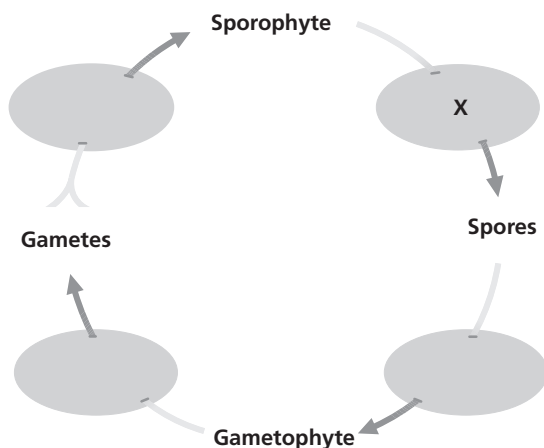


Standardized Test Preparation

DIRECTIONS: Choose the letter of the answer choice that best answers the question.

- Which of the following plants are bryophytes?
 - ferns and cycads
 - conifers and ginkgoes
 - hornworts and liverworts
 - horsetails and club mosses
- In which way do mosses help start new biological communities?
 - forming new soil
 - producing spores
 - detecting air pollution
 - slowing decomposition
- True roots, stems, and leaves are characteristics of which types of plants?
 - all plants
 - only seed plants
 - only angiosperms
 - all vascular plants
- Which of the following is a vascular seed plant?
 - ferns
 - cycads
 - horsetails
 - club mosses

INTERPRETING GRAPHICS: The diagram below shows a plant life cycle. Use the diagram to answer the question that follows.

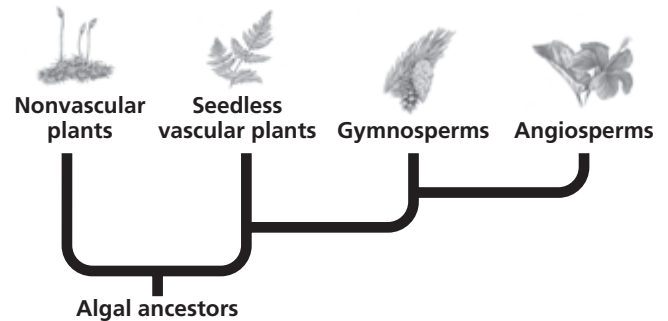


- Which process occurs at X in this life cycle?
 - mitosis
 - meiosis
 - alternation
 - fertilization
- Which of the following phrases describes monocots?
 - bear seeds in cones
 - have parallel venation
 - do not produce flowers
 - have vascular bundles arranged in a circle

DIRECTIONS: Complete the following analogy.

7. bryophyte : spore :: angiosperm :
- seed
 - cone
 - ovary
 - cuticle

INTERPRETING GRAPHICS: The phylogenetic diagram below shows a possible evolutionary relationship between plants and algae. Use the diagram to answer the question that follows.



8. According to this diagram, which plants have evolved most recently?
- angiosperms
 - gymnosperms
 - nonvascular plants
 - seedless vascular plants

SHORT RESPONSE

The plant kingdom is very diverse, from small non-vascular plants to large flowering vascular plants.

Explain why some plants have been more successful on land than other plants have been.

EXTENDED RESPONSE

All plants have a life cycle that alternates between haploid and diploid phases.

Part A Name the two phases of a plant life cycle and describe how they differ from each other.

Part B Describe the life cycle of one nonvascular plant and one vascular plant, including the relative sizes of the different forms and other characteristics.

Test TIP

For questions involving life cycles, draw as much of the life cycle as you can remember. Looking at such a model may help you understand the question better and determine the answer.

Observing Plant Diversity

OBJECTIVES

- Compare similarities and differences among phyla of living plants.
- Relate structural adaptations to the evolution of plants.

MATERIALS

- live and preserved specimens representing four plant phyla
- protective gloves
- lab apron
- stereomicroscope or hand lens
- compound light microscope
- prepared slides of male and female gametophytes of mosses and ferns



SAFETY



Background

1. How do plants you commonly see compare with their ancestors, the green algae?
2. What are the differences between nonvascular plants and vascular plants? How do these differences relate to the size of a plant?
3. What is alternation of generations? Is it found in all plants?
4. Do all plants produce spores? Do all plants produce seeds? What are the advantages of producing seeds?
5. What do you think was the evolutionary pressure that resulted in colorful flowers?

Procedure

1.   **CAUTION** Put on protective gloves. Keep your hands away from your face while handling plants. You will travel to four stations to observe plants from four phyla. Record the answers to the questions in your lab report.

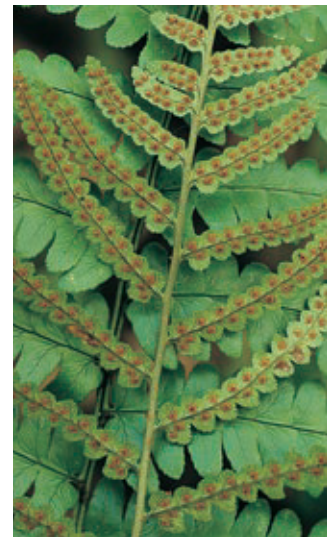


STATION 1 Mosses

2. Use a stereomicroscope or a hand lens to examine the samples of mosses, which are bryophytes. Which part of the moss is the gametophyte? Which part of the moss is the sporophyte? Make a sketch of your observations in your lab report. In your drawing, label the gametophyte and sporophyte portions of the moss plant and indicate whether each is haploid or diploid.
3. Use a compound microscope to look at the prepared slides of male and female gametophytes. What kinds of reproductive cells are produced in each of these structures? Draw the cells in your lab report.
4. Do mosses have roots? How do mosses obtain water and nutrients from the soil?

STATION 2 Ferns

5. Look at the examples of ferns at this station. The fern leaf is called a frond. Use the hand lens to examine the fronds.
 - a. How does water travel throughout a fern? List observations supporting your answer.
 - b. Make a drawing of the fern plant in your lab report.



- c. Indicate whether the leafy green frond in your drawing is haploid or diploid.
- d. Search the underside of the fern fronds for evidence of reproductive structures. Make a drawing of your findings in your lab report. What kind of reproductive cells are produced by these structures?
- 6. Examine the examples of fern gametophytes.
 - a. Locate and identify the reproductive organs found on the gametophytes. In your lab report, sketch and label these organs and identify the reproductive cells produced by each.
 - b. Are the gametophytes haploid or diploid?
- 7. In what ways are ferns like bryophytes? In what ways are they different?

STATION 3 Conifers



- 8. The gymnosperms most familiar to us are conifers. Look at the samples of conifers at this station.
 - a. When you look at the limb of a pine tree, which portion (gametophyte or sporophyte) of the plant life cycle are you seeing?
 - b. In what part of the conifer would you find reproductive structures?
- 9. Name an evolutionary advancement found in gymnosperms but lacking in ferns.



STATION 4 Angiosperms

- 10. Draw one of the representative angiosperms at this station in your lab report. Label the representative angiosperm as a monocot or a dicot, and list at least two characteristics you used to identify it.
- 11. Name an evolutionary development that is present in both gymnosperms and angiosperms but absent in bryophytes and ferns.



- 12. How do the seeds of angiosperms differ from those of gymnosperms?
- 13. Examine the fruits found at this station. How have fruits benefited angiosperms?
- 14.   Clean up your materials and wash your hands before leaving the lab.

Analysis and Conclusions

- 1. In bryophytes, how do the sperm travel from the male gametophyte to the female gametophyte?
- 2. In angiosperms, how do the sperm get to the part of the flower containing the egg?
- 3. Which portion of the plant life cycle is dominant in bryophytes? Which portion is dominant in ferns, gymnosperms, and angiosperms?
- 4. What is a seed? Why is the seed a helpful adaptation for terrestrial plants?
- 5. Why are gymnosperms referred to as *naked* seed plants?
- 6. Which group of plants is the most successful and diverse today? What are some adaptations found among members of this group?

Further Inquiry

- 1. Find out how the geographic distribution of the phyla of living plants relates to their structures.
- 2. Research the deforestation of tropical rain forests. How are the different groups of plants affected by deforestation?