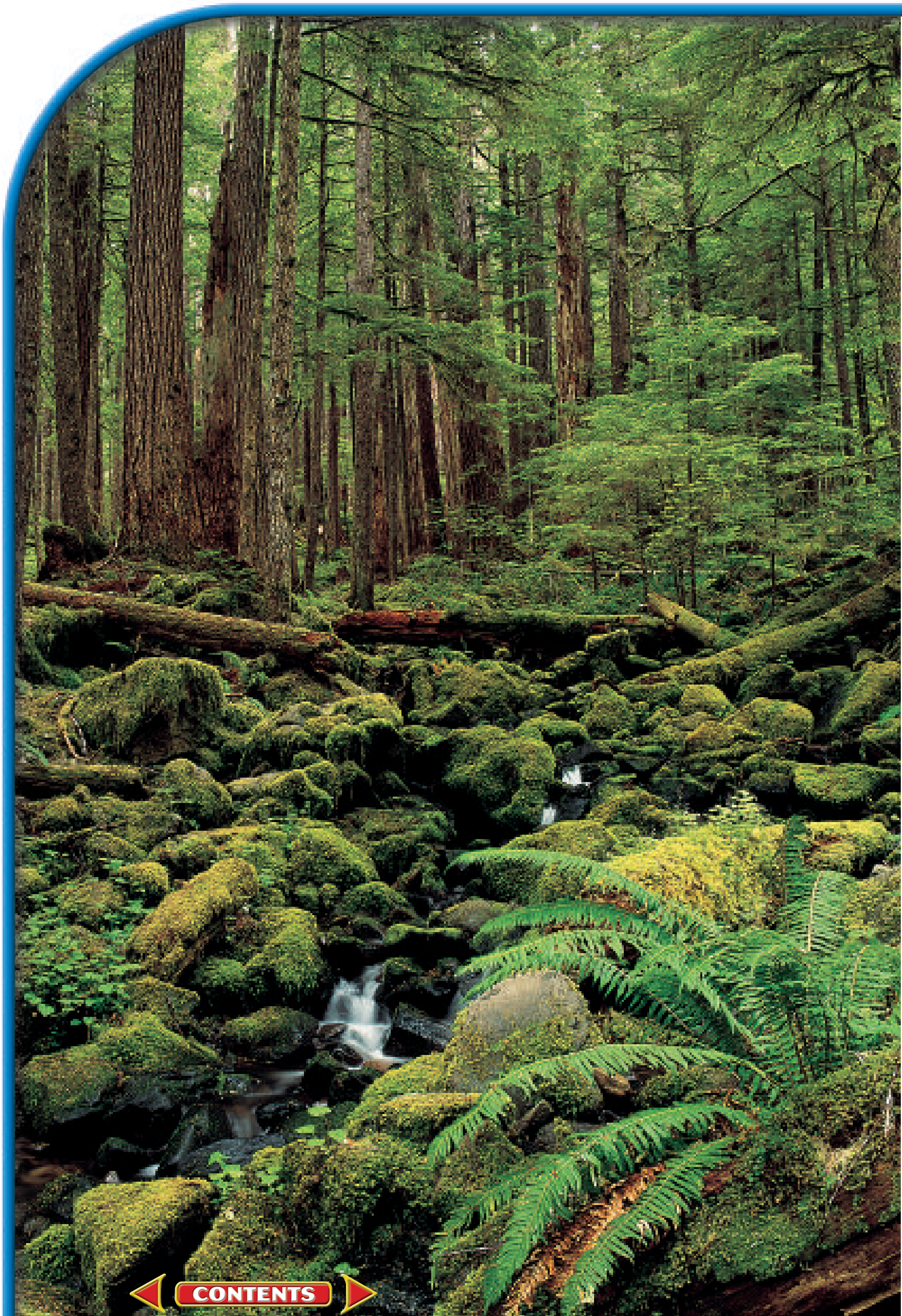
Chapter 22

The Diversity of Plants



What You'll Learn

- You will identify the characteristics of the major plant groups.
- You will identify and compare the distinguishing features of vascular and nonvascular plants.
- You will analyze the advantages of seed production.

Why It's Important

You can classify plants according to their diverse characteristics. Knowing about these characteristics of plants will help you analyze the relationships among plant divisions.

Understanding the Photo

Plants can be categorized as either non-seed plants or seed plants. The ferns and mosses covering the ground in this forest are non-seed plants. The trees and woody shrubs are seed plants.

Biology Online

Visit ca.bdol.glencoe.com to
- study the entire chapter online
- access Web Links for more information and activities on diversity of plants
- review content with the Interactive Tutor and self-check quizzes

Adam Jones

Section 22.1

Nonvascular Plants

SECTION PREVIEW

Objectives

Identify the structures of nonvascular plants.

Compare and contrast characteristics of the different groups of nonvascular plants.

Review Vocabulary

fertilization: fusion of male and female gametes (p. 253)

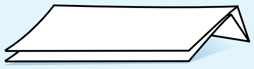
New Vocabulary

antheridium
archegonium

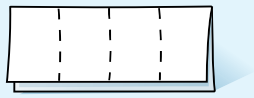
FOLDABLES Study Organizer

Diversity Make the following Foldable to help you organize information about the diversity of plants.

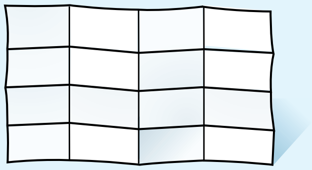
STEP 1 **Fold** one piece of paper in half lengthwise twice.



STEP 2 **Fold** the paper widthwise into fourths.



STEP 3 **Unfold,** lay the paper lengthwise, and draw lines along the folds.



STEP 4 **Label** your table as shown.

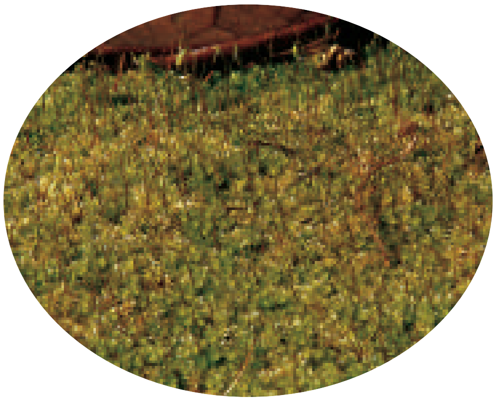
Plants	Divisions	Origins	Adaptations
Nonvascular			
Non-seed vascular			
Seed vascular			

Make a Table As you read Chapter 22, complete the table about the diversity of plants.

What is a nonvascular plant?

Nonvascular plants are not as common or as widespread in their distribution as vascular plants because life functions, including photosynthesis and reproduction, require a close association with water. Because a steady supply of water is not available everywhere, nonvascular plants are limited to moist habitats by streams and rivers or in temperate and tropical rain forests. Recall that a lack of vascular tissue also limits the size of a plant. In drier soils, there is not enough water to meet the needs of most nonvascular plants. Their long-term survival in dry environments is limited by this resource—water. However, nonvascular plants, such as the moss in ***Figure 22.1***, are successful in habitats with adequate water.

Figure 22.1
Bryum is a type of moss frequently found in moist forest habitats.



Alternation of generations

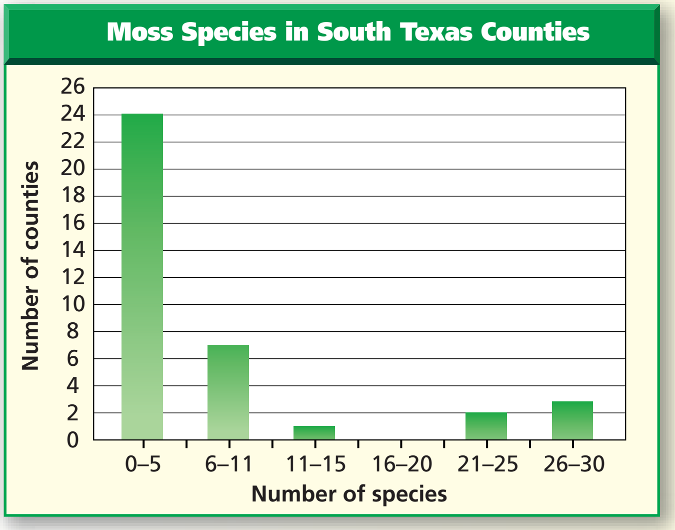
As in all plants, the life cycle of nonvascular plants includes an alternation of generations between a diploid sporophyte and a haploid gametophyte. However, nonvascular plant divisions include the only plants that have a dominant gametophyte generation. Sporophytes grow attached to and depend on gametophytes to take in water and other substances.

William J. Weber/Visuals Unlimited

Problem-Solving Lab 22.1

Interpret Data

Do bryophytes grow in South Texas? The presence and distribution of moss species in South Texas are displayed in the graph below.



Solve the Problem

Bryophytes need a moist environment and South Texas can be very hot and dry. Interpret the data and infer why the distribution of the numbers of moss species in South Texas counties is so varied.

Thinking Critically

1. **Estimate** Which is greater, counties in South Texas that have many moss species or counties in South Texas that have few moss species?
2. **Calculate** What percentage of counties in South Texas have five or fewer moss species?
3. **Calculate** What percentage of counties in South Texas have more than 20 moss species?
4. **Infer** How might the environment or geography in counties that have more than 20 moss species be different from the environment of counties that have no or very few moss species?

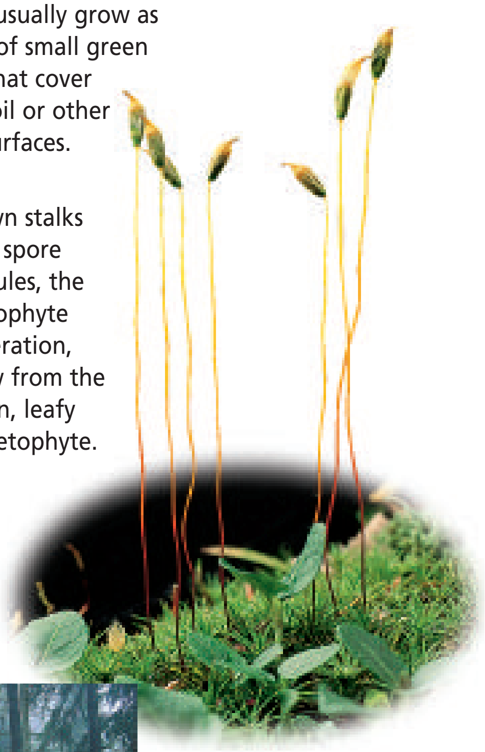
Non-photosynthetic sporophytes, like those shown in ***Figure 22.2A,*** depend on their gametophytes for food.

Gametophytes of nonvascular plants produce two kinds of sexual reproductive structures. The **antheridium** (an thuh RIH dee um) is the male reproductive structure in which sperm are produced. The **archegonium** (ar kih GOH nee um) is the female reproductive structure in which eggs are produced. Fertilization, which begins the sporophyte generation, occurs in the archegonium.

Adaptations in Bryophyta

There are several divisions of nonvascular plants. The first division you'll study are the mosses, or bryophytes.

Figure 22.2
Mosses usually grow as carpets of small green plants that cover damp soil or other damp surfaces.



A Brown stalks with spore capsules, the sporophyte generation, grow from the green, leafy gametophyte.

B Moss species sometimes are referred to as pioneer species because they often are some of the first species to inhabit newly formed or disturbed environments. These mosses are growing on the damp surfaces of fallen trees.
Analyze ***Describe the flow of matter between these mosses, trees, and the environment.***

Bryophytes are the most familiar of the nonvascular plant divisions. Mosses are small plants with leafy stems. The leaves of mosses are usually one cell thick. Mosses have rhizoids, colorless multicellular structures, which help anchor the stem to the soil. Although mosses do not contain true vascular tissue, some species do have a few, long water-conducting cells in their stems.

Mosses usually grow in dense carpets of hundreds of plants, as shown in ***Figure 22.2B.*** Some have upright stems; others have creeping stems that hang from steep banks or tree branches. Some mosses form extensive mats that help retard erosion on exposed rocky slopes.

Mosses grow in a wide variety of habitats, as stated in the *Problem-Solving Lab* on the opposite page. They even grow in the arctic during the brief growing season where sufficient moisture is present.

A well-known moss is *Sphagnum*, also known as peat moss. This plant thrives in acidic bogs in northern regions of the world. It is harvested for use as fuel and is a commonly used soil additive. Dried peat moss absorbs large amounts of water, so florists and gardeners use it to increase the water-holding ability of some soils.

Adaptations in Hepaticophyta

Another division of nonvascular plants is the liverworts, or hepaticophytes. Like mosses, liverworts are small plants that usually grow in clumps or masses in moist habitats. The name of the division is derived from the word *hepar*, which refers to the liver. The flattened body of a liverwort gametophyte is thought to resemble the shape of the lobes of an animal's liver. Liverworts occur in many environments worldwide.

Figure 22.3
Liverworts may have a flattened plant body called a thallus **(A)** or leafy stems **(B).**

A liverwort can be categorized as either thallose or leafy, as shown in ***Figure 22.3.*** The body of a thallose liverwort is called a thallus. It is broad and ribbonlike and resembles a fleshy, lobed leaf. Thallose liverworts like *Marchantia*, shown in ***Figure 22.3A,*** are usually found growing on damp soil. Leafy liverworts grow close to the ground and usually are common in tropical jungles and areas with persistent fog. Their stems have flat, thin leaves arranged in three rows—a row along each side of the stem and a row of smaller leaves on the stem's lower surface. Liverworts have rhizoids that are composed of only one elongated cell.

Reading Check **Examine** a hepaticophyte's method of growth. Evaluate its significance as an adaptation to a hepaticophyte's environment.

Word Origin

antheridium from the Medieval Latin word *anthera,* meaning "pollen"; Sperm are produced in the antheridium.

archegonium from the Greek word *archegonos,* meaning "originator"; Eggs are produced in the archegonium.

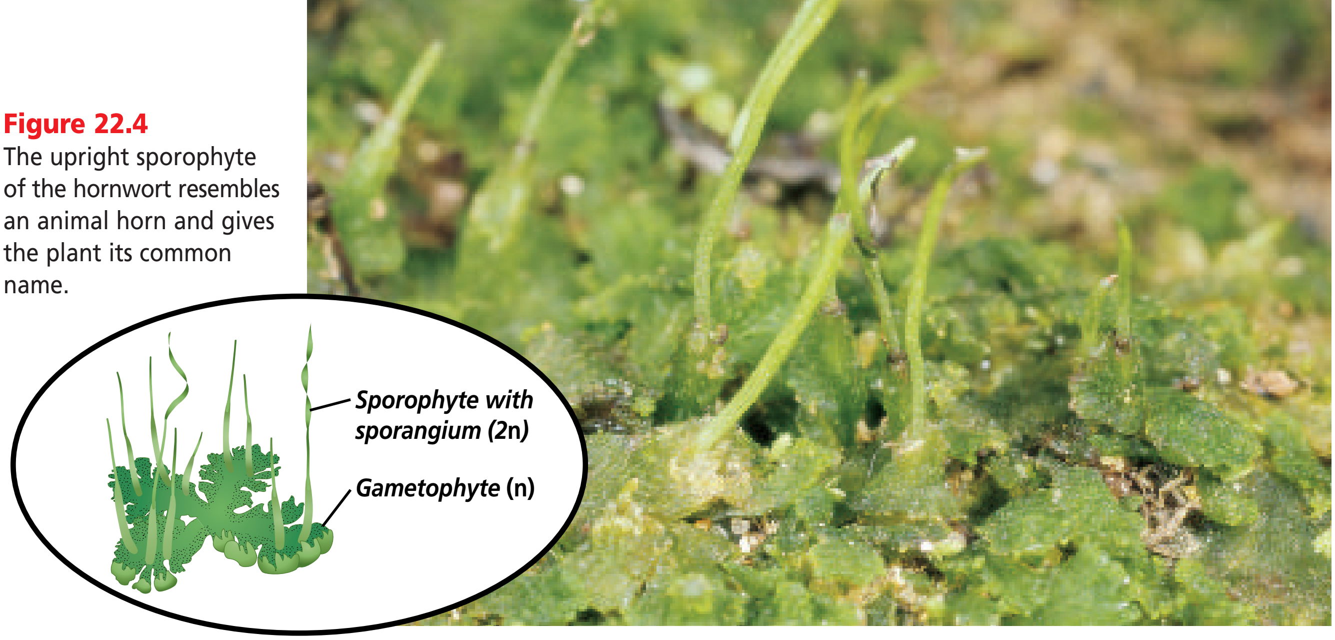


Figure 22.4
The upright sporophyte of the hornwort resembles an animal horn and gives the plant its common name.

Adaptations in Anthocerophyta

Anthocerophytes are the smallest division of nonvascular plants, currently consisting of only about 100 species. Also known as hornworts, these nonvascular plants are similar to liverworts in several respects. Like some liverworts, hornworts have a thallose body. The sporophyte of a hornwort resembles the horn of an animal, as shown in ***Figure 22.4***, which is why members of this division are commonly called "hornworts." Another feature unique to hornworts is the presence of one to several chloroplasts in each cell of the sporophyte depending upon the species. Unlike other nonvascular plants, the hornwort sporophyte, not the gametophyte, produces most of the food used by both generations.

Origins of Nonvascular Plants

Fossil and genetic evidence suggests that liverworts were the first land plants. Fossils that have been positively identified as nonvascular plants first appear in rocks from the early Paleozoic Era, more than 440 million years ago. However, paleobotanists suspect that nonvascular plants were present earlier than current fossil evidence suggests. Both nonvascular and vascular plants probably share a common ancestor that had alternating sporophyte and gametophyte generations, cellulose in their cell walls, and chlorophyll for photosynthesis.

Section Assessment

Understanding Main Ideas

1. Compare and contrast a leafy liverwort and a thallose liverwort.
2. Explain how the bryophyte sporophyte generation is dependent on the bryophyte gametophyte generation.
3. Identify characteristics shared by all nonvascular plants.
4. Evaluate the significance of nonvascular plant adaptations to their moist environments.

Thinking Critically

5. Identify the growth and development methods of mosses. Explain why these are advantageous in their environments.

Skill Review

6. **Compare and Contrast** Describe the variations in gametophyte and sporophyte generations of nonvascular plants. For more help, refer to *Compare and Contrast* in the **Skill Handbook.**

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Section 22.2

Non-Seed Vascular Plants

SECTION PREVIEW

Objectives

Evaluate the significance of plant vascular tissue to life on land.

Identify and analyze the characteristics of the non-seed vascular plant divisions.

Vocabulary Review

alternation of generations: type of life cycle found in some algae, fungi, and all plants where an organism alternates between a haploid (*n*) gametophyte generation and a diploid (2*n*) sporophyte generation (p. 516)

New Vocabulary

strobilus
prothallus
rhizome
sorus

Plants with Pipes

Using an Analogy You take a drink from a water fountain then watch the unused water flow down the drain. In the lab, another student turns a tap to get 50 mL of water for an investigation. These activities are possible because your school has plumbing that delivers water and carries away wastes. Plants, such the tree fern and others shown to the right, have plumbing too. This plant plumbing—called vascular tissues—distributes water and other dissolved substances throughout a plant.

Concept Map *After you read about non-seed vascular plants, make a concept map that identifies and analyzes the relationships among these organisms.*

Tree fern

What is a non-seed vascular plant?

The obvious difference between a vascular and a nonvascular plant is the presence of vascular tissue. As you may remember, vascular tissue is made up of tubelike, elongated cells through which water and sugars are transported. Vascular plants are able to adapt to changes in the availability of water, and thus are found in a variety of habitats. You will learn about three divisions of non-seed vascular plants: Lycophyta, Arthrophyta, and Pterophyta.

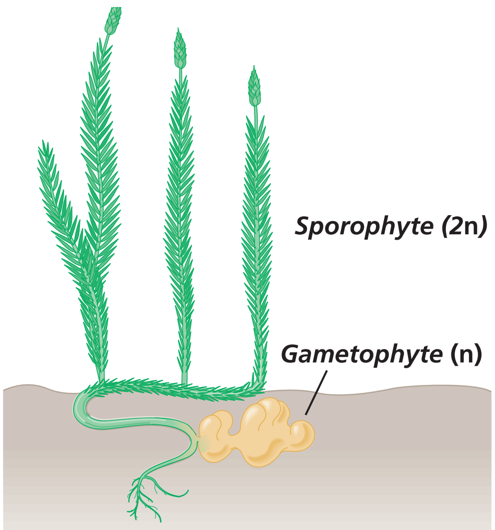
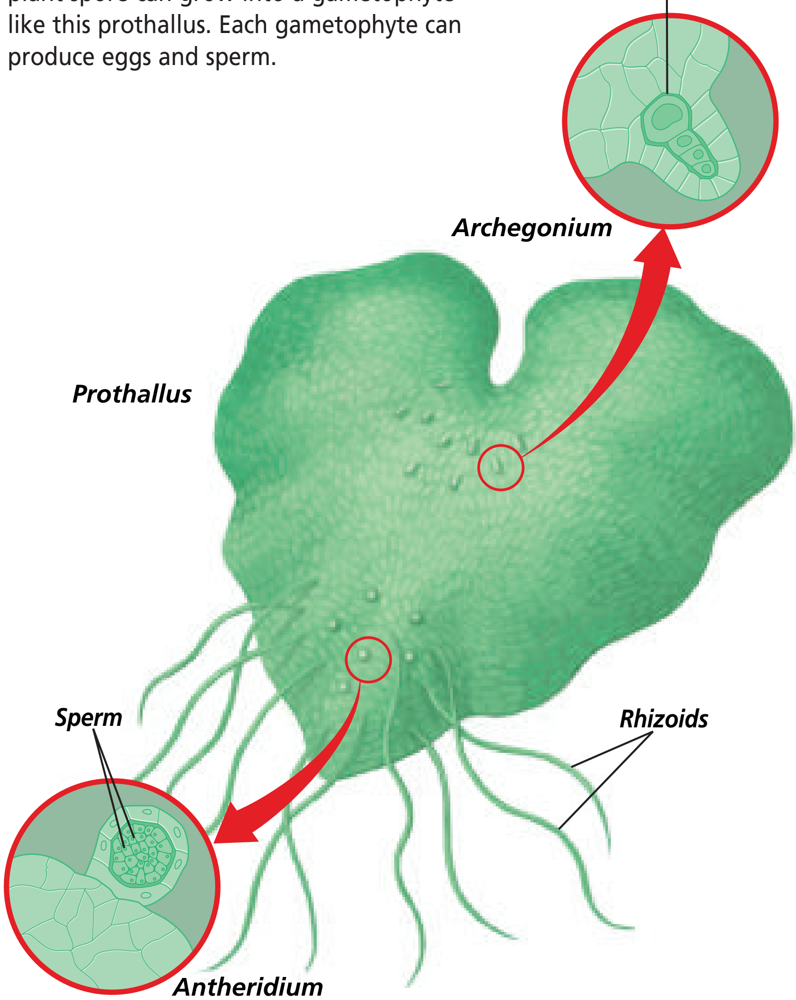


Figure 22.5 In non-seed vascular plants, the sporophyte generation is dominant.

Alternation of generations

Vascular plants, like all plants, exhibit an alternation of generations. Unlike nonvascular plants, the spore-producing vascular sporophyte is dominant and larger in size than the gametophyte, as shown in ***Figure 22.5***. The mature sporophyte does not depend on the gametophyte for water or nutrients.

Figure 22.6
In the proper environment, a non-seed plant spore can grow into a gametophyte like this prothallus. Each gametophyte can produce eggs and sperm.



A major advance in this group of vascular plants was the adaptation of leaves to form structures that protect the developing reproductive cells. In some non-seed vascular plants, spore-bearing leaves form a compact cluster called a **strobilus** (stroh BIH lus). The spores are released from the strobilus and can grow to form gametophytes. A fern gametophyte is called a **prothallus** (proh THA lus). Gametophytes are relatively small and live in or on the soil. Antheridia and archegonia develop on the gametophyte, as illustrated in ***Figure 22.6.*** Sperm are released from antheridia and require a continuous film of water to reach eggs in the archegonia. If fertilization occurs, a zygote can grow into a large, dominant sporophyte.

Adaptations in Lycophyta

From fossil evidence it is known that tree-sized lycophytes were members of the early forest community. Modern lycophytes, like the one in ***Figure 22.7***, are much smaller than their early ancestors. Lycophytes are commonly called club mosses and spike mosses. Their leafy stems resemble moss gametophytes, and their reproductive structures are club or spike shaped. However, unlike mosses, the sporophyte generation of the lycophytes is dominant. It has roots, stems, and small leaflike structures. A single vein of vascular tissue runs through each leaflike structure. The stems of lycophytes may be upright or creeping and have roots growing from the base of the stem.

Figure 22.7
Selaginella species inhabit a variety of environments, from damp greenhouse floors to tropical forests. The resurrection plant, *Selaginella lepidophylla,* is adapted to survive extreme drought **(A).** When moisture returns, the plant resumes normal functions **(B).**

A

B

(l)Richard F. Trump/ Photo Researchers (r)Virginia P. Weinland/Photo Researchers

Figure 22.8
The sporophyte generation of a horsetail, *Equisetum,* has thin, narrow leaflike structures that circle each joint of the slender, hollow stem. Spore-producing stems are not photosynthetic.

The club moss, *Lycopodium*, is commonly called ground pine because it is evergreen and resembles a miniature pine tree. Some species of ground pine have been collected for decorative uses in such numbers that the plants have become endangered.

Reading Check **Explain** why water limits the long-term survival of non-seed vascular plants.

Adaptations in Arthrophyta

Arthrophytes, or horsetails, represent a second group of ancient vascular plants. Like the lycophytes, early horsetails were tree-sized members of the forest community. Today's arthrophytes are much smaller than their ancestors, usually growing to about 1 m tall. There are only about 15 species in existence, all of the genus *Equisetum.*

The name horsetail refers to the bushy appearance of some species. These plants also are called scouring rushes because they contain silica, an abrasive substance, and were once used to scour cooking utensils. If you run your finger along a horsetail stem, you can feel how rough it is.

Most horsetails, like the ones shown in ***Figure 22.8,*** are found in marshes, in shallow ponds, on stream banks, and other areas with damp soil. Some species are common in the drier soil of fields and roadsides. The stem structure of horsetails is unlike most other vascular plants; it is ribbed and hollow, and appears jointed. At each joint, there is a whorl of tiny, scalelike leaves.

Like lycophytes, arthrophyte spores are produced in strobili that form at the tips of non-photosynthetic stems. After the spores are released, they can grow into gametophytes with antheridia and archegonia.

Word Origin

strobilus from the Greek word *strobos,* meaning "whirling"; Spore-bearing leaves form a compact cluster called a strobilus.

Problem-Solving Lab 22.2

Apply Concepts

Is water needed for fertilization? Non-seed vascular plants have a number of shared characteristics. One of these characteristics is related to certain requirements needed for reproduction.

Solve the Problem

Examine the following data table. Notice that some of the information is incomplete.

Data Table

Division	Example	Sperm Must Swim to Egg?	Water Needed for Fertilization?
Lycophyta	Club moss		
Arthrophyta	Horsetail		
Pterophyta	Ferns		

Thinking Critically

1. **Explain** How would you complete the column titled "Sperm Must Swim to Egg?"
2. **Explain** How is the column titled "Water Needed for Fertilization?" related to answers in the previous column?
3. **Describe** What environment is required for the growth of these three plant divisions?
4. **Predict** What other means might be possible for plant sperm delivery to eggs without the use of water?

Adaptations in Pterophyta

According to fossil records, ferns—division Pterophyta—first appeared nearly 375 million years ago during the time when club mosses and horsetails were the predominant members of Earth's plant population. Ancient ferns grew tall and treelike and formed vast forests. Over time, ferns evolved into many species, adapted to different environments, and today are more abundant than club mosses or horsetails.

Ferns range in size from a few meters tall, like tree ferns, to small, floating plants that are only a few centimeters in diameter, such as those in ***Figure 22.9.*** You may have seen shrub-sized ferns on damp forest floors or along stream banks. Some ferns inhabit dry areas, becoming dormant when moisture is scarce and resuming growth and reproduction only when water is available again. Explore the relationship between water and non-seed vascular plants in the *Problem-Solving Lab* on this page.

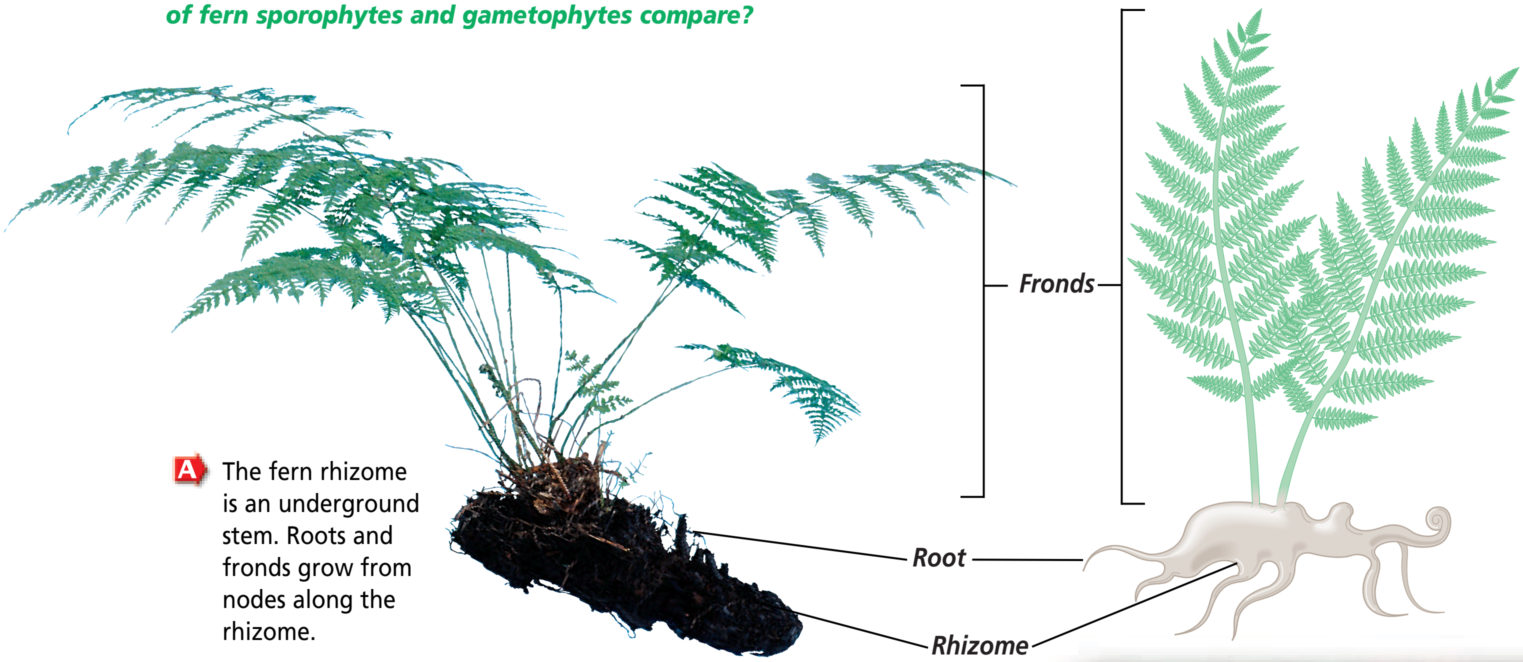
Figure 22.9
Today there are about 12 000 species of living ferns. Ferns occupy widely diverse habitats and have a variety of different forms and sizes.

A The center of this fern, where the fronds form, resembles a bird's nest. Bird's nest ferns often are grown as houseplants.

B The clover fern is an aquatic plant. Its roots grow underground at the muddy bottom of a body of water.

C Many species of tall tree ferns exist in the tropics.

Figure 22.10
Fern sporophyte structures include a rhizome, fronds, and roots. **Compare and Contrast** ***In general, how do the sizes of fern sporophytes and gametophytes compare?***



A The fern rhizome is an underground stem. Roots and fronds grow from nodes along the rhizome.

Fern structures

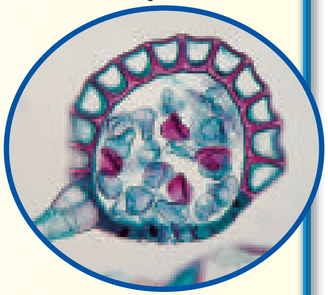
As with most vascular plants, it is the sporophyte generation of the fern that has roots, stems, and leaves. The part of the fern plant that we most commonly recognize is the sporophyte generation. The gametophyte in most ferns is a thin, flat structure that is independent of the sporophyte. In most ferns, the main stem is underground. This thick, underground stem is called a **rhizome.** It contains many starch-filled cells for storage. The leaves of a fern are called fronds and grow upward from the rhizome, as shown in ***Figure 22.10.*** The fronds are often divided into leaflets called pinnae, which are attached to a central rachis. Ferns are the first of the vascular plants to have evolved leaves with branching veins of vascular tissue. The branched veins in ferns transport water and food to and from all the cells.

B The form of fern fronds varies from species to species. Some fronds are broad, flat structures and others are finely divided into leaflets. Fronds are supported by a stemlike structure called a rachis.

C New fern fronds are called fiddleheads because their shape is similar to the neck of a violin.

MiniLab 22.1

Experiment


Stained LM Magnification: 100×

Fern sporangium

Identifying Fern Sporangia When you admire a fern growing in a garden or forest, you are admiring the plant's sporophyte generation. Upon further examination, you should be able to see evidence of spores being formed. Typically, the evidence you are looking for can be found on the underside of the fern's fronds.

Procedure

CAUTION: ***Use caution when handling a microscope, glass slides, and coverslips.***

1. Place a drop of water and a drop of glycerin at opposite ends of a glass slide.
2. Use forceps to gently pick off one sorus from a frond. Place it in the drop of water and add a coverslip.
3. Add a second sorus to the glycerin and add a coverslip.
4. Observe both preparations under low-power magnification and note any similarities and differences. Look for large sporangia (resembling heads on a stalk) and spores (tiny round bodies released from a sporangium).

Analysis

1. **Compare and Contrast** How does the appearance of spores in water and in glycerin differ?
2. **Explain** How did the glycerin affect the sporangium?
3. **Form a Hypothesis** Explain how sporangia naturally burst.
4. **Form a Hypothesis** Explain how sporangia were affected by glycerin.

The fern life cycle is representative of other non-seed vascular plants. Fern spores are produced in structures called sporangia. Clusters of sporangia form a structure called a **sorus** (plural, sori). Sori are usually found on the undersides of fronds, as shown in ***Figure 22.11***, but in some ferns, spores are borne on modified fronds. Practice your lab skills and learn more about fern spores and sporangia in the *MiniLab* on this page.

Origins of Non-Seed Vascular Plants

The earliest evidence of non-seed vascular plants is found in fossils from early in the Devonian Period, around 375 million years ago. Large tree-sized lycophytes, arthrophytes, and pterophytes were extremely abundant in the warm, moist forests that dominated Earth during the Carboniferous Period. Ancient lycophyte species grew as tall as 30 m. Many of these species of non-seed vascular plants died out about 280 million years ago—a time when Earth's climate was cooler and drier. Today's non-seed

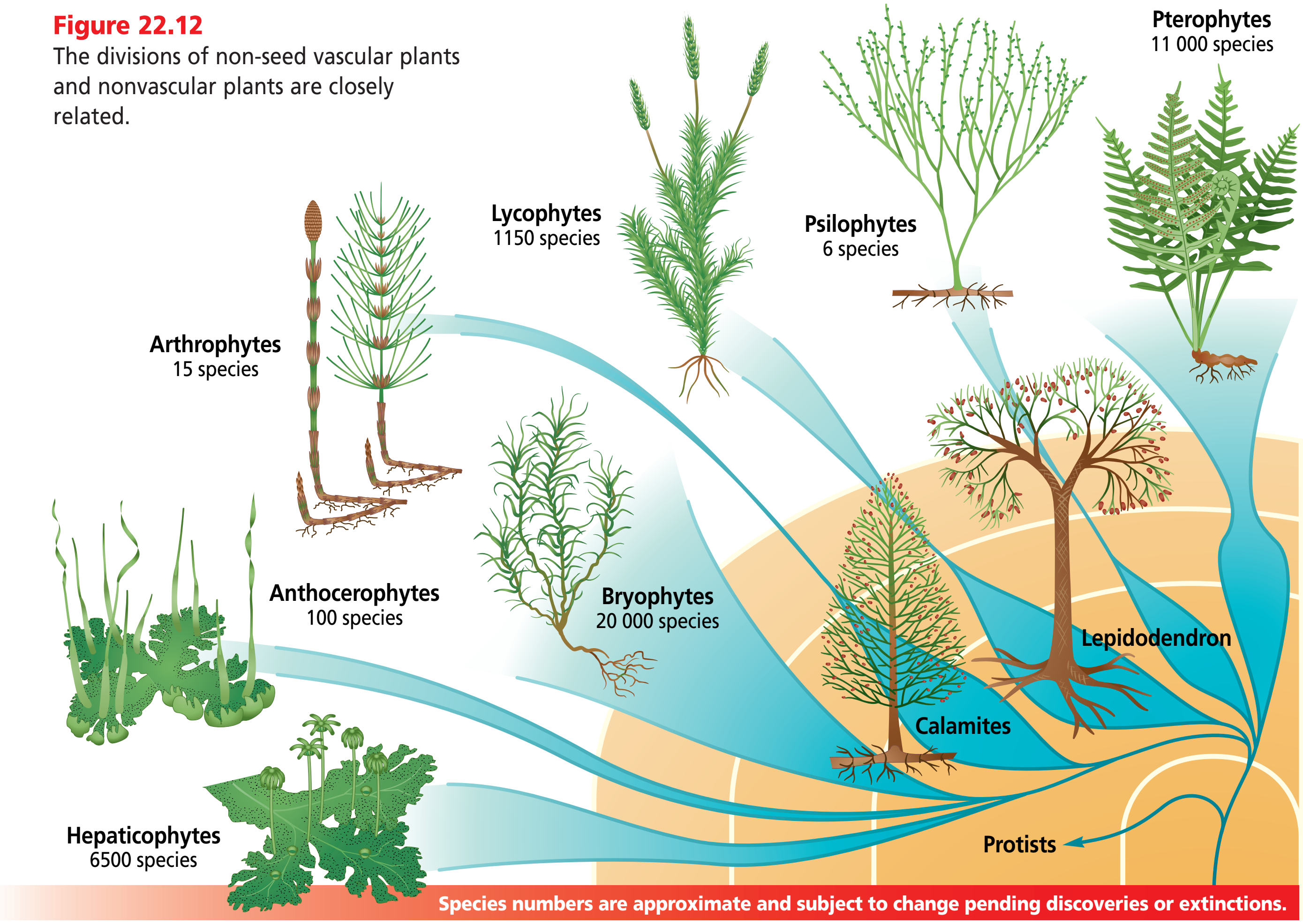
Figure 22.11
Sori found on the underside of fern fronds look like brown or rust-colored dust.


A Most sori are found as round clusters. The shape, color, and arrangement of clusters on a frond vary with fern species.


B Some species of ferns have sori on the edges of fronds.

CONTENTS

Figure 22.12
The divisions of non-seed vascular plants and nonvascular plants are closely related.



nonvascular plants are much smaller and less widespread in their distribution than their prehistoric ancestors.

The evolution of vascular tissue enabled these plants to live on land and to maintain larger body sizes in comparison with nonvascular plants. As you can infer from ***Figure 22.12***, non-seed vascular plants are closely related to nonvascular plants.

Section Assessment

Understanding Main Ideas

1. Explain why most non-seed vascular plants live in moist habitats.
2. Identify and analyze the characteristics of lycophyte and pterophyte sporophytes.
3. Compare and contrast non-seed vascular plants that exist today and those that lived in ancient forest communities.
4. What are the similarities and differences between the sporophyte of a non-seed vascular plant and the sporophyte of a nonvascular plant?
5. List the three structures common to all fern sporophytes and describe the function of each.

Thinking Critically

6. Hypothesize why there are fewer non-seed vascular plants today than there were 300 million years ago. Analyze, critique, and review your hypothesis as to its strengths and weaknesses based on scientific information.

Skill Review

7. **Observe and Infer** How do you think the presence of silica in the stems of arthrophytes might protect these plants from being eaten by animals? For more help, refer to *Observe and Infer* in the **Skill Handbook.**

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Section 22.3

Seed Plants

SECTION PREVIEW

Objectives

Identify and analyze the characteristics of seed plants.

Analyze the advantages of seed and fruit production.

Review Vocabulary

reproduction: production of offspring by an organism; a characteristic of all living things (p. 7)

New Vocabulary

pollen grain
ovule
embryo
cotyledon
fruit
deciduous plant
monocotyledon
dicotyledon
annual
biennial
perennial

. . . they're everywhere, they're everywhere . . .

Using Prior Knowledge Items derived from seed plants are a significant part of everyone's life. Cotton fabrics are woven from processed cottonseed fibers. Most paper begins as wood pulp, a product of seed plants. You eat seed plants and drink their products. Other organisms that eat seed plants are part of most diets. Products of seed plants are used in construction and manufacturing. Without seed plants, life on Earth would be impossible for most organisms.

Creative Writing *As a class, brainstorm and record items you use that are either seed plants or are derived from seed plants. Identify the seed plant(s) for each item. After reviewing your list, write a story about what your life would be like without seed plants.*

These girls are surrounded by items that are derived from seed plants.

What is a seed plant?

Some vascular plants produce seeds in which reduced sporophyte plants are enclosed within a protective coat. The seeds may be surrounded by a fruit or carried on the scales of a cone.

Seed plants produce spores

In seed plants, as in all other plants, spores are produced by the sporophyte generation. These spores develop into the male and female gametophytes. The male gametophyte develops inside a structure called a **pollen grain** that includes sperm cells, nutrients, and a protective outer covering. The female gametophyte, which produces the egg cell, is contained within a sporophyte structure called an **ovule.**

Fertilization and reproduction

The union of the sperm and egg, called fertilization, forms the sporophyte zygote. In most seed plants, this process does not require a continuous film of water as required by nonvascular and non-seed vascular plants. Remember that in non-seed plants, the sperm must swim through a continuous film of water in order to reach eggs in the archegonia of a gametophyte. Because they do not require a continuous film of water for fertilization, seed plants are able to grow and reproduce in a wide variety of habitats that have limited water availability.

Doug Martin

After fertilization, the zygote develops into an embryo. An **embryo** is an early stage of development of an organism. In plants, an embryo is the young diploid sporophyte stage of the plant. Embryos of seed plants include one or more cotyledons. **Cotyledons** (kah tuh LEE dunz) usually store or absorb food for the developing embryo. In conifers and many flowering plants, cotyledons are the leaflike structures on the plant's stem when the plant emerges from the soil.

Advantages of seeds

A seed consists of an embryo and its food supply enclosed in a tough, protective coat, as shown in ***Figure 22.13.*** Seed plants have several important advantages over non-seed plants. The seed contains a supply of food to nourish the young plant during the early stages of growth. This food is used by the plant until its leaves are developed enough to carry out photosynthesis. In conifers and some flowering plants, the embryo's food supply is stored in the cotyledons. The embryo is protected during harsh conditions by a tough seed coat. The seeds of many species are also adapted for easy dispersal to new areas. Then the new plants do not have to compete with their parent plant for sunlight, water, soil nutrients, and living space. You can learn more about seed structure in *MiniLab 22.2.*

MiniLab 22.2

Compare and Contrast

Comparing Seed Types Anthophytes are classified into two classes, the monocotyledons (monocots) and dicotyledons (dicots) based on the number of cotyledons.

Procedure

1. Copy the data table shown below.
2. Examine the variety of seeds given to you. Use forceps to gently remove the seed coat or covering from each seed if one is present.
3. Determine the number of cotyledons present. If two cotyledons are present, the seed will easily separate into two equal halves. If one cotyledon is present, it will not separate into halves. Record your observations in the data table.
4. Add a drop of iodine to each seed. Note the color change. Record your observations in the data table. **CAUTION:** ***Wash your hands with soap and water after handling chemicals.***

Data Table

Seed Name	Number of Cotyledons	Monocot or Dicot	Color with Iodine
Lima bean			
Rice			
Pea			
Rye			

Analysis

1. **Observe** Starch turns purple when iodine is added to it. Describe the color change when iodine was added to each seed.
2. **Form a Hypothesis** Why do seeds contain stored starch?

Figure 22.13
Seeds exhibit a variety of structural adaptations.

A A tough seed coat protects some pine seeds until favorable conditions exist for germination. As growth begins, the seed coat breaks down and eventually drops off.

B The feathery tuft attached to milkweed seeds aids in their dispersal.

A

B

Figure 22.14
Cycads have a terminal rosette of leaves. Male cones **(A)** produce pollen grains that are released in great masses into the air. Female cones **(B)** contain ovules with eggs.

Diversity of seed plants

In some plants, seeds develop on the scales of woody strobili called cones. This group of plants is sometimes referred to as gymnosperms. The term gymnosperm means "naked seed" and is used with these plants because their seeds are not protected by a fruit. The gymnosperm plant divisions you will learn about are Cycadophyta, Ginkgophyta, Gnetophyta, and Coniferophyta.

Flowering plants, also called angiosperms, produce seeds enclosed within a fruit. A **fruit** includes the ripened ovary of a flower. The fruit provides protection for seeds and aids in seed dispersal. The Anthophyta division contains all species of flowering plants.

Figure 22.15
Unlike cycads, the seeds of the ginkgo develop a fleshy outer covering **(A)**. The ginkgo is sometimes called the maidenhair tree because its lobed leaves **(B)** resemble the fronds of a maidenhair fern.

Adaptations in Cycadophyta

About 100 species of cycads exist today, exclusively in the tropics and subtropics. The only present-day species that grows wild in the United States is found in Florida, although you may see cycads cultivated in greenhouses or botanical gardens.

Cycads have male and female reproductive systems on separate plants, as shown in ***Figure 22.14.*** The male system includes cones that produce pollen grains, which produce motile sperm. Cycads are one of the few seed plants that produce motile sperm. The female system includes cones that produce ovules. The trunks and leaves of many cycads resemble those of palm trees, but cycads and palms are not closely related because palms are anthophytes.

Adaptations in Ginkgophyta

Today, this division is represented by only one living species, *Ginkgo biloba.* All ginkgoes are cultivated trees, and they are not known to exist in the wild. Like cycads, ginkgo male and female reproductive systems are on separate plants. The male ginkgo produces pollen grains in strobiluslike cones that grow from the bases of leaf clusters. Also like cycads, ginkgo pollen grains produce motile sperm. The female ginkgo produces ovules which, when fertilized, develop fleshy, apricot-colored seed coats, as shown in ***Figure 22.15.*** These soft seed coats give off a foul odor when broken or crushed. Ginkgoes often are planted in urban areas because they tolerate smog and pollution. Gardeners and landscapers usually only plant male gingkoes because they do not produce seeds with soft

(t)E.F. Anderson/Visuals Unlimited (c)Andrew Henderson/Photo/Nats

(bl)Runk-Schoenberger/Grant Heilman Photography (br)Alfred Pasieka/Science Photo Library/Photo Researchers seed coats. Do the *BioLab* at the end of this chapter to explore what other trees are planted in urban areas.

Reading Check **Infer** what structural adaptations give ginkgoes a tolerance of urban environments.

Adaptations in Gnetophyta

Most living gnetophytes can be found in the deserts or mountains of Asia, Africa, North America, and Central and South America. The division Gnetophyta contains only three genera, which have different structural adaptations to their environments. The genus *Gnetum* is composed of tropical climbing plants. The genus *Ephedra* contains shrublike plants and is the only gnetophyte genus found in the United States. The third genus, *Welwitschia*, is a bizarre-looking plant found only in South Africa. It grows close to the ground, has a large tuberous root, and may live 1000 years. *Ephedra* and *Welwitschia* are pictured in ***Figure 22.16.***

Adaptations in Coniferophyta

The sugar pine is one of many familiar forest trees that belong to the division Coniferophyta. The conifers are trees and shrubs with needlelike or scalelike leaves. They are abundant in forests throughout the world, and include pine, fir, spruce, juniper, cedar, redwood, yew, and larch.

The reproductive structures of most conifers are produced in cones. Most conifers have male and female cones on different branches of the same tree. The male cones produce pollen. They are small and easy to overlook. Female cones are much larger. They stay on the tree until the seeds have matured. Examples of both types of cones are shown in ***Figure 22.17.***

Figure 22.16
Most gnetophytes have separate male and female plants.

A Members of the genus *Ephedra* are a source of ephedrine, a medicine used to treat asthma, emphysema, and hay fever.

B *Welwitschia* may live 1000 years. The plant has only two leaves, which continue to lengthen as the plant grows older.

Figure 22.17
Male and female cones of conifers differ in structure and function.

A Male cones are made up of thin papery scales that disintegrate soon after the cones open and shed clouds of pollen grains.

B In many conifers, including spruce, two seeds develop at the base of each of the woody scales that make up a female cone.

CONTENTS

Figure 22.18 Most conifers are evergreen plants.

A The Douglas fir is one of the most important lumber trees in North America. It grows straight and tall, to a height of about 100 m.

B Spruce trees are popular ornamental trees because of their graceful shape and color variations.

Evergreen conifers

Most conifers, like those pictured in ***Figure 22.18***, are evergreen plants—plants that retain some of their leaves for more than one year. Although individual leaves drop off as they age or are damaged, the plant never loses all of its leaves at one time.

Plants that retain some of their leaves year-round can photosynthesize whenever favorable environmental conditions exist. This is an advantage in environments where the growing season is short. Another advantage of leaf retention is that a plant's food reserves are not depleted each spring to produce a whole set of new leaves.

Evergreen leaves usually have a heavy coating of cutin, a water-insoluble, waxy material that helps reduce water loss. For conifers, leaf shape—needlelike or scalelike—also helps reduce water loss. To learn more about conifer needles, see ***Figure 22.20*** on the next page.

Figure 22.19 Some trees, including these bald cypress trees, lose their leaves in the fall as an adaptation for reducing water loss.

Deciduous trees lose their leaves

A few conifers, including larches and bald cypress trees, are deciduous, ***Figure 22.19***. **Deciduous plants** drop all their leaves each fall or when water is scarce or unavailable as in the tundra or in deserts. Plants lose most of their water through the leaves; very little is lost through bark or roots. Dropping all leaves is an adaptation for reducing water loss. However, a tree with no leaves cannot photosynthesize and must remain dormant during this time.

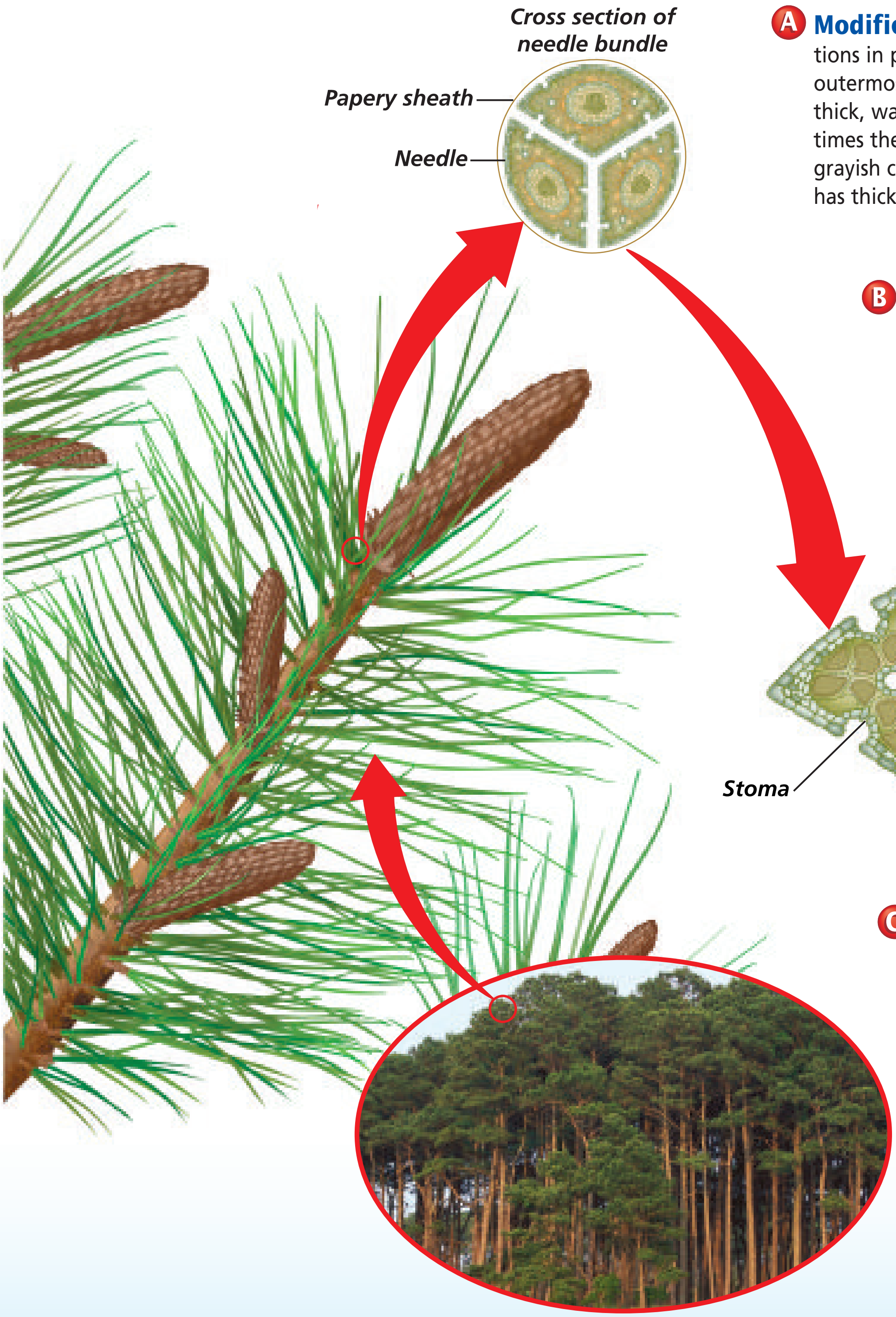
Word Origin

deciduous from the Latin word *decidere,* meaning to "fall off"; Deciduous trees drop all of their leaves at the end of the growing season.

Pine Needles

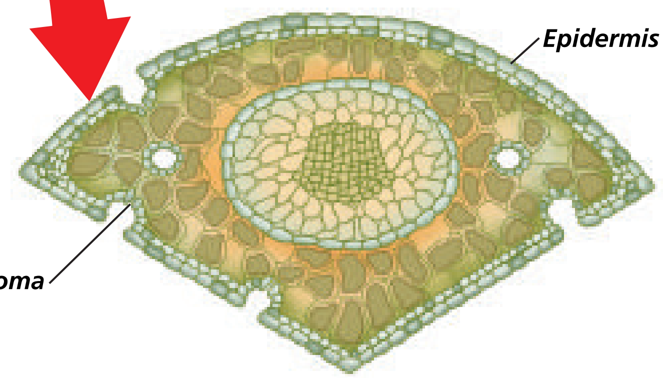
Figure 22.20

When you look at a snow-covered pine forest, you may be surprised to learn that winter can be considered a dry time for plants. The cold temperature means that the soil moisture is unavailable because it is frozen. The needles of pines have several adaptations that enable the plants to conserve water during the cold dry winter and the dry heat of the summer. **Critical Thinking** ***How does the structure of pine needles enhance the survival of conifers during hot and dry summers as well as cold and snowy winters?***



A Modified leaf cells There are leaf-cell modifications in pine needles that help reduce water loss. The outermost layer of cells, called the epidermis, has a thick, waxy, waterproof coating called a cuticle. Sometimes the cuticle is so thick that it gives needles a grayish color. The layer of cells just below the epidermis has thick cell walls that also help to reduce water loss.

B Bundles of needles The needles of pines usually grow in bundles of two, three, or five needles. The number of needles per bundle and the shape of needles are genetically determined. A papery sheath surrounds the base of each bundle.



C Recessed stomata A pine-needle stoma is located in a recessed cavity of the epidermis. This position provides more protection from harsh environmental conditions than on the surface of the epidermis. The result is reduced water loss from leaf tissues.

Kenneth J. Stein, Ph.D./ Phototake

Figure 22.21
A florist's display is a good place to see an assortment of flowering plants.

Adaptations in Anthophyta

Flowering plants are classified in the division Anthophyta. They are the most well-known plants on Earth with more than 250 000 identified species. See if you are familiar with some of the plants in ***Figure 22.21.*** Like other seed plants, anthophytes have roots, stems, and leaves. But unlike the other seed plants, anthophytes produce flowers and form seeds enclosed in a fruit. Many different species of flowering plants inhabit tropical forests. As you will discover in *Biology and Society* at the end of this chapter, different groups of people have different viewpoints on preserving this rich habitat.

Fruit production

Anthophyta is unique among plant divisions. It is the only division in which plants have flowers and produce fruits. A fruit develops from a flower's female reproductive structure(s). Sometimes, other flower parts become part of the fruit and, as in pineapples, the fruit develops from more than one flower. A fruit usually contains one or more seeds. One of the advantages of fruit-enclosed seeds is the added protection the fruit provides for the young embryo.

Fruits often aid in the dispersal of seeds. Animals may eat them or carry them off to store for food. Seeds of some species that are eaten pass through the animal's digestive tract unharmed and are distributed as the animal wanders. In fact, some seeds must pass through a digestive tract before they can begin to grow a new plant. Some fruits have structural adaptations that help disperse the seed by wind or water. Some examples of fruits are illustrated in ***Figure 22.22.***

Figure 22.22
Fruits exhibit a wide variety of structural adaptations that aid in seed protection and dispersal.

A The maple fruit has a winglike structure that helps keep it airborne.

B The fruit of a magnolia contains many seeds each with a bright red covering that attracts birds and small animals.

C The tough fibrous fruit of a coconut provides protection as well as a flotation device.

Monocots and dicots

The division Anthophyta is divided into two classes: monocotyledons and dicotyledons. The two classes are named for the number of cotyledons in the seed. **Monocotyledons** (mah nuh kah tuh LEE dunz) have one seed leaf; **dicotyledons** (di kah tuh LEE dunz) have two seed leaves. These two classes often are called monocots and dicots. ***Table 22.1*** compares the characteristics of monocots and dicots. About 65 000 species of monocots have been identified and include grasses, orchids, lilies, and palms. Identified dicot species number about 185 000. They include nearly all of the familiar shrubs and trees (except conifers), cacti, wildflowers, garden flowers, vegetables, and herbs.

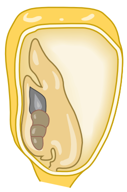
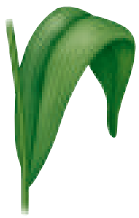
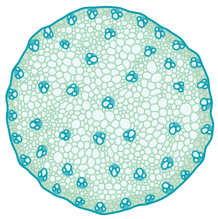
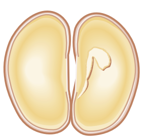
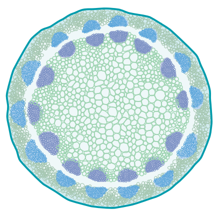
Life spans of anthophytes

Why do some plants live longer than people, and others live only a few weeks? The life span of a plant is genetically determined and reflects strategies for surviving periods of harsh conditions.

Annual plants live for only a year or less. They sprout from seeds, grow, reproduce, and die in a single growing season. Most annuals are herbaceous, which means their stems are green and do not contain woody tissue. Many food plants such as corn, wheat, peas, beans, and squash are annuals, as are many weeds of the temperate garden. Annuals form drought-resistant seeds that can survive the winter.

Biennial plants have life spans that last two years. Many biennials develop large storage roots, such as carrots, beets, and turnips. During the first year, biennials grow many leaves and develop a strong root system. Over the winter, the aboveground portion of the plant dies back, but the roots remain alive. Under ground roots are able to survive conditions that leaves and stems cannot endure. During the second spring, food stored in the root is used to produce new shoots that produce flowers and seeds.

Table 22.1 Distinguishing Characteristics of Monocots and Dicots

	Seed Leaves	Vascular Bundles in Leaves	Vascular Bundles in Stems	Flower Parts
Monocots	One cotyledon 	Usually parallel 	Scattered 	Multiples of three 
Dicots	Two cotyledons 	Usually netlike 	Arranged in ring 	Multiples of four and five 

Careers in Biology

Lumberjack

If you like to spend time in the forest, consider a career as a lumberjack or a logging industry worker. Besides being outdoors, you will get lots of exercise.

Skills for the Job

The logging industry now includes many different workers. Cruisers choose which trees to cut. Fallers use chainsaws and axes to cut, or "fell," the chosen trees. Buckers saw off the limbs and cut the trunk into pieces. Logging supervisors oversee these tasks. Other workers turn the tree into logs or wood chips that are used to make paper. After finishing high school, most loggers learn on the job. However, with a two-year degree, you can become a forest technician. A four-year degree qualifies you as a professional forester who manages the forest resources. Most logging jobs are in the Northwest, Northeast, South, and Great Lakes regions.

For more careers in related fields, visit ca.bdol.glencoe.com/careers

Perennials live for several years, producing flowers and seeds periodically—usually once each year. Some survive harsh conditions by dropping their leaves or dying back to soil level, while their woody stems or underground storage organs remain intact and dormant. Examples of plants with different lifespans are shown in *Figure 22.23.*

Origins of Seed Plants

Seed plants first appeared about 360 million years ago during the Paleozoic Era. Some seed plants, such as ancient relatives of cycads and ginkgoes, shared Earth's forest with

Figure 22.23
Anthophytes may be annuals, biennials, or perennials.

A Vegetable gardeners grow biennial parsley for its leaves.

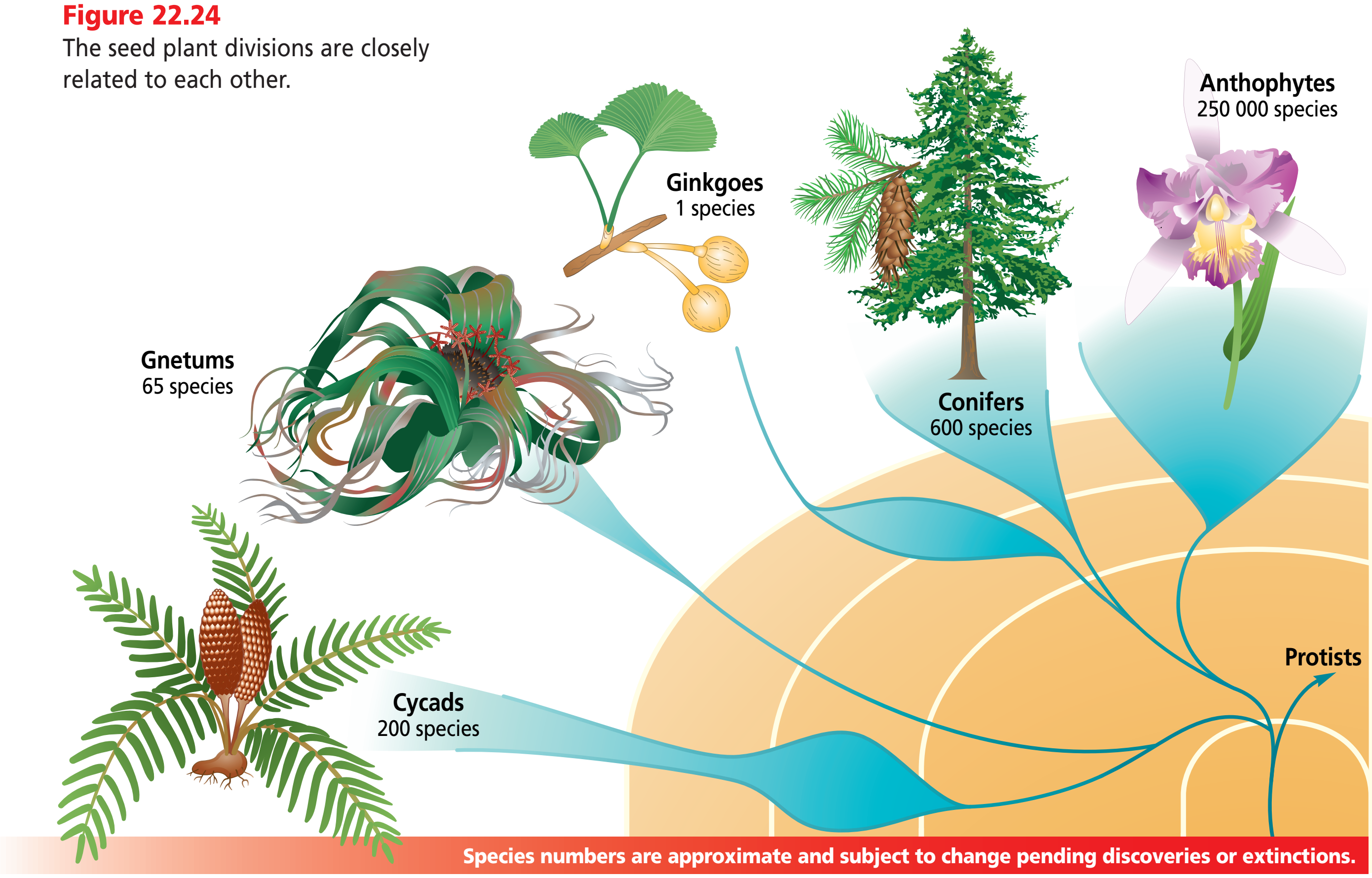
B Some woody perennials, like brambles, drop their leaves and become dormant during the winter.

C These tomatoes are annual plants.

D Herbaceous perennials often have underground storage organs used for overwintering.

(t)Inga Spence/Tom Stack & Associates (bl)Jane Grusho/Grant Heilman Photography (bc)R. Calentine/Visuals Unlimited
(bcr)Runk-Schoenberger/Grant Heilman Photography (br)Fred Whitehead/Earth Scenes

Figure 22.24
The seed plant divisions are closely related to each other.



the dinosaurs during the Mesozoic Era. However, about 65 million years ago, most members of the Ginkgophyta died out along with many organisms during a mass extinction.

According to fossil evidence, the first conifers emerged around 250 million years ago. During the Jurassic Period, conifers became predominant forest inhabitants and remain so today.

Anthophytes first appeared about 140 million years ago late in the Jurassic Period of the Mesozoic Era.

The evolutionary relationships among the divisions of vascular seed plants are illustrated in ***Figure 22.24.***

Section Assessment

Understanding Main Ideas

1. Identify two adaptations that help seed plants reproduce on land.
2. Explain why needlelike leaves are an adaptation in climates where water may be a limited resource.
3. What adaptations help make flowering plants so successful?
4. Compare and contrast characteristics of anthophytes and coniferophytes.

Thinking Critically

5. Infer why the development of the seed might have affected the lives of herbivorous animals living in Earth's ancient forests.

Skill Review

6. **Get the Big Picture** Compare the formation of a spore in ferns and a seed in conifers. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

ca.bdol.glencoe.com/self_check_quiz

INTERNET
BioLab

Researching Trees on the Internet

Before You Begin

Imagine that you are employed as a forester in a city's department of Urban Planning. You have just been handed an assignment by the city manager. The assignment? Research the types of trees that would be most suitable for planting along the streets of your community.

Preparation

Problem

Use the Internet to find different tree species that would be suitable for planting along the streets in your community.

Objectives

In this BioLab, you will:

- **Research** the characteristics of five different tree species.
- **Use the Internet** to collect and compare data from other students.
- **Conclude** which tree species would be most suitable for planting along the streets in your community.

Materials

Internet access

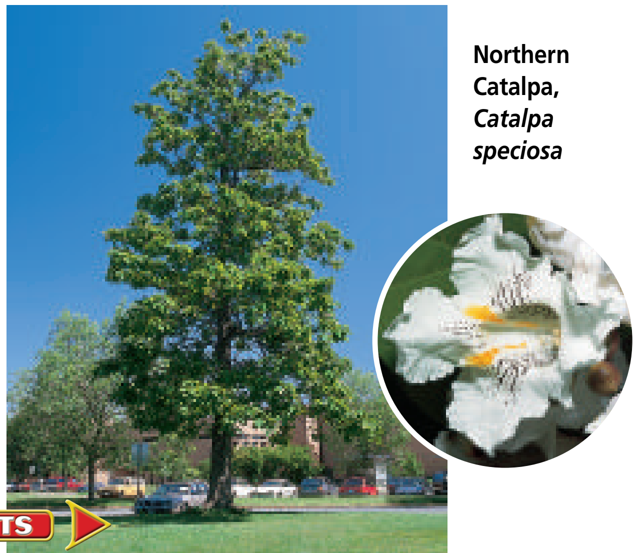
Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

Procedure

1. Make a copy of the data table.
2. Pick five tree species that you wish to research. (Note: Your teacher may provide you with suggestions if necessary.)
3. Visit ca.bdol.glencoe.com/internet_lab to find links to information needed for this BioLab.
4. Record the information in your data table.

California redbud, *Cercis occidentalis*



Northern Catalpa, *Catalpa speciosa*

(bl)Kennan Ward/DRK Photo (bcl)D. Cavagnaro/DRK Photo (bcr)Jim Strawser/Grant Heilman Photography (br)R.J. Erwin/Photo Researchers

Data Table

	1	2	3	4	5
Tree name (common name)					
Scientific name					
Division					
Soil/Water preference					
Temperature tolerance					
Height at maturity					
Rate of growth					
General shape					
Diseases/Pests					
Special care					
Deciduous or evergreen					
Additional information					

Flowering dogwood, *Cornus florida*

Southern Magnolia, *Magnolia grandiflora*

Analyze and Conclude

1. **Define Operationally** Explain the difference between trees classified as either Coniferophyta or Anthophyta.
2. **Analyze** Was the information provided on the Internet helpful in completing your data table? Explain your answer.
3. **Think Critically** What do you consider to be the most important characteristic when deciding on the most suitable tree for your community? Explain your answer.
4. **Use the Internet** Using the information you gathered from the Internet, which tree species would most likely be the:
   - **a.** most suitable along a street in your community? Explain your answer.
   - **b.** least suitable along a street in your community? Explain your answer.
5. **Apply** Explain why tree selections would differ if your community were located in:
   - **a.** a desert biome
   - **b.** a taiga biome
   - **c.** a tropical rain forest biome

Share Your Data

Classify Find this BioLab using the link below, and post your findings in the table provided for this activity. Using the additional data from other students on the Internet, prepare a dichotomous key that allows you to identify your five trees.

ca.bdol.glencoe.com/internet_lab

(tl)Jerome Wyckoff/Earth Scenes (tr)Doug Wechsler/Earth Scenes (bl)Dick Keen/Visuals Unlimited (br)Michael A. Dirr, University of Georgia, Athens

Biology and Society

Environment: Keeping a Balance

Tropical rain forests are Earth's most biologically diverse ecosystems. Many people live within areas of tropical rain forests and most depend directly or indirectly on the extraction of resources from them through mining, growing crops, ranching, and timber harvesting. This has resulted in the loss of large areas of these forests each year.

Agriculture in rain forests Traditional methods of growing crops, ranching, and tree harvesting involved clearing land of tropical rain forest vegetation in order to provide space to grow crops, allow plants to grow as food for cattle, or to remove the most economically valuable trees. Often referred to as slash-and-burn agriculture, the land was cleared then used for agriculture until the soil's nutrients were depleted, after which it was abandoned to allow the regrowth of trees and other plants. This system worked as long as the removal rate of the forest vegetation did not exceed the recovery rate of the forest vegetation.

Logged rain forest

A sustainable harvest Thousands of plant species grow in tropical rain forests, yet only a few species are considered valuable. Many ecologists and conservation groups are working to promote more sustainable alternatives to obtaining resources from tropical rain forests. Agroforestry—an ecological approach to land use that integrates the use of trees on individual farms and in entire regions—has been used for centuries to manage land for trees, crops, and animals together. The philosophy behind agroforestry is to maintain more of the tropical rain forest's structure and function while providing food and other resources for the farmer, such as wood that can be used or sold. In many areas where trees have been removed, new trees have been planted that do not compete with crops. This creates a more diverse and sustainable system. While agroforestry does not prevent the loss of species, it is hoped that by using more sustainable agricultural methods less tropical rain forest will be slashed and burned in the future.

Perspectives Only a small fraction of the world's tropical rain forests are managed sustainably. Efforts are being made to promote agroforestry and other agricultural practices. However, not all trees and crops are suited to an agroforestry system, and agroforestry still results in a reduction of biodiversity because many plants are removed from the understory to prevent competition with crops.

Forming Your Opinion

Analyze Brainstorm in groups for reasons why some trees may be suited for agroforestry while others are not. Discuss the link between agriculture and the loss of tropical forests. How might more sustainable agricultural methods decrease rain forest destruction? Analyze, critique, and review your explanations as to their strengths and weaknesses using scientific information and evidence.

To find out more about rain forest destruction and sustainable forestry, visit ca.bdol.glencoe.com/biology_society

Study Guide

Section 22.1

Nonvascular Plants

Key Concepts

- Nonvascular plants lack vascular tissue and reproduce by producing spores. The gametophyte generation is dominant.
- There are three divisions of nonvascular plants: Bryophyta, Hepaticophyta, and Anthocerophyta.

Vocabulary

archegonium (p. 578)
antheridium (p. 578)

Section 22.2

Non-Seed Vascular Plants

Key Concepts

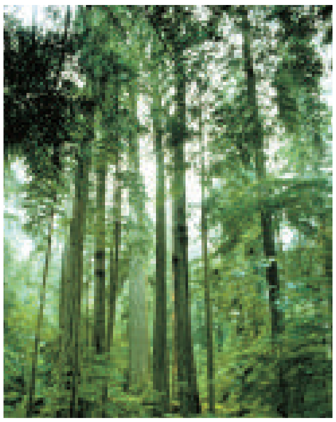
- The non-seed vascular plants were predominant in Earth's ancient forests. They are represented by modern species.
- Vascular tissues provide the structural support that enables vascular plants to grow taller than nonvascular plants.
- There are three divisions of non-seed vascular plants: Lycophyta, Arthrophyta, and Pterophyta.

Vocabulary

prothallus (p. 582)
rhizome (p. 585)
sorus (p. 586)
strobilus (p. 582)

Section 22.3

Seed Plants



Key Concepts

- Seeds contain a supply of food to nourish the young plant, protect the embryo during harsh conditions, and provide methods of dispersal.
- There are four divisions of vascular plants that produce naked seeds: Cycadophyta, Gnetophyta, Ginkgophyta, and Coniferophyta.
- Anthophytes produce flowers and have seeds enclosed in a fruit.
- Fruits provide protection for the seeds and aid in their dispersal.
- Anthophytes are either monocots or dicots based on the number of cotyledons present in the seed.
- Anthophytes may be annuals, biennials, or perennials.

Vocabulary

annuals (p. 595)
biennials (p. 595)
cotyledon (p. 589)
deciduous plant (p. 592)
dicotyledons (p. 595)
embryo (p. 589)
fruit (p. 590)
monocotyledons (p. 595)
ovule (p. 588)
perennials (p. 596)
pollen grain (p. 588)

FOLDABLES Study Organizer To help you review the diversity of plants, use the Organizational Study Fold on page 577.

ca.bdol.glencoe.com/vocabulary_puzzlemaker

Chapter 22 Assessment

Vocabulary Review

Review the Chapter 22 vocabulary words listed in the Study Guide on page 601. Match the words with the definitions below.

1. the thick underground stem of a fern
2. gametophyte's female reproductive structure in which eggs develop
3. gametophyte of a fern
4. seed structure that stores food for the embryo
5. anthophyte that has a life span of two years

Understanding Key Concepts

6. Bryophytes, hepaticophytes, and anthocerophytes are the three divisions of ________ plants.
   A. vascular **C.** nonvascular
   B. seed **D.** evergreen
7. Lycophytes include ________.
   A. ferns **C.** mosses
   B. conifers **D.** club mosses
8. Anthophytes and coniferophytes are divisions that are BOTH ________.
   A. vascular and seed-producing
   B. vascular and non-seed
   C. nonvascular and non-seed
   D. nonvascular and seed-producing
9. Vascular tissue is important to a plant because it ________.
   A. anchors it in the soil
   B. reproduces
   C. transports water and nutrients
   D. photosynthesizes
10. The plant in the photograph is a(n) ________.
   A. Anthophyte
   B. Pterophyte
   C. Arthrophyte
   D. Gnetophyte

11. The gametophyte generation is dominant in which of the following plants?
   A. pine trees **C.** apple trees
   B. ferns **D.** mosses
12. Which of the following is NOT a part of a seed?
   A. gametophyte **C.** food supply
   B. protective coat **D.** embryo
13. An orange tree would be classified in the same division as which of the following?
   A. pine tree **C.** cycad
   B. moss **D.** sunflower

Constructed Response

14. **Open Ended** Evaluate the significance of the adaptation—fertilization that does not require a film of water for sperm to reach the egg—for land plants.
15. **Open Ended** Cycads and ginkgoes do not have needlelike leaves like pines and spruces do. For these coniferophytes, explain the significance of leaf shape as an adaptation to the biomes in which they grow.
16. **Open Ended** What might be the advantage of having the sporophyte dependent on the gametophyte?

Thinking Critically

17. **Observe and Infer** Examine the needle cross section in ***Figure 22.20***. Infer how the position of stomata helps reduce water loss.
18. **REAL WORLD BIOCHALLENGE** Forests are essential to our economy and for the preservation of biodiversity. Visit ca.bdol.glencoe.com to investigate what is being done to preserve biodiversity of forest resources near you. Make a map of one area and indicate where projects are planned or are in place that help preserve biodiversity.
19. **Concept Map** Construct a concept map that shows the relationships among the following terms: eggs, prothallus, archegonia, antheridia, sperm, fern, gametophyte.

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CONTENTS

Chapter 22 Assessment

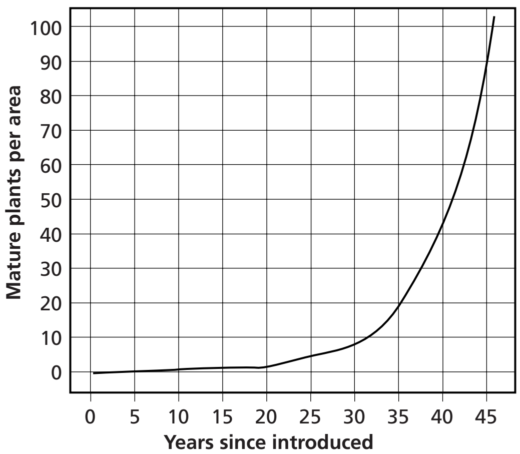
California Standards Practice

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Russian olive is an introduced, nonnative seed plant that is crowding out native plants in certain parts of the United States. Study the graph below and answer questions 20–22.

Russian Olive Plants Over Time



20. How many years does it take for there to be 50 mature Russian olive plants in an area?

A. 45 **C.** 40
B. 100 **D.** none of these

21. After an area has 50 mature plants, how many years must pass before there are 100 mature plants?

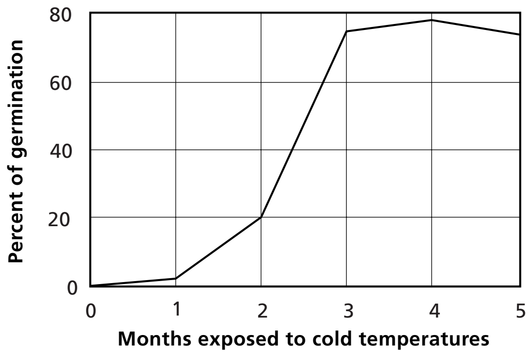
A. 45 **C.** 15
B. 5 **D.** 25

22. The general pattern of development and establishment of Russian olive plants in an area can be described as ________.

A. fast for many years then slow thereafter
B. slow for many years then a rapid increase
C. steady throughout its time in an area
D. very rapid from the start

Use the graph below to answer questions 23 and 24.

Seed Germination Rate After Exposure to Cold



23. What would be the minimum time you would keep the experimental seeds under refrigeration before planting?

A. 1 month **C.** 6 months
B. 3 months **D.** 80 months

24. How long does it take to get 50 percent germination?

A. 2½ months **C.** 1 month
B. 6 months **D.** 4 months

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

25. **Open Ended** Which two plant divisions do you think are the most important? Why?

26. **Open Ended** On gametophytes of certain mosses, the outer surfaces of cells are curved, as shown to the right. Describe the environment of mosses with such an adaptation.