22–1 Introduction to Plants

What color is life? That's a silly question, of course, because living things can be just about any color. But consider it in a different way. Imagine yourself in a place on Earth where the sounds and scents of life are all around you. The place is so abundant with life that when you stand on the ground, living things blot out the sun. Now, what color do you see? If you have imagined a thick forest or a teeming jungle, then one color will fill the landscape of your mind—green—the color of plants.

Plants dominate the landscape. Where plants are plentiful, other organisms, such as animals, fungi, and microorganisms, take hold and thrive. Plants provide the base for food chains on land. They also provide shade, shelter, and oxygen for animals of every size and kind. The oldest fossil evidence of plants dates from about 470 million years ago. Since then, plants have colonized and transformed nearly every corner of Earth.

Guide for Reading

Key Concepts
- What is a plant?
- What do plants need to survive?
- How did the first plants evolve?

Vocabulary
sporophyte
gametophyte

Reading Strategy: Using Prior Knowledge
Before you read the chapter, make a list of the different groups of plants that you know. As you read, revise your list to include new information about plant groups.

What Is a Plant?

Plants are members of the kingdom Plantae. **Plants are multicellular eukaryotes that have cell walls made of cellulose. They develop from multicellular embryos and carry out photosynthesis using the green pigments chlorophyll *a* and *b*.** Plants include trees, shrubs, and grasses, as well as other organisms, such as mosses and ferns. Most plants, including the one in **Figure 22–1,** are autotrophs, although a few are parasites or saprobes that live on decaying materials.

Plants are so different from animals that sometimes there is a tendency to think of them as not being alive. With few exceptions, plants do not gather food nor do they move about or struggle directly with their predators. Plants can neither run away from danger nor strike blows against an adversary. But as different as they are from animals, plants are everywhere. How have they managed to be so successful?

That question has many answers. In the next few chapters, we will explore some of them. For now, it might help to think of plants as a well-known botanist once described them—as "stationary animals that eat sunlight"!

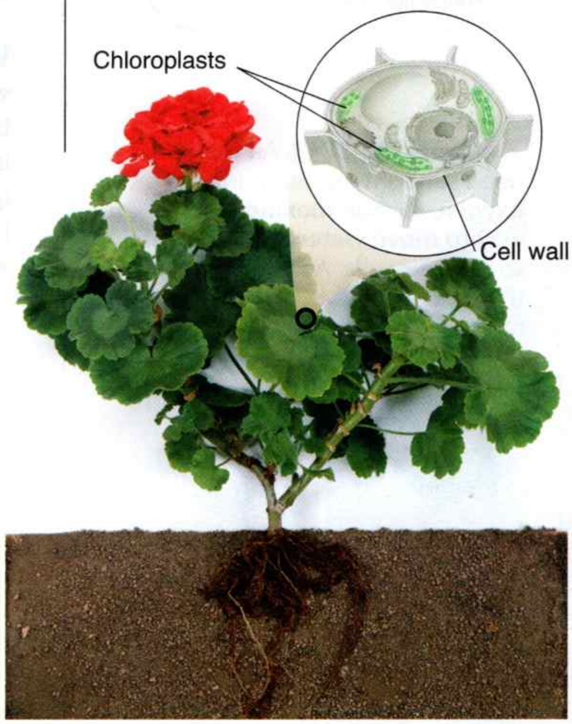
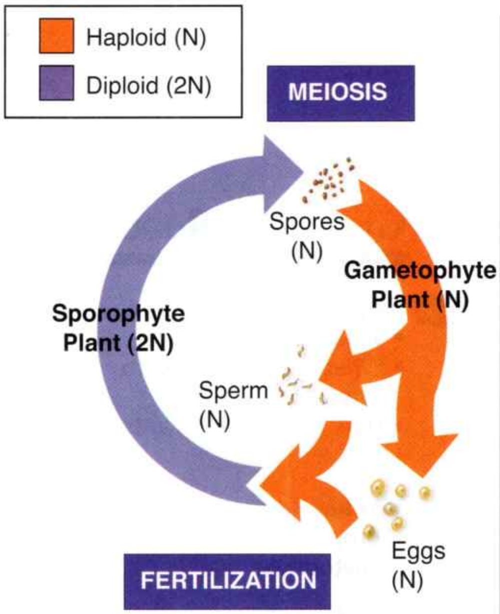


Figure 22–1 **All plants are multicellular eukaryotes that have cell walls made of cellulose.** Their leaves appear green because of the photosynthetic pigments chlorophyll *a* and *b*, which are located in chloroplasts.



▲ **Figure 22–2** All plants have a life cycle with alternation of generations, in which the haploid gametophyte phase alternates with the diploid sporophyte phase.

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▼ **Figure 22–3 All plants need sunlight, water, minerals, oxygen, carbon dioxide, and a way to move water and nutrients to all their cells.** Adaptations allow them to live in even the driest locations, such as this desert.

The Plant Life Cycle

Plant life cycles have two alternating phases, a diploid (2N) phase and a haploid (N) phase, known as alternation of generations. During the two phases of the life cycle, shown in **Figure 22–2,** mitosis and meiosis alternate to produce the two types of reproductive cells—gametes and spores. The diploid (2N) phase is known as the **sporophyte,** or spore-producing plant. The haploid (N) phase is known as the **gametophyte,** or gamete-producing plant. Plant spores are haploid (N) reproductive cells formed in the sporophyte plant by meiosis that can grow into new individuals. The new individual is the gametophyte. A gamete is a reproductive cell that is produced by mitosis and fuses during fertilization with another gamete to produce a new individual, the diploid sporophyte.

The earliest plants, mosses and ferns, require water to reproduce. Seed plants, which appeared more recently, have reproductive cycles that can be carried out without water. Many plants also have forms of vegetative, or asexual, reproduction.

What Plants Need to Survive

Surviving as stationary organisms on land is a difficult task, but plants have developed a number of adaptations that enable them to succeed. **The lives of plants center on the need for sunlight, water and minerals, gas exchange, and the transport of water and nutrients throughout the plant body.**

Sunlight Plants use the energy from sunlight to carry out photosynthesis. As a result, every plant displays adaptations shaped by the need to gather sunlight. Photosynthetic organs such as leaves are typically broad and flat and are arranged on the stem so as to maximize light absorption.

Water and Minerals All cells require a constant supply of water. For this reason, plants must obtain and deliver water to all their cells—even those that grow aboveground in the dry air. Water is one of the raw materials of photosynthesis, so it is used up quickly when the sun is shining. Sunny conditions can cause living tissues to dry out. Thus, plants have developed structures that limit water loss. As they absorb water, plants also absorb minerals. Minerals are nutrients in the soil that are needed for plant growth.

Gas Exchange Plants require oxygen to support cellular respiration as well as carbon dioxide to carry out photosynthesis. They must exchange these gases with the atmosphere without losing excessive amounts of water through evaporation.

Movement of Water and Nutrients Plants take up water and minerals through their roots but make food in their leaves. Most plants have specialized tissues that carry water and nutrients upward from the soil and distribute the products of photosynthesis throughout the plant body. Simpler types of plants carry out these functions by diffusion.

Problem Solving

"Plantastic" Voyage

You are part of a team that is planning a space mission that will send astronauts into space for two years. As part of their food, the astronauts will be growing yam plants, *Dioscorea composita*. Your job is to develop a plan to help plants grow on the spacecraft.

Defining the Problem In your own words, state the problem at hand.

Organizing Information Research the types of conditions these plants would need. What requirements would the plants have for moisture? Soil conditions? Light intensity? Day length?

Creating a Solution Make a detailed scale drawing of a container for growing 10 of these plants. (*Dioscorea* plants are vines; assume that each is 10 cm long and 0.5 cm wide.) Determine what material(s) you will use for your container. As you devise your plan, be sure to keep a journal in which you record your team's ideas, drawings, data, and other information.

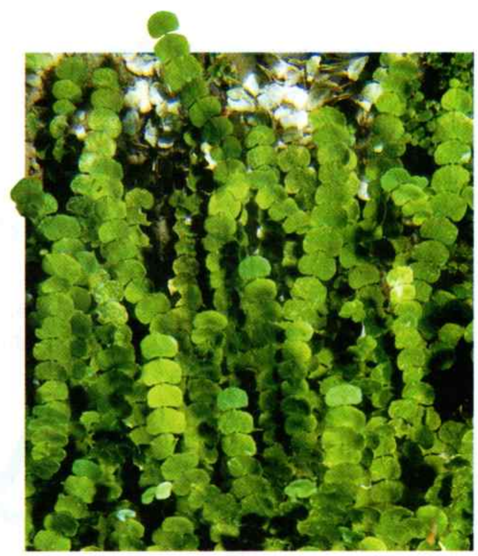
Presenting Your Plan Prepare a multimedia presentation for your classmates as if they were the managers of the space mission. Describe how your team solved the problem, the sources of information you used, the design itself, and what you learned during the project.

Early Plants

For most of Earth's history, plants did not exist. Life was concentrated in oceans, lakes, and streams. Algae and photosynthetic prokaryotes added the oxygen to our planet's atmosphere and provided food for animals and microorganisms.

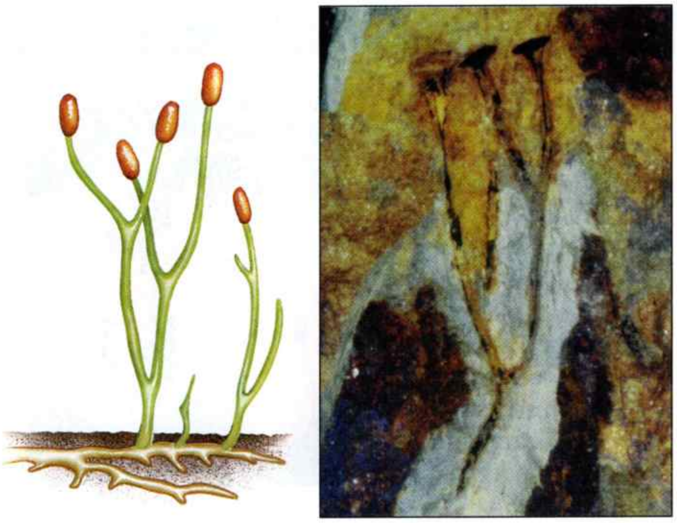
When plants appeared, much of the existing life on Earth changed. As these new photosynthetic organisms colonized the land, they changed the environment in ways that made it possible for other organisms to develop. New ecosystems emerged, and organic matter began to form soil. How did plants adapt to the conditions of life on land? How plants evolved structures that acquire, transport, and conserve water is the key to answering this question.

Origins in the Water You may recall from Chapter 20 that green algae, shown in **Figure 22–4**, are photosynthetic, plantlike protists. Many of these algae are multicellular. **The first plants evolved from an organism much like the multicellular green algae living today.** Multicellular green algae have the size, color, and appearance of plants. But the resemblance of many green algae to plants is more than superficial. They have reproductive cycles that are similar to those of plants. In addition, green algae have cell walls and photosynthetic pigments that are identical to those of plants.



▲ **Figure 22–4 The first plants evolved from an organism much like the modern multicellular green algae.** The alga *Halimeda* is found in Honduras in Central America. It has many cellular features in common with plants.

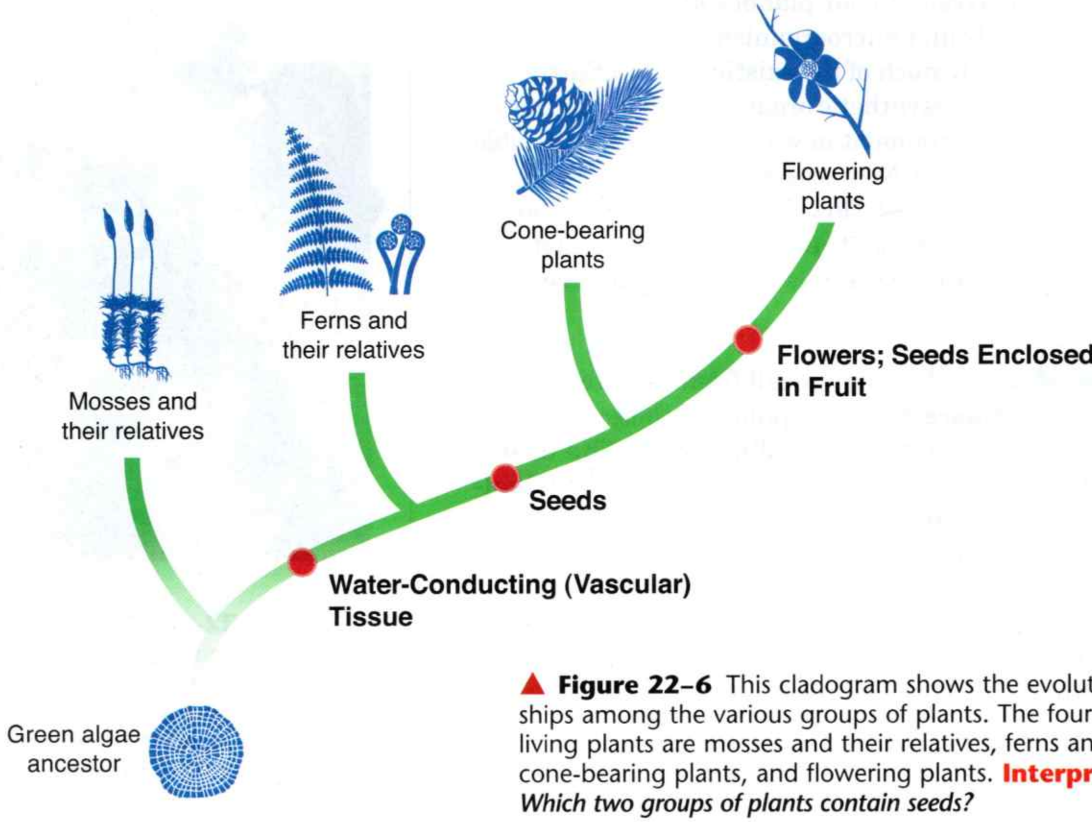
CHECKPOINT *What was the greatest "challenge" to plants as they began to live on land?*



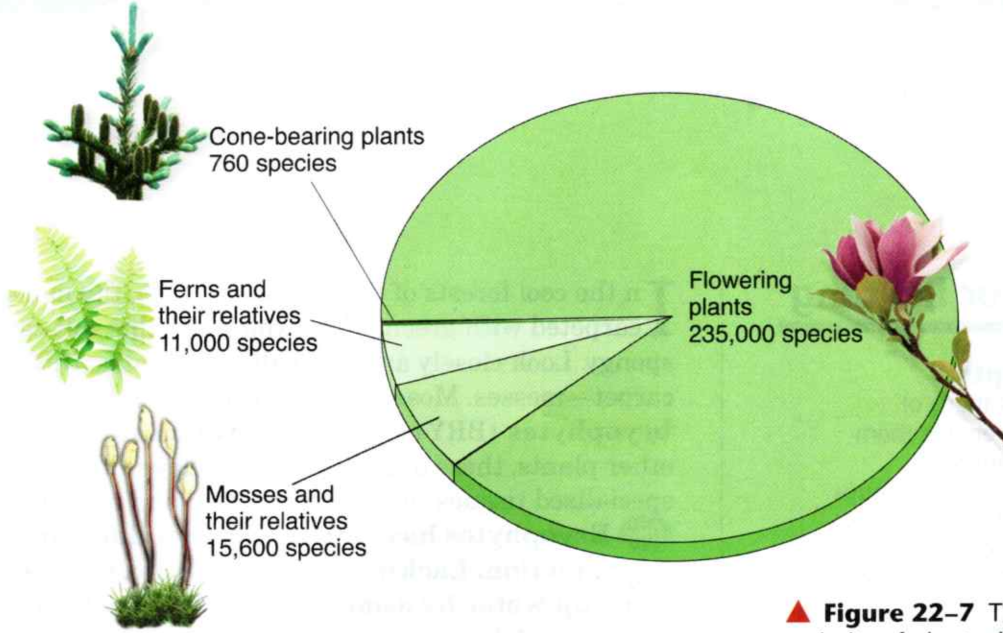
▲ **Figure 22–5** One of the earliest fossil vascular plants was *Cooksonia,* which looked similar to mosses living today. *Cooksonia* had simple branched stalks that bore reproductive structures at their tips. The figure above shows an artist's drawing of *Cooksonia* and a photograph of the fossil. **Inferring** ***Which structures of this early plant might have carried out photosynthesis? Obtained water and minerals?***

The First Plants Plants share many characteristics with the green algae described in Chapter 20, including their photosynthetic pigments and the composition of their cell walls. DNA sequences confirm that plants are closely related to certain groups of green algae, further suggesting that the ancestors of the first plants were indeed algae. The oldest known fossils of plants, nearly 450 million years old, show that the earliest plants were similar to today's mosses. As shown in **Figure 22–5,** they had a simple structure and grew close to the damp ground. The fossils also suggest that the first true plants were still dependent on water to complete their life cycles. Over time, the demands of life on land favored the evolution of plants more resistant to the drying rays of the sun, more capable of conserving water, and more capable of reproducing without water.

From these plant pioneers, several major groups of plants evolved. One group developed into the mosses and their relatives. Another lineage gave rise to all the other plants on Earth today—ferns, cone-bearing plants, and flowering plants. All of these groups of plants are now successful in living on dry land, but they have evolved very different adaptations for a wide range of terrestrial environments.



▲ **Figure 22–6** This cladogram shows the evolutionary relationships among the various groups of plants. The four main groups of living plants are mosses and their relatives, ferns and their relatives, cone-bearing plants, and flowering plants. **Interpreting Graphics** ***Which two groups of plants contain seeds?***



▲ **Figure 22–7** The great majority of plants alive today are angiosperms, which are also known as flowering plants. **Interpreting Graphics** *What is the second largest group of plants?*

Overview of the Plant Kingdom

Botanists divide the plant kingdom into four groups based on three important features: water-conducting tissues, seeds, and flowers. The relationship of these groups is shown in **Figure 22–6.** There are, of course, many other features by which plants are classified, including reproductive structures and body plan.

Today, plant scientists can classify plants more precisely by comparing the DNA sequences of various species. Since 1994, a team of biologists from twelve nations has begun to change our view of plant relationships. Their project, Deep Green, has provided strong evidence that the first plants evolved from green algae living in fresh water, not in the sea as had been thought.

In the rest of this chapter, we will explore how important plant traits evolved over the course of millions of years. In particular, we will examine the success of the flowering plants. As shown in **Figure 22–7,** flowering plants consist of 235,000 species—almost 90 percent of all living species of plants.

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22–1 Section Assessment

1. **Key Concept** Identify the characteristics of the plant kingdom.
2. **Key Concept** To live successfully on land, what substances must plants obtain from their environment?
3. **Key Concept** From which group of protists did the first plants evolve? How are plants similar to these protists?
4. **Critical Thinking Comparing and Contrasting** Compare the gametophyte and sporophyte stages of the plant life cycle. Which is haploid? Which is diploid?
5. **Critical Thinking Comparing and Contrasting** Compare the roles of mitosis and meiosis in a plant life cycle. Which of these processes is related to sexual reproduction? To asexual reproduction?

Focus on the BIG Idea

Structure and Function
How do the cells of plants differ from those of animals? How are they different from those of fungi? You may wish to use labeled diagrams or a compare-and-contrast table to present your results. Refer to Chapters 7 and 21 for help in answering these questions.

22–2 Bryophytes

Guide for Reading

Key Concepts
- What adaptations of bryophytes enable them to live on land?
- What are the three groups of bryophytes?
- How do bryophytes reproduce?

Vocabulary
bryophyte
rhizoid
gemma
protonema
antheridium
archegonium

Reading Strategy: Using Visuals
Before you read, preview **Figure 22–11,** which shows the life cycle of a moss. In your own words, describe the basic process of reproduction shown. As you read the section, add information that you learn about reproduction in bryophytes.

In the cool forests of the northern woods, the moist ground is carpeted with green. When you walk, this soft carpet feels spongy. Look closely and you will see the structure of this carpet—mosses. Mosses and their relatives are generally called **bryophytes** (BRY-oh-fyts), or nonvascular plants. Unlike all other plants, these organisms do not have vascular tissues, or specialized tissues that conduct water and nutrients. **Bryophytes have life cycles that depend on water for reproduction. Lacking vascular tissue, these plants can draw up water by osmosis only a few centimeters above the ground.** This method of development keeps them relatively small. During at least one stage of their life cycle, bryophytes produce sperm that must swim through water to reach the eggs of other individuals. Therefore, they must live in places where there is rainfall or dew for at least part of the year.

Groups of Bryophytes

The most recognizable feature of bryophytes is that they are low-growing plants that can be found in moist, shaded areas. Wherever water is in regular supply—in habitats from the polar regions to the tropics—these plants thrive. **Bryophytes include mosses, liverworts, and hornworts.** Today, most botanists classify these groups of plants in three separate phyla.

Mosses The most common bryophytes are mosses, which are members of the phylum Bryophyta (bry-oh-FYT-uh). Mosses grow most abundantly in areas with water—in swamps and bogs, near streams, and in rain forests. Bryophytes are well adapted to life in wet habitats and nutrient-poor soils. Many mosses can tolerate low temperatures, allowing them to grow in harsh environments where other plants cannot. In fact, mosses are the most abundant plants in the polar regions.

Mosses vary in appearance from miniature evergreen trees to small, filamentous plants that together form a threadlike carpet of green, as shown in **Figure 22–8.** The moss plants that you might have observed on a walk through the woods are actually clumps of gametophytes growing close together. Each moss plant has a thin, upright shoot that looks like a stem with tiny leaves. These are not true stems or leaves, however, because they do not contain vascular tissue. When mosses reproduce, they produce thin stalks, each containing a capsule. This is the sporophyte stage, as shown in **Figure 22–9.**

◀ **Figure 22–8** Mosses grow best in moist environments, such as on the rocks by this waterfall. **Like all bryophytes, mosses have life cycles that depend on water for reproduction.**

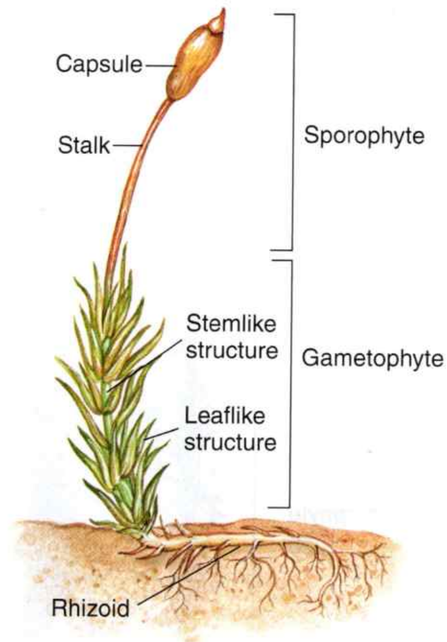
Because the "leaves" of mosses are only one cell thick, these plants lose water quickly if the surrounding air is dry. The lack of vascular tissues also means that mosses do not have true roots. Instead, they have **rhizoids,** which are long, thin cells that anchor them in the ground and absorb water and minerals from the surrounding soil. Water moves from cell to cell through the rhizoids and into the rest of the plant.

Liverworts If you have come across odd little plants that look almost like flat leaves attached to the ground, you have probably seen a liverwort, shown in **Figure 22–10.** These plants belong to the phylum Hepaticophyta (hih-PAT-ik-oh-fy-tuh) and get their name from the fact that some species resemble the shape of a liver. In their method of development, the liverwort gametophytes form broad and thin structures that draw up moisture directly from the surface of the soil. When the plants mature, the gametophytes produce structures that look like tiny green umbrellas. These "umbrellas" carry the structures that produce eggs and sperm.

Some liverworts can also reproduce asexually by means of gemmae. **Gemmae** (JEM-ee; singular: gemma) are small multicellular reproductive structures. In some species of liverworts, gemmae are produced in cuplike structures called gemma cups. When washed out of the gemma cup, the gemmae can divide by mitosis to produce a new individual.

Hornworts Hornworts are members of the phylum Anthocerophyta (an-tho-SEHR-oh-fy-tuh). Like the liverworts, hornworts are generally found only in soil that is damp nearly year-round. Their gametophytes look very much like those of liverworts. The hornwort sporophyte, however, looks like a tiny green horn.

CHECKPOINT *How do bryophytes reproduce asexually?*

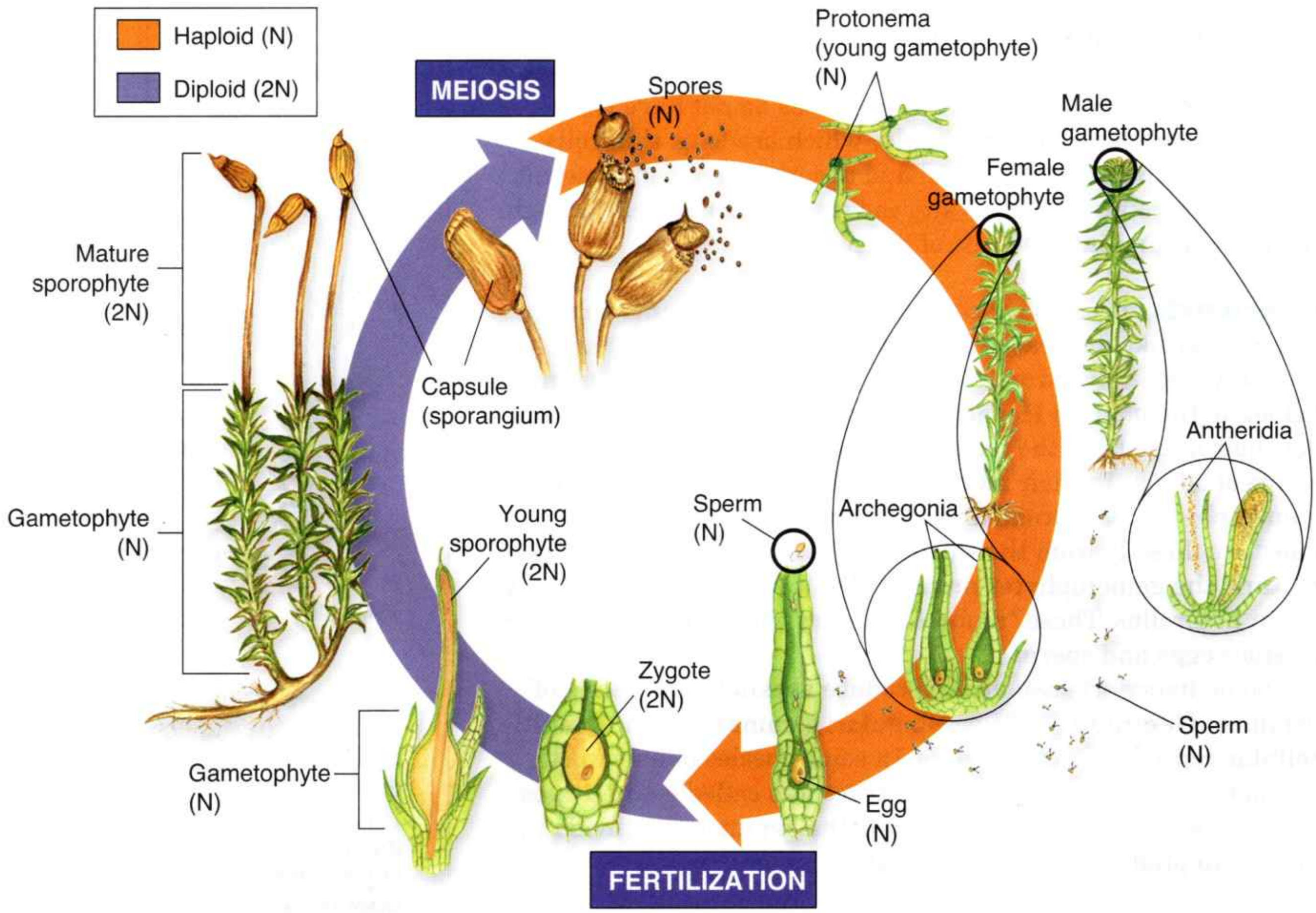


▲ **Figure 22–9** This illustration shows the structure of a typical moss plant. The green photosynthetic portion is the gametophyte. The brown structure on the tip of the gametophyte is the sporophyte. **Applying Concepts** ***Which stage of the moss plant provides nutrients for the other stage?***

Liverworts

Hornworts

◀ **Figure 22–10** **Bryophytes include liverworts and hornworts.** The liverworts produce gametes in structures that look like little green umbrellas. The tiny cuplike structures on the liverworts are gemma cups. The hornworts have sporophytes that look like tiny green horns.



▲ **Figure 22–11 In bryophytes, the gametophyte is the dominant, recognizable stage of the life cycle and is the form that carries out photosynthesis.** Sporophytes, which produce haploid spores, grow at the top of the gametophyte plant. When the spores are ripe, they are shed from the capsule like pepper from a shaker. In some species, gametes (sperm and eggs) are produced on separate male and female gametophyte plants.

Life Cycle of Bryophytes

Like all plants, bryophytes display a method of reproduction and development involving alternation of generations. **In bryophytes, the gametophyte is the dominant, recognizable stage of the life cycle and is the stage that carries out most of the plant's photosynthesis.** The sporophyte is dependent on the gametophyte for supplying water and nutrients.

Dependence on Water For fertilization to occur, the sperm of a bryophyte must swim to an egg. Because of this dependence on water for reproduction, bryophytes must live in habitats where water is available at least part of the year.

Life Cycle of a Moss The life cycle of a moss, shown in **Figure 22–11,** helps illustrate how bryophytes reproduce and develop. When a moss spore lands in a moist place, it germinates and grows into a mass of tangled green filaments called a **protonema** (proh-toh-NEE-muh). As the protonema grows, it forms rhizoids that grow into the ground and shoots that grow into the air. These shoots grow into the familiar green moss plants, which are the gametophyte stage of its life cycle.

CHECKPOINT *What is a protonema?*

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Gametes are formed in reproductive structures at the tips of the gametophytes. Sperm with whiplike tails are produced in **antheridia** (an-thur-ID-ee-uh; singular: antheridium), and egg cells are produced in **archegonia** (ahr-kuh-GOH-nee-uh; singular: archegonium). Some species produce both sperm and eggs on the same plant, whereas other species produce sperm and eggs on separate plants. Once sperm are released and reach egg cells, fertilization produces a diploid zygote. This zygote is the beginning of the sporophyte stage of the life cycle. It grows directly out of the body of the gametophyte and actually depends on it for water and nutrients. The mature sporophyte is a long stalk ending in a capsule that looks like a saltshaker. Inside the capsule, haploid spores are produced by meiosis. When the capsule ripens, it opens and haploid spores are scattered to the wind to start the cycle again.

▼ **Figure 22–12** The compacted remains of sphagnum moss may eventually form thick deposits of peat. When it is cut and dried, it can be burned to produce heat. Peat has been used as a form of fuel in Ireland for many centuries. **Inferring** ***What can you infer about the climate of an area where sphagnum moss grows abundantly in peat bogs?***

Human Use of Mosses

Sphagnum (SFAG-num) mosses are a group of mosses that thrive in the acidic water of bogs. Dried sphagnum moss absorbs many times its own weight in water and thus acts as a sort of natural sponge. In certain environments the dead remains of sphagnum accumulate to form thick deposits of peat. Peat can be cut from the ground, as shown in **Figure 22–12,** and then burned as a fuel.

Peat moss is also used in gardening. Gardeners add peat moss to the soil because it improves the soil's ability to retain water. Peat moss also has a low pH, so when added to the soil it increases the soil's acidity. Some plants, such as azaleas, grow well only if they are planted in acidic soil.

22–2 Section Assessment

1. **Key Concept** How is water essential in the life cycle of a bryophyte?
2. **Key Concept** List the three groups of bryophytes. In what type of habitat do they live?
3. **Key Concept** What is the relationship between the gametophyte and the sporophyte in mosses and other bryophytes?
4. What is an archegonium? An antheridium? How are these structures important in the life cycle of a moss?
5. **Critical Thinking Inferring** What characteristic of bryophytes is responsible for their small size? Explain.

Writing in Science

Descriptive Writing

You are writing a pocket field guide about plants and are working on the bryophytes chapter. Develop several paragraphs to help your readers distinguish among the mosses, hornworts, and liverworts. *Hint:* Do additional library or Internet research to find examples of bryophytes in your locality.

22–3 Seedless Vascular Plants

Guide for Reading

Key Concepts
- How is vascular tissue important to ferns and their relatives?
- What are the characteristics of the three phyla of seedless vascular plants?
- What are the stages in the life cycle of ferns?

Vocabulary
vascular tissue • tracheid
xylem • phloem • lignin
root • leaf • vein • stem
rhizome • frond
sporangium • sorus

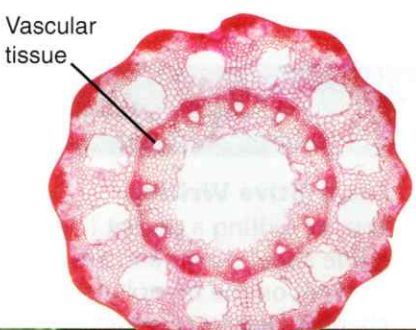
Reading Strategy: Building Vocabulary
Before you read, preview new vocabulary by skimming the section and making a list of the highlighted, boldface terms. Leave space to make notes about each term as you read.

Bryophytes have only one way to transport water—from cell to cell by osmosis. This fact limits their height to just a few centimeters; for millions of years, plants grew no larger. About 420 million years ago, something remarkable happened. The small, mosslike plants on land were suddenly joined by some plants more than a meter tall and others as large as small trees. Fossil evidence shows that these new plants were the first to have a transport system with **vascular tissue,** which is specialized to conduct water and nutrients throughout the plant.

Evolution of Vascular Tissue: A Transport System

The first vascular plants had a new type of cell that was specialized to conduct water. **Tracheids** (TRAY-kee-idz), shown in **Figure 22–13,** were one of the great evolutionary innovations of the plant kingdom. They are the key cells in **xylem** (ZY-lum), a transport subsystem that carries water upward from the roots to every part of a plant. Tracheids are hollow cells with thick cell walls that resist pressure. They are connected end to end like a series of drinking straws. Tracheids allow water to move through a plant more efficiently than by diffusion alone.

Vascular plants have a second transport subsystem composed of vascular tissue called phloem. **Phloem** (FLOH-um) transports solutions of nutrients and carbohydrates produced by photosynthesis. Like xylem, the main cells of phloem are long and specialized to move fluids throughout the plant body. **Both forms of vascular tissue—xylem and phloem—can move fluids through the plant body, even against the force of gravity**. Together, xylem and phloem form an integrated transport system that moves water, nutrients, and other dissolved materials from one end of the plant to the other. In many plants, the combination of the thick walls of xylem and **lignin,** a substance that makes cell walls rigid, enables vascular plants to grow upright and reach great heights.



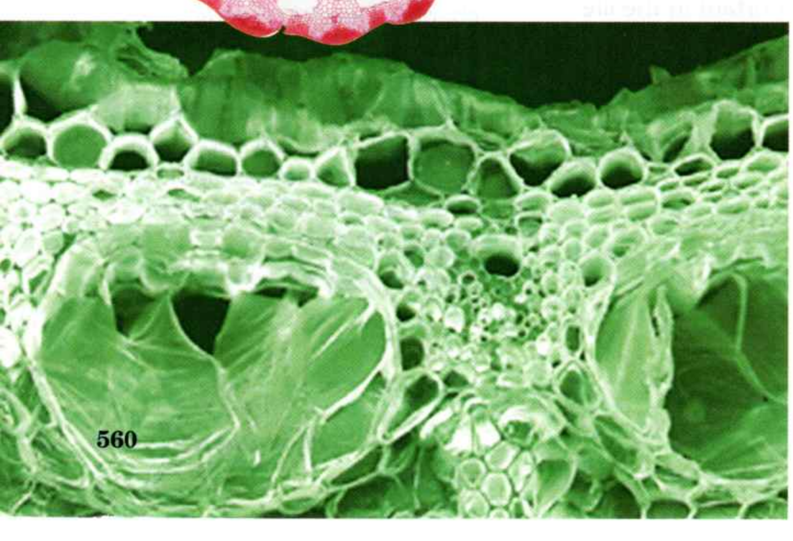


Figure 22–13 **Vascular tissue conducts water and nutrients throughout the plant body.** It also provides support for the leaves and other organs of the plant. The two types of vascular tissue are xylem, which conducts water, and phloem, which conducts solutions of nutrients. The cross section (top) shows the vascular tissue of the horsetail stem. The bottom photo shows a much-magnified view of tracheids from the xylem of the horsetail.

Ferns and Their Relatives

Seedless vascular plants include club mosses, horsetails, and ferns. The most numerous phylum of these is the ferns. Like other vascular plants, ferns and their relatives have true roots, leaves, and stems. **Roots** are underground organs that absorb water and minerals. Water-conducting tissues are located in the center of the root. **Leaves** are photosynthetic organs that contain one or more bundles of vascular tissue. This vascular tissue is gathered into **veins** made of xylem and phloem. **Stems** are supporting structures that connect roots and leaves, carrying water and nutrients between them.

Club Mosses What was once a large and ancient group of land plants—phylum Lycophyta (LY-koh-fy-tuh)—exists now as a much smaller group that includes the club mosses. Once, ancient club mosses grew into huge trees—up to 35 meters tall—and some produced Earth's first forests. The fossilized remains of these forests exist today as huge beds of coal.

Today, club mosses are small plants that live in moist woodlands. Members of the genus *Lycopodium,* the common club mosses shown in **Figure 22–14,** look like miniature pine trees. For this reason they are also called "ground pines."

Horsetails The only living genus of Arthrophyta (AHR-throh-fy-tuh) is *Equisetum,* which is a plant that usually grows about a meter tall. Like the club mosses, *Equisetum* has true leaves, stems, and roots. Its nonphotosynthetic, scalelike leaves are arranged in distinctive whorls at joints along the stem. *Equisetum* is called horsetail, or scouring rush, because its stems look similar to horses' tails and contain crystals of abrasive silica. During colonial times, horsetails were commonly used to scour pots and pans.

CHECKPOINT *What substance makes the stems of* Equisetum *abrasive?*

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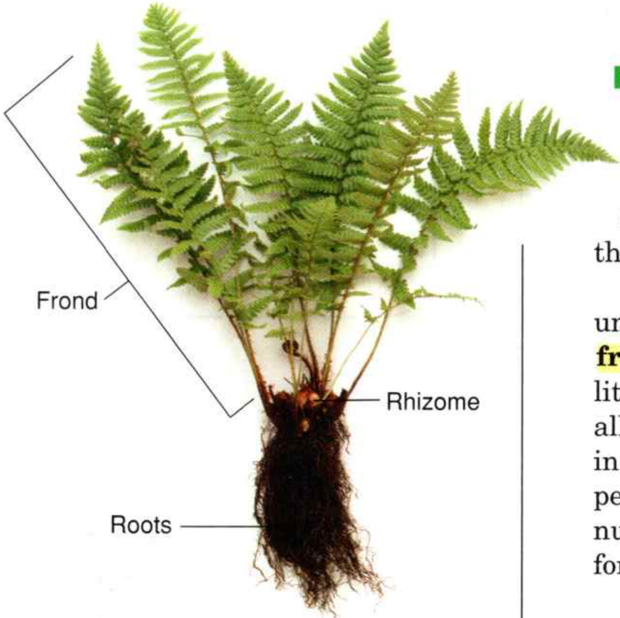
Figure 22–14 Club mosses and horsetails are seedless vascular plants. The club moss *Lycopodium* (left) looks like a tiny pine tree growing on the forest floor. The only living genus of Arthrophyta is *Equisetum,* or horsetail (above).



▲ **Figure 22–15** Ferns are easily recognized because of their delicate leaves, which are called fronds. Fronds grow from a rhizome, which grows horizontally through the soil. **Applying Concepts** *Is the plant shown a sporophyte or a gametophyte?*

Ferns Ferns, members of phylum Pterophyta (TEHR-oh-fy-tuh), probably evolved about 350 million years ago, when great club moss forests covered ancient Earth. Ferns have survived during Earth's long history in numbers greater than any other group of spore-bearing vascular plants. More than 11,000 species of ferns are living today.

Ferns have true vascular tissues, strong roots, creeping or underground stems called **rhizomes,** and large leaves called **fronds,** shown in **Figure 22–15.** Ferns can thrive in areas with little light. They are most abundant in wet, or at least seasonally wet, habitats around the world. They are often found living in the shadows of forest trees, where direct sunlight hardly penetrates the forest's leafy umbrella. Ferns are found in great numbers in the rain forests of the Pacific Northwest. In tropical forests, some species grow as large as small trees.

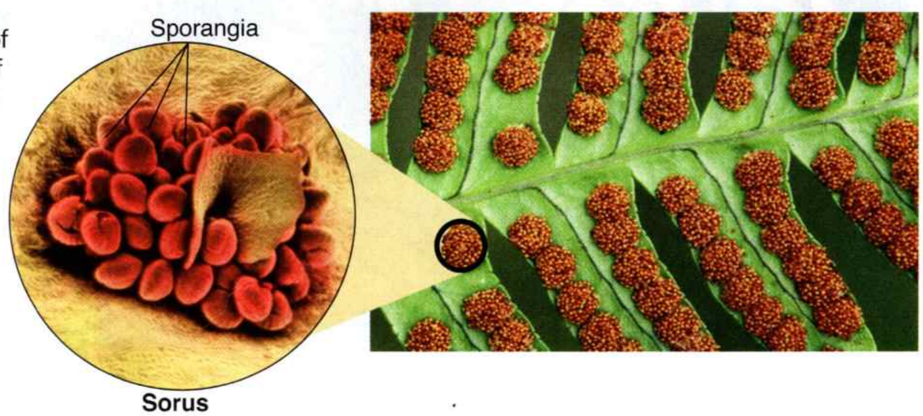
Life Cycle of Ferns

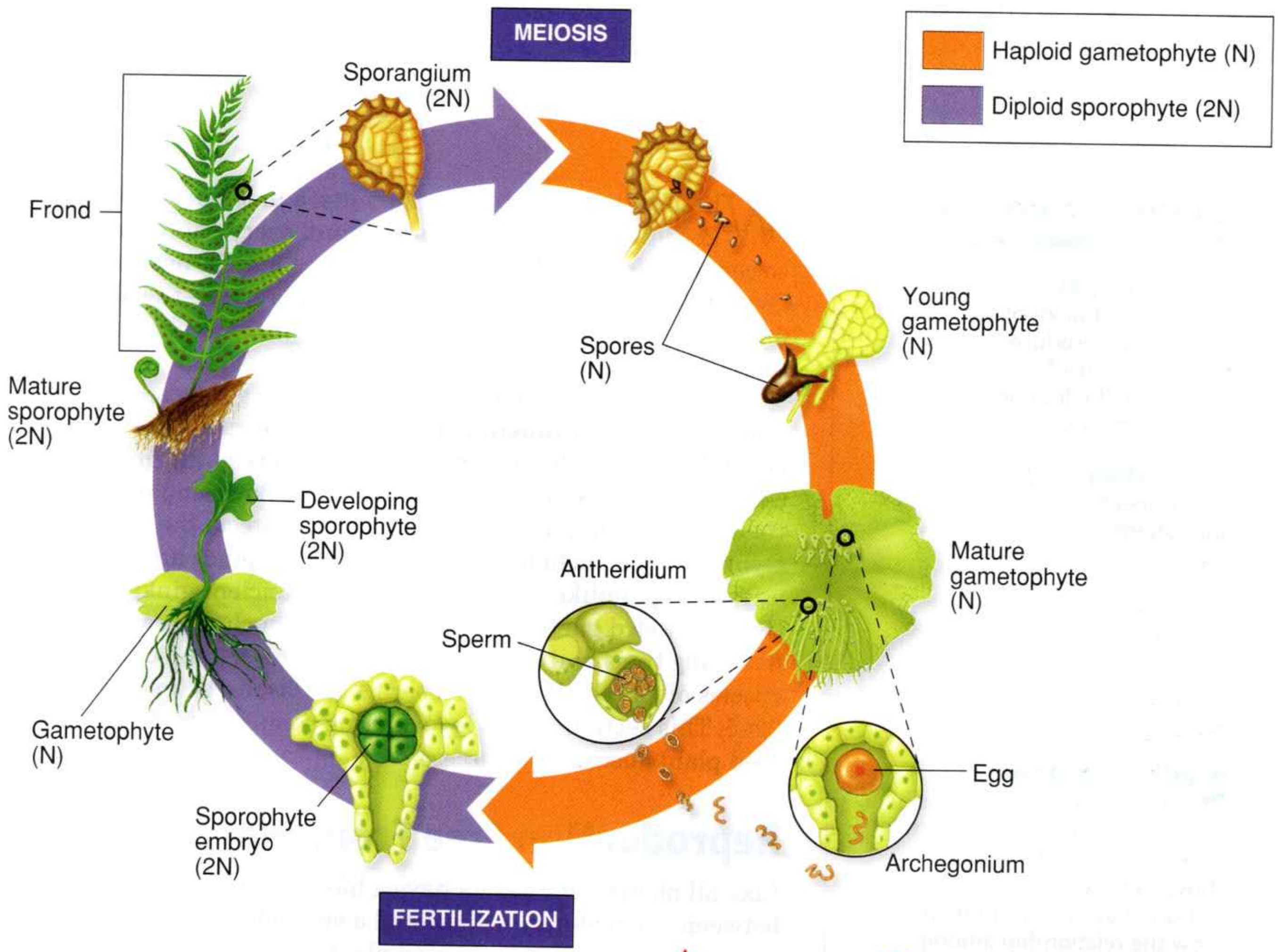
The large plants we recognize as ferns are actually diploid sporophytes. **Ferns and other vascular plants have a life cycle in which the diploid sporophyte is the dominant stage.** Fern sporophytes develop haploid spores on the underside of their fronds in tiny containers called **sporangia** (spoh-RAN-jee-uh; singular: sporangium). Sporangia are grouped into clusters called **sori** (SOH-ry; singular: sorus), shown in **Figure 22–16.** The life cycle and method of development of a typical fern are shown in **Figure 22–17.**

When the spores germinate, they develop into haploid gametophytes. The small gametophyte first grows a set of rootlike rhizoids. It then flattens into a thin, heart-shaped, green structure that is the mature gametophyte. Although it is tiny, the gametophyte grows independently of the sporophyte.

The antheridia and archegonia are found on the underside of the gametophyte. As in bryophytes, fertilization requires at least a thin film of water, allowing the sperm to swim to the eggs. The diploid zygote produced by fertilization immediately begins to develop into a new sporophyte plant. As the sporophyte grows, the gametophyte withers away. Fern sporophytes often live for many years. In some species, the fronds produced in the spring die in the fall, but the rhizomes live through the winter and produce new leaves again the following spring.

▶ **Figure 22–16** Many clusters of sporangia form on the underside of fern leaves—each cluster is called a sorus. In each sporangium, cells undergo meiosis to produce spores. **Inferring** *Are these spores haploid or diploid?*





▲ **Figure 22–17 In the life cycle of a fern, the dominant and recognizable stage is the diploid sporophyte.** The tiny, heart-shaped gametophyte grows close to the ground and relies on dampness for the sperm it produces to fertilize an egg. The young sporophyte grows from the gametophyte.

22–3 Section Assessment

1. **Key Concept** What are the two types of vascular tissue? Describe the function of each.
2. **Key Concept** What are the three phyla of seedless vascular plants? Give an example of each.
3. **Key Concept** What is the dominant stage of the fern life cycle? What is the relationship of the fern gametophyte and sporophyte?
4. **Critical Thinking Inferring** The size of plants increased dramatically with the evolution of vascular tissue. How might these two events be related?
5. **Critical Thinking Applying Concepts** Explain why xylem and phloem together can be considered to be a transport system.

Thinking Visually

Making a Visual Essay
Find out more about club mosses, horsetails, and ferns. Research information such as description, method of development, ecology, and scientific name. Use this information along with photographs or drawings of these plants to create a two-page photo essay about seedless vascular plants.

22–4 Seed Plants

Guide for Reading

Key Concepts
- What adaptations allow seed plants to reproduce without standing water?
- What are the four groups of gymnosperms?

Vocabulary
gymnosperm
angiosperm
cone
flower
pollen grain
pollination
seed
embryo
seed coat

Reading Strategy: Building Vocabulary As you read, make notes about the meaning of each term listed above. After you have read the section, draw a concept map to show the relationship among these terms.

Whether they are acorns, pine nuts, dandelion seeds, or kernels of corn, seeds can be found everywhere. Seeds are so common, in fact, that their importance may be overlooked. Over millions of years, plants with a single trait—the ability to form seeds—became the most dominant group of photosynthetic organisms on land.

Seed plants are divided into two groups: gymnosperms and angiosperms. **Gymnosperms** (JIM-noh-spurmz) bear their seeds directly on the surfaces of cones, whereas **angiosperms** (AN-jee-oh-spurmz), which are also called flowering plants, bear their seeds within a layer of tissue that protects the seed. Gymnosperms include the conifers, such as pines and spruces, as well as palmlike plants called cycads, ancient ginkgoes, and the very weird gnetophytes. Angiosperms include grasses, flowering trees and shrubs, and all wildflowers and cultivated species of flowers. The angiosperms are discussed in Section 22–5. This section begins by exploring some of the reasons that seed plants became so successful.

Reproduction Free From Water

Like all plants, seed plants have a life cycle that alternates between a gametophyte stage and a sporophyte stage. Unlike mosses and ferns, however, seed plants do not require water for fertilization of gametes. Because of this method of development, seed plants can live just about anywhere—from moist habitats that are often dominated by seedless plants, to dry and cold habitats where most seedless plants cannot survive. **Adaptations that allow seed plants to reproduce without water include flowers or cones, the transfer of sperm by pollination, and the protection of embryos in seeds.**

Cones and Flowers The gametophytes of seed plants grow and mature within sporophyte structures called **cones,** which are the seed-bearing structures of gymnosperms, and **flowers,** which are the seed-bearing structures of angiosperms. The cones of a common gymnosperm are shown in **Figure 22–18.** The gametophyte generations of seed plants live inside these reproductive structures.

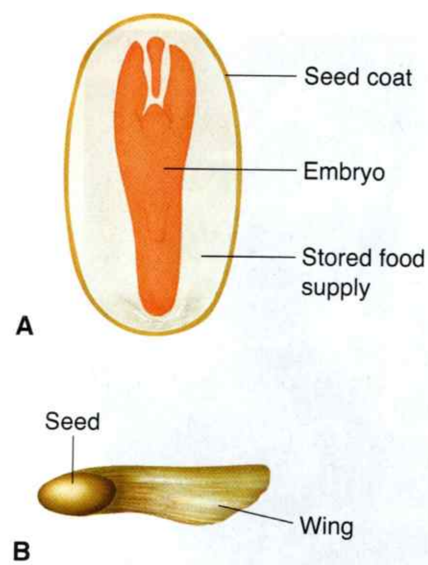
◀ **Figure 22–18** **Adaptations that allow seed plants to reproduce without water include reproduction in flowers or cones, the transfer of sperm by pollination, and the protection of embryos in seeds.** Gymnosperms, such as this spruce tree, bear their seeds on the scales of cones.

Pollen In seed plants, the entire male gametophyte is contained in a tiny structure called a **pollen grain.** Sperm produced by this gametophyte do not swim through water to fertilize the eggs. Instead, the pollen grain is carried to the female reproductive structure by wind, insects, or small animals. The transfer of pollen from the male reproductive structure to the female reproductive structure is called **pollination.**

Seeds A **seed** is an embryo of a plant that is encased in a protective covering and surrounded by a food supply. An **embryo** is an organism in its early stage of development. A plant embryo is diploid and is the early developmental stage of the sporophyte plant. The seed's food supply provides nutrients to the embryo as it grows. The **seed coat** surrounds and protects the embryo and keeps the contents of the seed from drying out. Seeds may also have special tissues or structures that aid in their dispersal to other habitats. Some seed coats are textured so that they stick to the fur or feathers of animals. Other seeds are contained in fleshy tissues that are eaten and dispersed by animals.

After fertilization, the zygote contained within a seed grows into a tiny plant—the embryo. The embryo often stops growing while it is still small and contained within the seed. The embryo can remain in this condition for weeks, months, or even years. When the embryo begins to grow again, it uses nutrients from the stored food supply. Seeds can survive long periods of bitter cold, extreme heat, or drought—beginning to grow only when conditions are once again right.

CHECKPOINT *What is a pollen grain?*



▲ **Figure 22–19** (A) This longitudinal section shows the internal structure of the seed of a pine tree. (B) The pine tree seed, found on the scale of a cone, is winged. **Predicting** *How might the food stored in the seed affect the reproductive success of the pine tree?*

Quick Lab

How do seeds differ from spores?

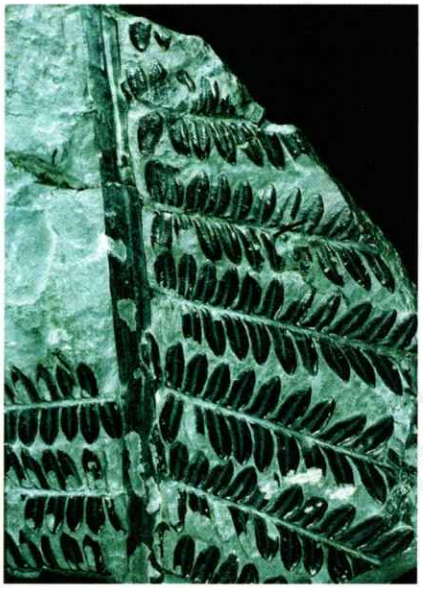
Materials Fern frond with sori, microscope, scalpel, microscope slide, coverslip, dropper pipette, sunflower seeds in shells, brown paper bag, hand lens

Procedure

1. Use a scalpel to scrape sporangia from the underside of a fern frond onto a microscope slide. Add a drop of water and a coverslip and examine the slide under low power. Sketch a few spores. **CAUTION:** *Use care with the scalpel.*
2. **CAUTION:** *Do not perform steps 2 and 3 if you are allergic to sunflower seeds. Do not eat the sunflower seeds.* Open a sunflower seed. With a hand lens, examine the nutlike kernel of the seed and sketch the embryo.
3. Rub the seed on brown paper and hold the paper up to the light. A bright spot indicates lipids. Wash your hands.

Analyze and Conclude

1. **Observing** What evidence do you have that nutrients are stored in sunflower seeds?
2. **Predicting** A spore and a seed are deposited in an area where the soil is poor in nutrients. Which is more likely to survive in a nutrient-poor environment? Explain.
3. **Formulating Hypotheses** Consider two populations of ferns and seed plants. How might their reproductive strategies, or methods of reproduction, have an impact on their survival? Over time, how might these events affect the overall diversity of plants?



▲ **Figure 22–20** Seed ferns are part of the fossil record. They represent a link between ferns, which do not form seeds, and seed plants. This ancient plant had leaves that resemble the leaves of modern ferns. **Comparing and Contrasting** ***If this plant were alive, what structures would distinguish it from a fern?***

▼ **Figure 22–21** The *Welwitschia* plant (below), a type of gnetophyte, is an odd desert plant that produces only two leaves during its entire life. Cones are produced at the bases of the two leaves. **Classifying** ***In what phylum is this plant classified?***

Evolution of Seed Plants

The fossil record indicates that ancestors of seed plants evolved new adaptations that enabled them to survive in many places where most mosses and ferns could not—from frigid mountains to scorching deserts. The most important of these adaptations was the seed itself, which can survive dry conditions and extreme temperatures.

Mosses and ferns underwent major adaptive radiations during the Carboniferous and Devonian periods, 300 to 400 million years ago. During these periods, land environments were much wetter than they are today. Tree ferns and other seedless plants flourished and developed into forests that covered much of Earth. Over millions of years, however, continents became much drier, making it harder for seedless plants to survive and reproduce. Many moss and fern species became extinct, replaced by seed plants adapted to live in drier conditions. Similarities in DNA sequences from modern plants provide evidence that today's seed plants are all descended from common ancestors.

Fossils of seed-bearing plants exist from almost 360 million years ago. As shown in **Figure 22–20**, some of these early seed plants outwardly resembled ferns. Seed fern fossils document several evolutionary stages in the development of the seed.

The early seed plants reached every landmass on Earth. Together with now-extinct seed ferns and other seedless vascular plants, seed plants formed dense forests and swamps that spread over much of what is now the eastern United States. Their remains now exist in the form of coal deposits.

Gymnosperms—Cone Bearers

The most ancient surviving seed plants are the gymnosperms. **Gymnosperms include gnetophytes, cycads, ginkgoes, and conifers.** These plants all reproduce with seeds that are exposed—gymnosperm means "naked seed."

Gnetophytes About 70 present-day species of the phylum Gnetophyta (NEE-toh-fy-tuh) are known, placed in just three genera. The reproductive scales of these plants are clustered into cones. *Welwitschia,* an inhabitant of the Namibian desert in southwestern Africa, is one of the most remarkable gnetophytes. It has only two huge leathery leaves, shown in **Figure 22–21**, which grow continuously and spread across the ground.

Cycads Cycads, members of the phylum Cycadophyta (SY-kad-oh-fy-tuh), are beautiful palmlike plants that reproduce with large cones. Cycads first appeared in the fossil record during the Triassic Period, 225 million years ago. Huge forests of cycads thrived when dinosaurs roamed Earth. Today, only nine genera of cycads exist. Cycads can be found growing naturally in tropical and subtropical places such as Mexico, the West Indies, Florida, and parts of Asia, Africa, and Australia.

Ginkgoes Ginkgoes were common when dinosaurs were alive, but today the phylum Ginkgophyta (GING-koh-fy-tuh) contains only one species, *Ginkgo biloba.* The living *Ginkgo* species looks similar to its fossil ancestors, so it is truly a living fossil. In fact, *G. biloba,* shown in **Figure 22–22,** may be one of the oldest seed plant species alive today. Ginkgo trees were carefully cultivated in China, where they were often planted around temples. Ginkgoes are now often planted in urban settings in the United States, where their toughness and resistance to air pollution make them popular shade trees.

CHECKPOINT ***How many different species of ginkgoes exist?***

Conifers By far the most common gymnosperms, with more than 500 known species, are the conifers. The phylum Coniferophyta (koh-nif-ur-oh-FYT-uh) includes pines, spruces, firs, cedars, sequoias, redwoods, junipers, and yews. Some conifers, such as the bristlecone pine tree, can live for more than 4000 years. Other species, such as giant redwoods, can grow to more than 100 meters in height.

Figure 22–22 **Cycads, ginkgoes, and conifers are gymnosperms.** Some cycads (top left) produce seeds in reproductive structures that look like giant pine cones. The bristlecone pine (top right) is a conifer that can live for thousands of years. The ginkgo tree (bottom) is sometimes called a "living fossil" because it has changed little over millions of years.

22–5 Angiosperms—Flowering Plants

Flowering plants, or angiosperms, are members of the phylum Anthophyta (AN-tho-fy-tuh). They first appeared during the Cretaceous Period, about 135 million years ago, making their origin the most recent of all plant phyla. Flowering plants originated on land and soon came to dominate Earth's plant life. The vast majority of living plant species have a method of reproduction and development involving flowers and fruits.

Guide for Reading

Key Concepts
- What are the characteristics of angiosperms?
- What are monocots and dicots?
- What are the three categories of plant life spans?

Vocabulary
fruit
monocot
dicot
cotyledon
annual
biennial
perennial

Reading Strategy: Finding Main Ideas
Angiosperms are the most diverse group of plants. As you read, take notes on the ways by which their diversity can be organized.

Flowers and Fruits

Angiosperms develop unique reproductive organs known as flowers. In general, flowers are an evolutionary advantage to plants because they attract animals such as bees, moths, or hummingbirds, which then transport pollen from flower to flower. This means of pollination is much more efficient than the wind pollination of most gymnosperms.

Flowers contain ovaries, which surround and protect the seeds. The presence of an ovary gives angiosperms their name: Angiosperm means "enclosed seed." After pollination, the ovary develops into a fruit, which protects the seed and aids in its dispersal.

The unique angiosperm **fruit**—a wall of tissue surrounding the seed—is another reason for the success of these plants. When an animal eats a fruit, seeds from the core of the fruit generally enter the animal's digestive system. By the time these seeds leave the digestive system—ready to sprout—the animal may have traveled many kilometers. By using fruit to attract animals, flowering plants increase the ranges they inhabit, spreading seeds over hundreds of square kilometers.

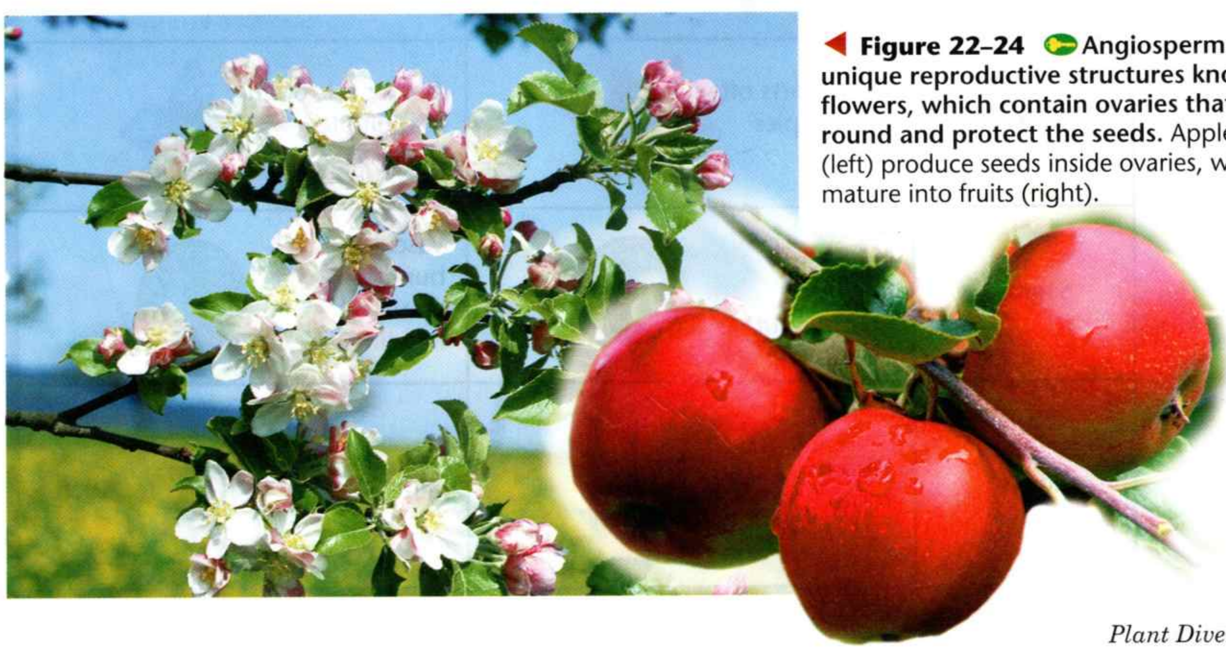


Figure 22–24 **Angiosperms develop unique reproductive structures known as flowers, which contain ovaries that surround and protect the seeds.** Apple flowers (left) produce seeds inside ovaries, which mature into fruits (right).

24–1 Reproduction With Cones and Flowers

Seed plants are well adapted to the demands of life on land, especially in how they reproduce. The gametes of seedless plants, such as ferns and mosses, need water for fertilization to be successful. Water allows gametes to move from plant to plant. The gametes of seed plants, however, can achieve fertilization even when the plants are not wet from rain or dew. So, they can reproduce nearly anywhere. The way in which seed plants reproduce has allowed them to survive the dry conditions on land.

Guide for Reading

Key Concepts
- What are the reproductive structures of gymnosperms and angiosperms?
- How does pollination differ between angiosperms and gymnosperms?

Vocabulary
pollen cone • seed cone
ovule • pollen tube
sepal • petal • stamen
filament • anther • carpel
ovary • style • stigma
embryo sac • endosperm
double fertilization

Reading Strategy: Making Comparisons Before you read, preview **Figure 24–4** and **Figure 24–7.** As you read, compare the life cycles of gymnosperms and angiosperms.

Alternation of Generations

All plants have a life cycle in which a diploid sporophyte generation alternates with a haploid gametophyte generation. Gametophyte plants produce male and female gametes—sperm and eggs. When the gametes join, they form a zygote that begins the next sporophyte generation. In some plants, the two stages of the life cycle are distinct, independent plants. In most ferns, for instance, the gametophyte is a small, heart-shaped plant that grows close to the ground. The sporophyte is the familiar fern plant itself made up of graceful fronds.

Where are these two generations in seed plants? You may remember from Mendel's work on peas that such plants are diploid. Therefore, in seed plants, the familiar, recognizable form of the plant is the diploid sporophyte.

If the sporophyte is what we recognize as the plant, then where is the gametophyte? The answer may surprise you. As shown in **Figure 24–1,** the gametophytes of seed plants are actually hidden deep within tissues of the sporophyte plant. In gymnosperms they are found inside cones, and in angiosperms they are found inside flowers. Cones and flowers represent two different methods of reproduction.

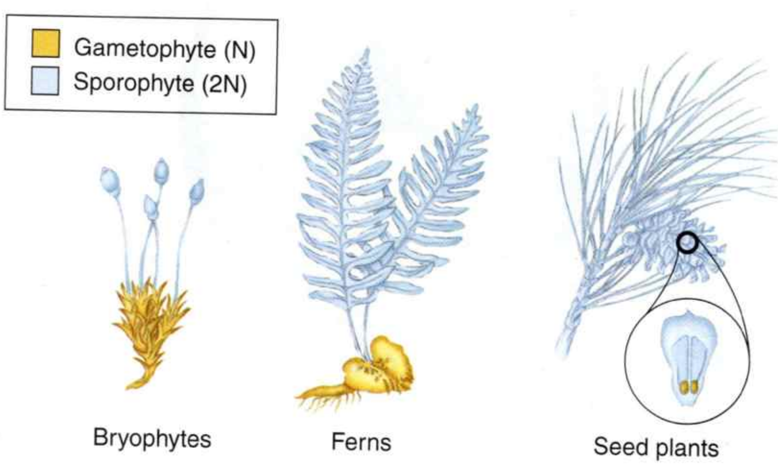


Figure 24–1 An important trend in plant evolution is the reduction of the gametophyte and the increasing size of the sporophyte. Bryophytes consist of a relatively large gametophyte and smaller sporophytes. Seedless vascular plants, such as ferns, have a small gametophyte and a larger sporophyte. Seed plants have an even smaller gametophyte that is contained within sporophyte tissues. **Interpreting Graphics** ***How does the relative size of the haploid and diploid stages of plants differ between bryophytes and seed plants?***

▲ **Figure 24–2** **Reproduction in gymnosperms takes place in structures called cones.** In this pine tree, pollen cones, shown on the top, produce male gametophytes, which are pollen grains. Seed cones, such as the one shown on the bottom, produce female gametophytes that develop into a new embryo following fertilization.

Life Cycle of Gymnosperms

Pine trees and other gymnosperms are diploid sporophytes. As you will see, this sporophyte develops from a zygote that is contained within a seed. How and where is this seed produced? **Reproduction in gymnosperms takes place in cones, which are produced by a mature sporophyte plant.** Gymnosperms produce two types of cones: pollen cones and seed cones.

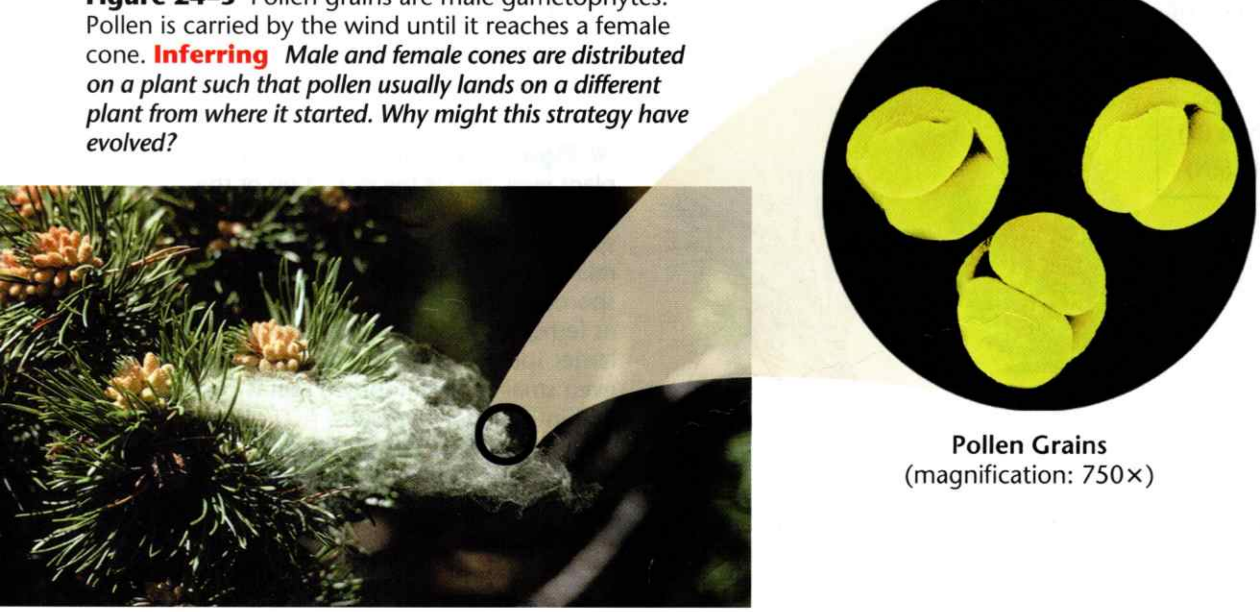
Pollen Cones and Seed Cones **Pollen cones,** shown in **Figure 24–2,** are also called male cones. Pollen cones produce the male gametophytes, which are called pollen grains. As tiny as it is, the pollen grain makes up the entire male gametophyte stage of the gymnosperm life cycle. One of the haploid nuclei in the pollen grain will divide later to produce two sperm nuclei.

The more familiar **seed cones,** which produce female gametophytes, are generally much larger than pollen cones. Near the base of each scale are two **ovules** in which the female gametophytes develop. Within the ovules, meiosis produces haploid cells that grow and divide to produce female gametophytes. These gametophytes may contain hundreds or thousands of cells. When mature, each gametophyte contains a few large egg cells, each ready for fertilization by sperm nuclei.

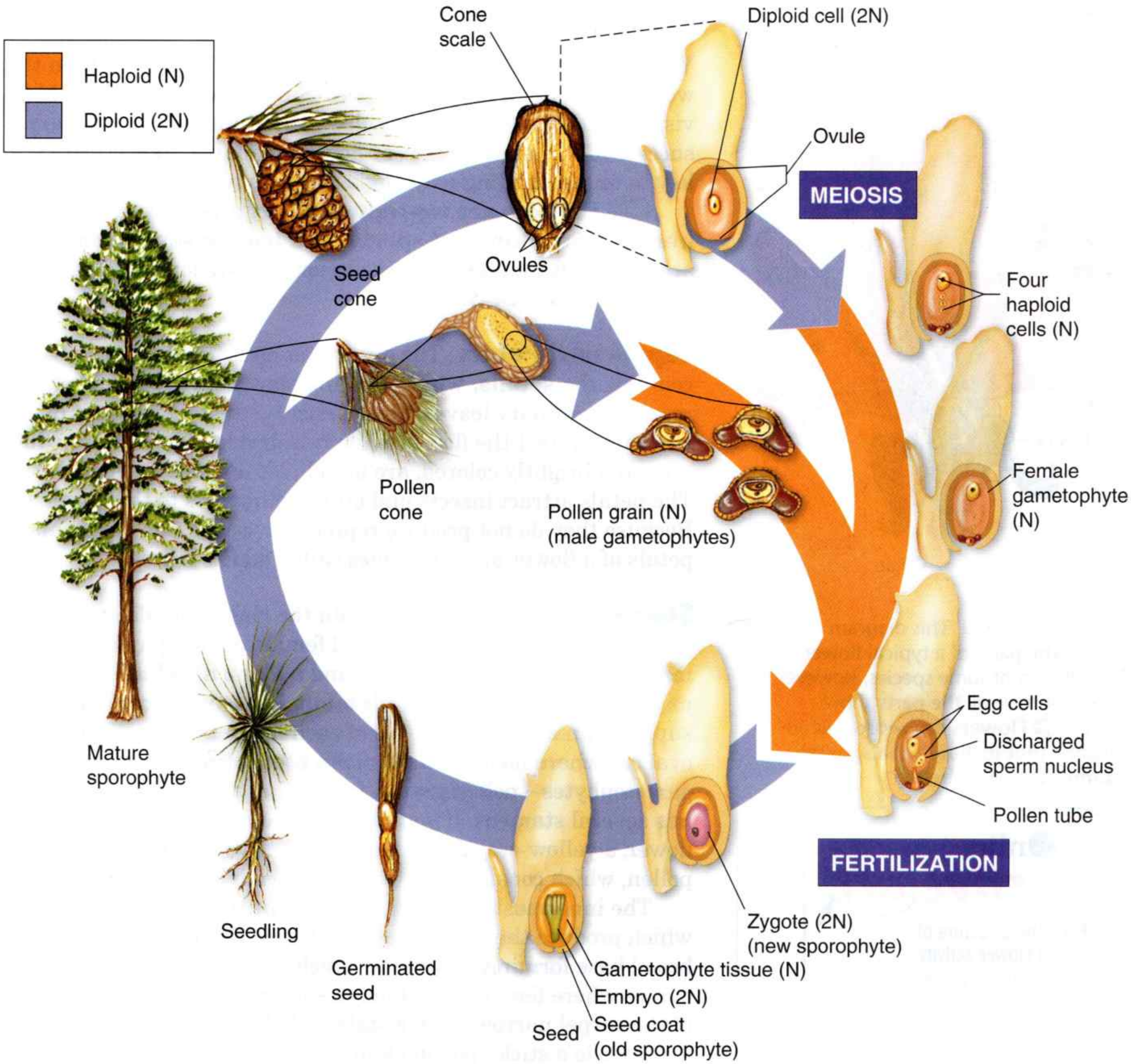
Pollination The gymnosperm life cycle typically takes two years to complete. The cycle begins in the spring as male cones release enormous numbers of pollen grains. This pollen is carried by the wind, as shown in **Figure 24–3.** Some of these pollen grains reach female cones. There, some pollen grains are caught in a sticky secretion on one of the scales of the female cone. This sticky material, known as a pollination drop, ensures that pollen grains stay on the female cone.

CHECKPOINT *What are pollen cones and seed cones?*

Figure 24–3 Pollen grains are male gametophytes. Pollen is carried by the wind until it reaches a female cone. **Inferring** *Male and female cones are distributed on a plant such that pollen usually lands on a different plant from where it started. Why might this strategy have evolved?*

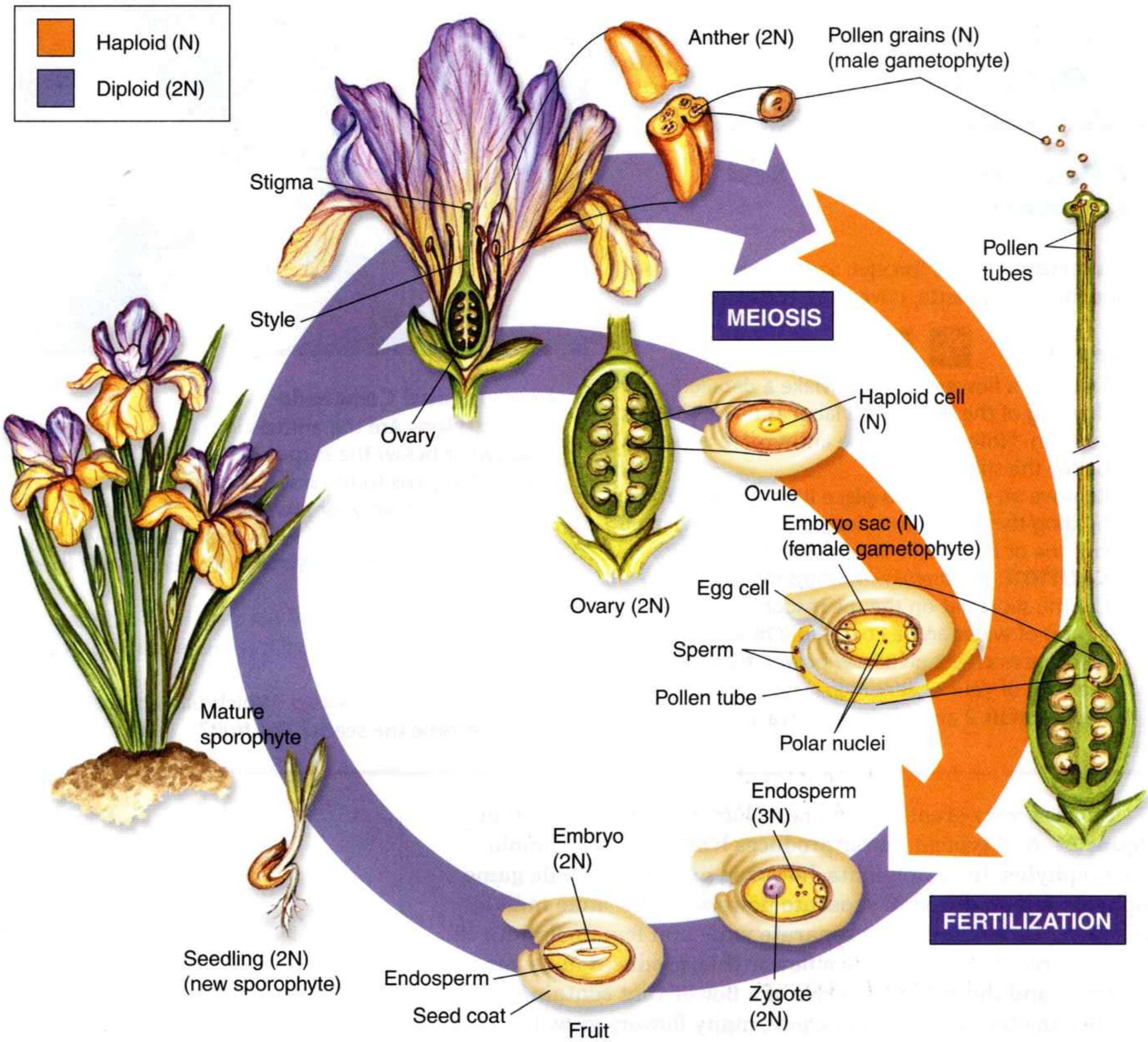


Pollen Grains
(magnification: 750×)



Fertilization and Development If a pollen grain lands near an ovule, the grain splits open and begins to grow a structure called a **pollen tube,** which contains two haploid sperm nuclei. Once the pollen tube reaches the female gametophyte, one sperm nucleus disintegrates, and the other fertilizes the egg contained within the female gametophyte. If sperm from another pollen tube reaches the female gametophyte, more than one egg cell may be fertilized, but just one embryo develops. As shown in **Figure 24–4,** fertilization produces a diploid zygote—the new sporophyte plant. This zygote grows into an embryo. During this time, it is encased within what will soon develop into a seed. The seed consists of three generations of the life cycle. The outer seed coat is part of the old sporophyte generation, the haploid cells surrounding the embryo are part of the female gametophyte, and the embryo is the new sporophyte plant.

▲ **Figure 24–4** This illustration shows the life cycle of a typical gymnosperm. A pine tree—the mature sporophyte—produces male and female cones. Male cones produce pollen, and female cones produce ovules located on cone scales. If an egg is fertilized by the sperm, it becomes a zygote that is nourished by the female cone. In time, the zygote develops into a new sporophyte plant. **Classifying** *Classify each of the following terms as to whether they belong to the haploid or diploid stage of the pine tree's life cycle: pollen tube, seed cone, embryo, ovule, seedling.*



▲ **Figure 24–7** This illustration shows the life cycle of a typical angiosperm—an iris. The developing seeds of a flowering plant are protected and nourished inside the ovary, which is located at the base of the flower. **Reproduction in angiosperms takes place within the flower. After pollination, the seeds of angiosperms develop inside protective structures.**

Life Cycle of Angiosperms

Reproduction in angiosperms takes place within the flower. Following pollination and fertilization, the seeds develop inside protective structures. The life cycle of angiosperms is shown in **Figure 24–7.** You can think of the angiosperm life cycle as beginning when the mature sporophyte produces flowers. Each flower contains anthers and an ovary. Inside the anthers—the male part of the flower—each cell undergoes meiosis and produces four haploid spore cells. Each of these cells becomes a single pollen grain. The wall of each pollen grain thickens, protecting the contents of the pollen grain from dryness and physical damage when it is released from the anther.

The nucleus of each pollen grain undergoes one mitotic division to produce two haploid nuclei. The pollen grain, which is the entire male gametophyte, usually stops growing until it is released from the anther and deposited on a stigma.

The ovary of the flower contains the ovules, in which the female gametophyte develops. A single diploid cell goes through meiosis to produce four haploid cells, three of which disintegrate. The remaining cell undergoes mitosis to produce eight nuclei. These eight nuclei and the surrounding membrane are called the **embryo sac.** The embryo sac, contained within the ovule, is the female gametophyte of a flowering plant. One of the eight nuclei, near the base of the gametophyte, is the egg nucleus—the female gamete. If fertilization takes place, this cell will become the zygote that grows into a new sporophyte plant. Inside the ovary, the cells of the growing embryo begin to differentiate. That is, they begin to specialize, developing from a ball of cells into an embryonic sporophyte. The new sporophyte, or seedling, is shown in **Figure 24–7.**

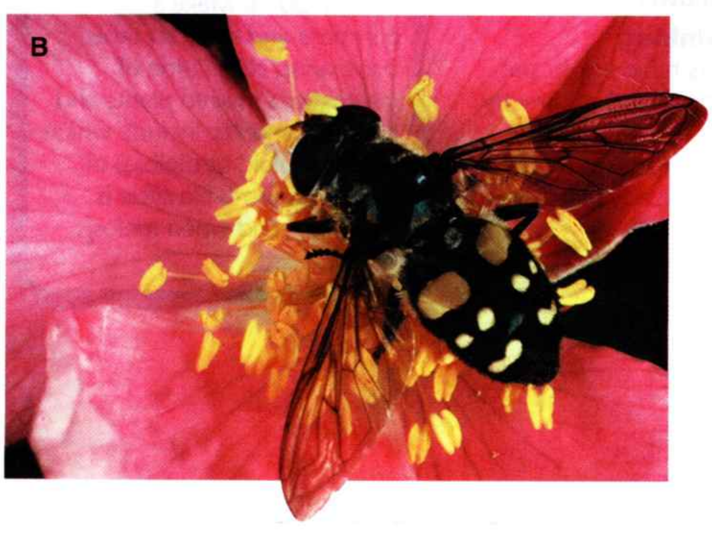
CHECKPOINT *Where does the female gametophyte develop?*

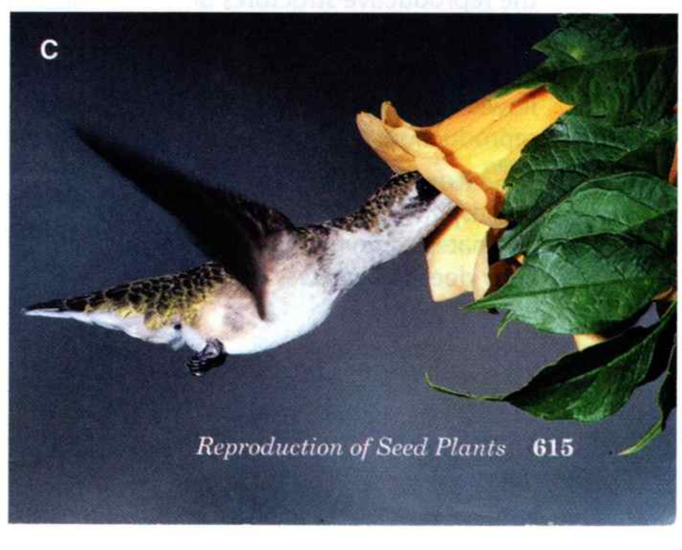
Pollination

Once the gametophytes have developed inside the flower, pollination takes place. **Most gymnosperms and some angiosperms are wind pollinated, whereas most angiosperms are pollinated by animals.** These animals, mainly insects, birds, and bats, carry pollen from one flower to another. Because wind pollination is less efficient than animal pollination, wind-pollinated plants, such as the oak tree in **Figure 24–8,** rely on favorable weather and sheer numbers to get pollen from one plant to another. Animal-pollinated plants have a variety of adaptations, such as bright colors and sweet nectar, to attract animals. Animals have evolved body shapes that enable them to reach nectar deep within certain flowers.

Insect pollination is beneficial to insects and other animals because it provides a dependable source of food—pollen and nectar. Plants also benefit because the insects take the pollen directly from flower to flower. Insect pollination is more efficient than wind pollination, giving insect-pollinated plants a greater chance of reproductive success. Botanists suggest that insect pollination is the factor largely responsible for the displacement of gymnosperms by angiosperms during the past 100 million years.

Figure 24–8 Most angiosperms are pollinated by animals, although some are pollinated by wind. The shape of a flower often indicates how it is pollinated. The flowers of an oak tree (A) are typical of wind-pollinated flowers in that they are small, are not brightly colored, and produce vast amounts of pollen. To attract insects and other animals, many animal-pollinated flowers are large and brightly colored. The rose flower (B) is pollinated by a variety of insects, whereas the trumpet creeper flower (C) has a tube shape that is adapted specifically to the long beak of a hummingbird.





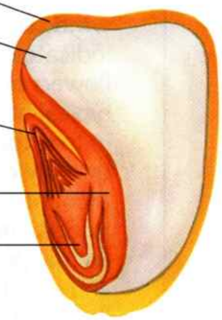
Fertilization in Angiosperms

If a pollen grain lands on the stigma of an appropriate flower of the same species, it begins to grow a pollen tube. The generative nucleus within the pollen grain divides and forms two sperm nuclei. The pollen tube now contains a tube nucleus and two sperm nuclei. The pollen tube grows into the style. There, it eventually reaches the ovary and enters the ovule.

Inside the embryo sac, two distinct fertilizations take place. First, one of the sperm nuclei fuses with the egg nucleus to produce a diploid zygote. The zygote will grow into the new plant embryo. Second, the other sperm nucleus does something truly remarkable—it fuses with two polar nuclei in the embryo sac to form a triploid (3N) cell. This cell will grow into a food-rich tissue known as **endosperm,** which nourishes the seedling as it grows.

As shown in **Figure 24–9,** a seed of corn, a monocot, contains a rich supply of endosperm. In many dicots, including garden beans, the cotyledons absorb the endosperm as the seed develops. The cotyledons then serve as the stored food supply for the embryo when it begins to grow.

Because two fertilization events take place between the male and female gametophytes, this process is known as **double fertilization.** Double fertilization may be one of the reasons why the angiosperms have been so successful. Recall that in gymnosperms, the food reserve built up in seeds is produced before fertilization takes place. As a result, if an ovule is not fertilized, those resources are wasted. In angiosperms, if an ovule is not fertilized, the endosperm does not form, and food is not wasted by preparing for a nonexistent zygote.



▲ **Figure 24–9** The endosperm of a corn seed develops through the process of double fertilization. After one sperm nucleus fertilizes the egg cell, the zygote forms. Then, the other sperm nucleus fuses with the two polar nuclei to form a triploid cell, which develops into the endosperm. **Predicting** ***What will happen to the endosperm when the seed begins to grow?***

24–1 Section Assessment

1. **Key Concept** What are the reproductive structures of gymnosperms?
2. **Key Concept** Describe the flower and how it is involved in reproduction.
3. **Key Concept** Are angiosperms typically wind pollinated or animal pollinated? How does this process occur?
4. What is endosperm? Where does it form in a flowering plant?
5. **Critical Thinking Inferring** Many flowers have bright patterns of coloration that directly surround the reproductive structures. How might this type of coloration be advantageous to the plant?

Focus on the BIG Idea

Information and Heredity
Review the life cycle of the green alga *Chlamydomonas* in Section 20–4. Make a compare-and-contrast table comparing alternation of generations in seed plants and *Chlamydomonas*. Include which stage (haploid or diploid) of each organism's life cycle is dominant and when meiosis occurs.

24–2 Seed Development and Germination

Guide for Reading

Key Concepts
- How do fruits form?
- How are seeds dispersed?
- What factors influence the dormancy and germination of seeds?

Vocabulary
dormancy
germination

Reading Strategy: Summarizing As you read, take notes on the development, dispersal, dormancy, and germination of seeds. Write a few sentences summarizing each of these processes.

The development of the seed, which provides protection and nutrition for the embryo, was a major factor in the success of plants on land. The angiosperm seed, encased within a fruit formed by the ovary wall, offers even more. As you will see, by helping a seed get into the best possible location to start its new life, angiosperm seeds were immediately favored by natural selection.

Seed and Fruit Development

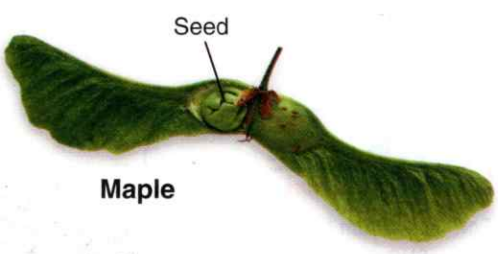
Once fertilization is complete, nutrients flow into the flower tissue and support the development of the growing embryo within the seed. **As angiosperm seeds mature, the ovary walls thicken to form a fruit that encloses the developing seeds.** A fruit is a ripened ovary that contains angiosperm seeds. Examples of fruits are shown in **Figure 24–10.** Parts of the ovule toughen to form a seed coat, which is the outer layer that protects the delicate embryo and its tiny food supply. The ovary wall then thickens and may join with other parts of the flower stem. These structures together form a fruit that encloses the seeds.

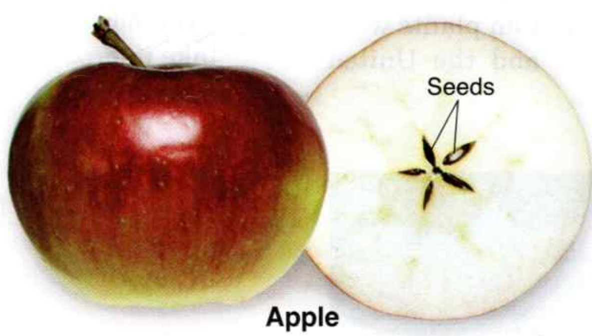
The term *fruit,* biologically speaking, applies to any seed that is enclosed within its embryo wall. The term applies to the things we usually think of as fruits, such as apples, grapes, and strawberries. However, foods such as peas, corn, beans, rice, cucumbers, and tomatoes, which we commonly call vegetables, are also fruits. Whether it tastes sweet or not, if it contains a seed enclosed inside the ovary wall, it is a fruit.

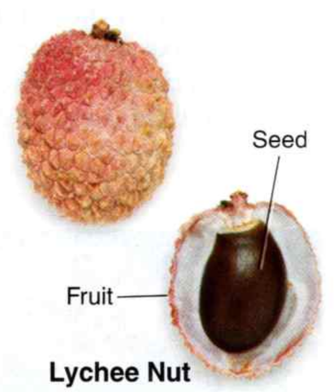
The ovary wall surrounding a simple fruit may be fleshy, as it is in grapes and tomatoes, or tough, like the pod of a bean. In some fruits, such as peaches and cherries, the inner wall of the ovary is attached rigidly to the surface of the seed. In others, such as the maple, the dry fruit forms an aerodynamic shape that helps the seed whirl gracefully down when it is released from the parent plant.

CHECKPOINT *What is a fruit?*

Figure 24–10 As seeds mature, the ovary walls thicken to form a fruit that encloses the developing seeds. Like the flowers from which they develop, fruits vary in structure. They can contain one seed, as in the lychee nut, or several, as in the apple. Fruits also have different amounts of tissue, which often relates to the mode of seed dispersal.







Seed Dispersal

What are fruits for, and why have they been favored by natural selection? They are not there to nourish the seedling—the endosperm does that. Why should an entire phylum of plants have seeds that are wrapped in an additional layer of nutrient-packed tissue—tissue that is later discarded when the fruit is released from the plant? It seems pointless, but in evolutionary terms, it makes all the sense in the world.

Think of the blackberries that grow wild in the forests of North America. Each seed is enclosed in a sweet, juicy fruit, making it a tasty treat for all kinds of birds and mammals. What good does all that sweetness do the fruit? All it does is get the seed eaten! Well, believe it or not, that's exactly the point.

▲ **Figure 24–11** **Seeds that are dispersed by animals typically contain fleshy, sweet tissue.** A cedar waxwing feasts on mountain ash berries. Berries are enclosed in sugary tissue that is eaten by birds or other animals. Berries contain seeds that pass through the animal and are dispersed away from the parent plant.

Dispersal by Animals The seeds of many plants, especially those with sweet, fleshy fruits, are eaten by animals, such as the cedar waxwing in **Figure 24–11.** The seeds are covered with tough coatings that protect them from digestive chemicals, enabling them to pass through an animal's digestive system unharmed. The seeds then sprout in the feces eliminated from the animal. **Seeds dispersed by animals are typically contained in fleshy, nutritious fruits.** These fruits provide nutrition for the animal and also help the plant disperse its seeds—often to areas where there is less competition with the parent plants.

Dispersal by Wind and Water Animals are not the only means by which plants can scatter their seeds. Seeds are also adapted for dispersal by wind and water. **Seeds dispersed by wind or water are typically lightweight, allowing them to be carried in the air or to float on the surface of the water.** The seeds of ash and maple trees are encased in winglike structures that spin and twirl as they are released, helping them glide considerable distances from their parent plants. Westerners are familiar with tumbleweed plants, shown in **Figure 24–12.** These plants break off at their roots and tumble along the dry plains, scattering their seeds as they are blown by the wind. An example of a seed that is dispersed by water is the coconut. This seed contains a liquid endosperm layer (the "milk" of the coconut). A coconut is buoyant enough to float in seawater within its protective coating for many weeks. Water dispersal is one reason for the success of this species in reaching remote islands.

▶ **Figure 24–12** **Wind-dispersed seeds are typically lightweight.** Tumbleweed plants, which live in a hot, dry, and windy environment, release small seeds as the plants are blown along open stretches of land. **Inferring** *How do the structural adaptations of tumbleweeds enable them to survive?*