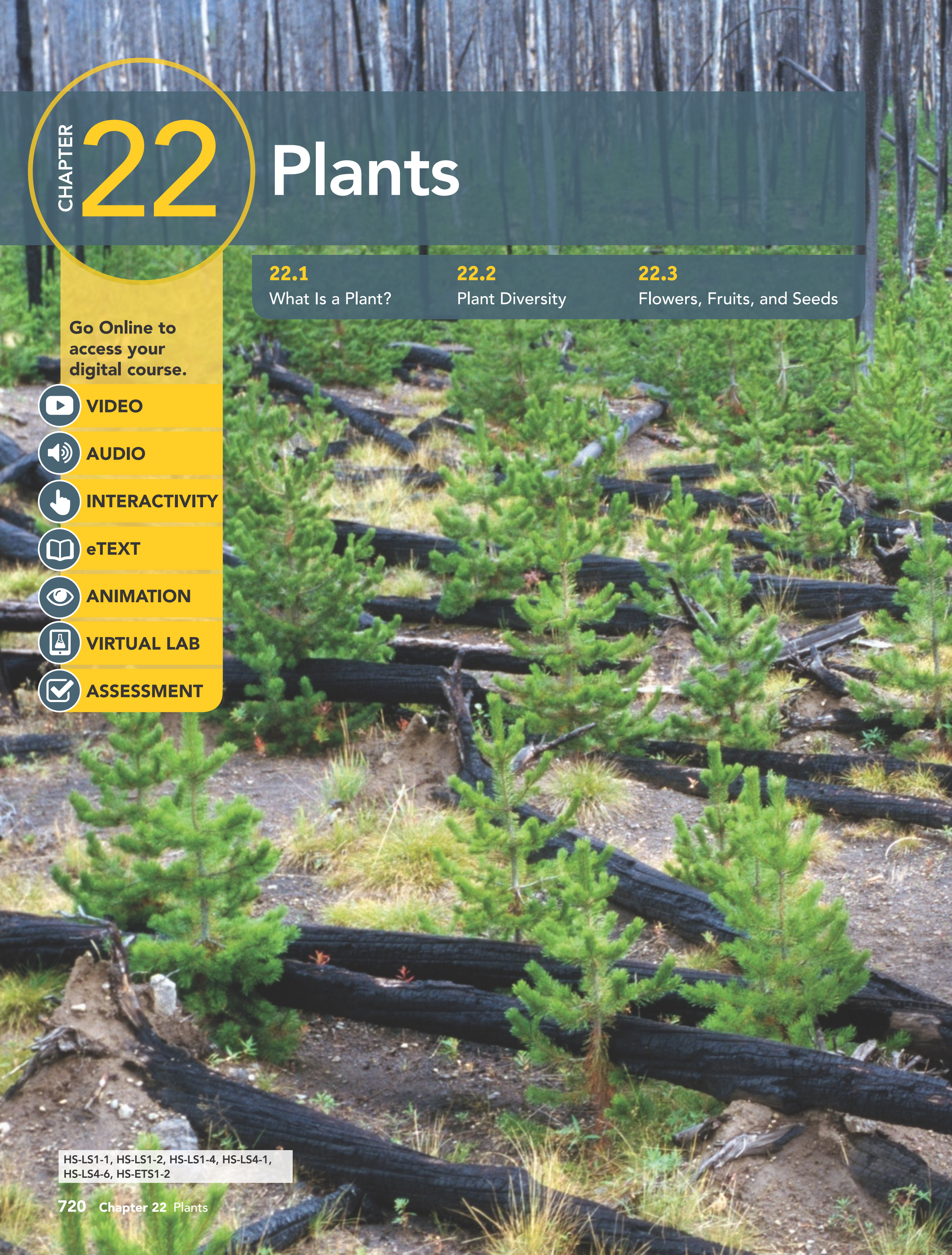

CHAPTER 22 Plants

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- AUDIO
- INTERACTIVITY
- eTEXT
- ANIMATION
- VIRTUAL LAB
- ASSESSMENT

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS4-1, HS-LS4-6, HS-ETS1-2

CASE STUDY

How did plants conquer the land?

In 1988, a tremendous fire burned vast tracts of forest in Yellowstone National Park. Many people were upset, thinking that a large area of the park had been permanently destroyed. Forest rangers reminded the public that fire is a natural event and the forest is adapted to survive fire. In fact, one type of tree in Yellowstone depends on fire to reproduce. This tree is the lodgepole pine. A resin seals the tree's seeds within cones. The resin only melts at the high temperature of a forest fire.

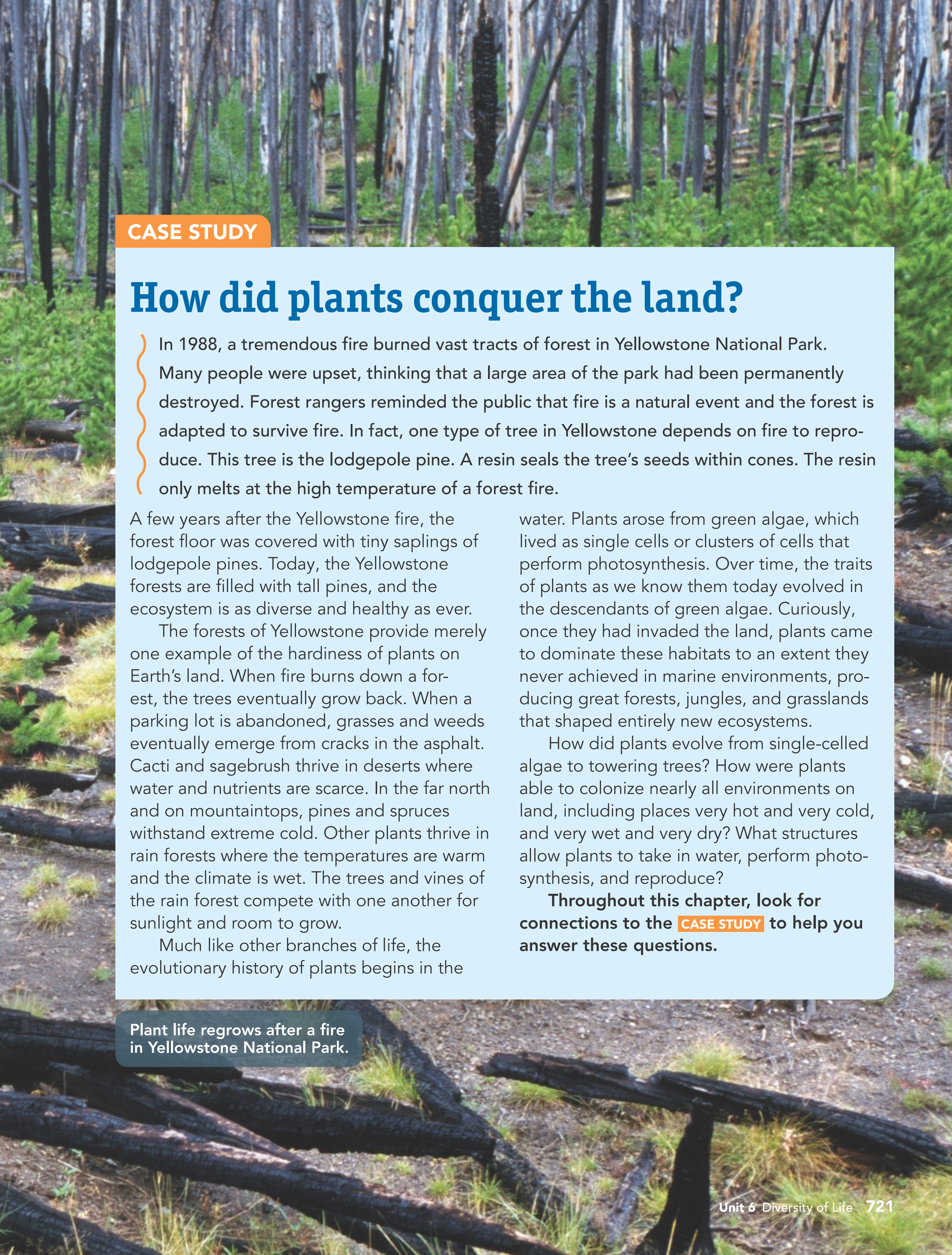
A few years after the Yellowstone fire, the forest floor was covered with tiny saplings of lodgepole pines. Today, the Yellowstone forests are filled with tall pines, and the ecosystem is as diverse and healthy as ever.

The forests of Yellowstone provide merely one example of the hardiness of plants on Earth's land. When fire burns down a forest, the trees eventually grow back. When a parking lot is abandoned, grasses and weeds eventually emerge from cracks in the asphalt. Cacti and sagebrush thrive in deserts where water and nutrients are scarce. In the far north and on mountaintops, pines and spruces withstand extreme cold. Other plants thrive in rain forests where the temperatures are warm and the climate is wet. The trees and vines of the rain forest compete with one another for sunlight and room to grow.

Much like other branches of life, the evolutionary history of plants begins in the water. Plants arose from green algae, which lived as single cells or clusters of cells that perform photosynthesis. Over time, the traits of plants as we know them today evolved in the descendants of green algae. Curiously, once they had invaded the land, plants came to dominate these habitats to an extent they never achieved in marine environments, producing great forests, jungles, and grasslands that shaped entirely new ecosystems.

How did plants evolve from single-celled algae to towering trees? How were plants able to colonize nearly all environments on land, including places very hot and very cold, and very wet and very dry? What structures allow plants to take in water, perform photosynthesis, and reproduce?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.



Plant life regrows after a fire in Yellowstone National Park.

LESSON **22.1**

What Is a Plant?

KEY QUESTIONS

- *What are the basic needs of plants?*
- *How did plants adapt to life on land?*
- *What feature defines most plant life cycles?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

VOCABULARY
alternation of generations
sporophyte
gametophyte

READING TOOL

As you read this lesson, identify the things that plants need to survive. Fill in the graphic organizer in your **Biology Foundations Workbook.**

INTERACTIVITY

Explore what makes a plant a plant.

What color is life? Living things can be just about any color, of course. Now, imagine yourself in a place so abundant with life that living things blot out the sun. What color do you see? If you've imagined a thick forest or a jungle teeming with life, then just one color will fill the landscape of your mind: green—the color of plants. You know that plants dominate this planet. Have you ever wondered why?

What Do Plants Need to Survive?

Life is tough, especially for a plant that is literally rooted in just one place. As a result, plants have developed adaptations to their stationary lifestyle that enable them to fulfill each of their basic needs, as shown in **Figure 22-1**. ***The lives of plants depend upon sunlight, gas exchange, water, and minerals.***

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.

Gas Exchange Plants require oxygen to support cellular respiration as well as carbon dioxide to carry out photosynthesis. Therefore, they need to be able to exchange these gases with the atmosphere.

Water and Minerals Water is one of the raw materials of photosynthesis. So, land plants have evolved structures to draw water from the ground that also enable them to take in essential minerals from the soil. Many plants have specialized tissues that carry water and minerals upward from the soil and distribute them throughout the plant.

READING CHECK **Infer** Why are plants not found in deep underground caves?

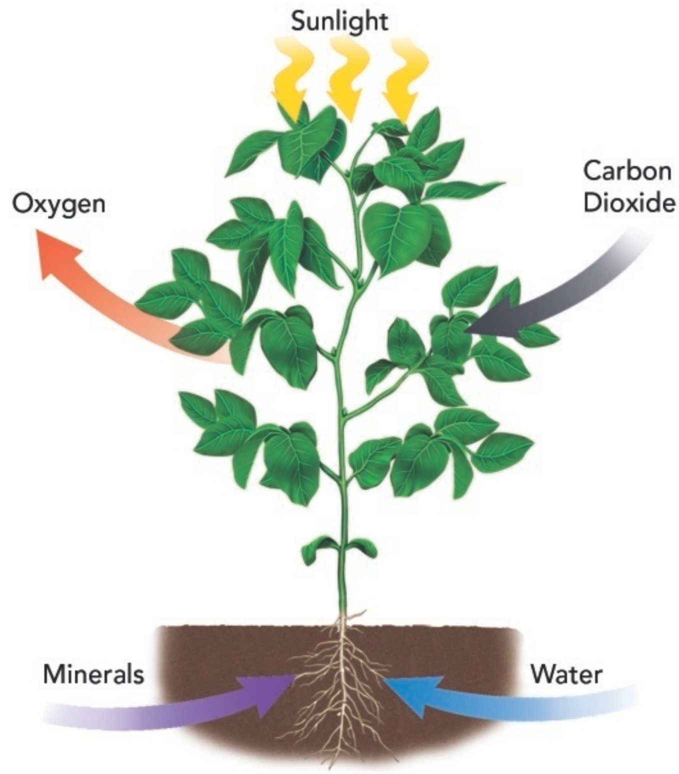


Figure 22-1

Basic Needs of a Plant

All plants have the same basic needs: sunlight, water, minerals, and a way to exchange gases with the surrounding air. **Observe** Where do water and minerals enter the plant?

The History and Evolution of Plants

For most of Earth's history, land plants did not exist. Life was concentrated in oceans, lakes, and streams. Photosynthetic prokaryotes added oxygen to our planet's atmosphere and provided food for consumers.

VIDEO

Investigate the interrelationship between a changing Earth and major stages of plant evolution.

Origins in the Water The fossil record indicates that the ancestors of land plants were water-dwelling organisms similar to today's green algae. Most of these microorganisms were unicellular, but some were composed of multiple cells. At one time biologists classified green algae as protists. But since green algae have cell walls and photosynthetic pigments identical to those of land plants, they are now considered to be part of the plant kingdom.

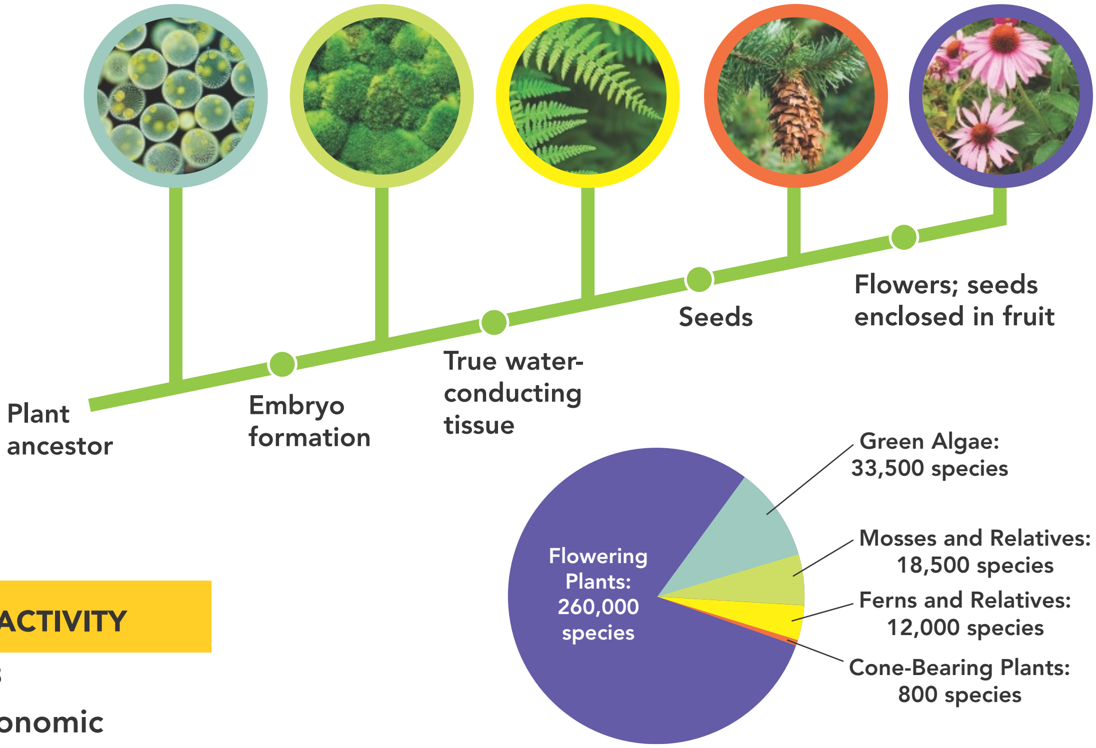
The First Land Plants The oldest traces of land plants date to 472 million years ago. These plants, such as *Cooksonia*, shown in **Figure 22-2**, lacked leaves and roots and were only a few centimeters tall. The greatest challenge they faced was obtaining water. They solved this challenge by growing close to the ground in damp locations. ***The demands of life on land favored the evolution of plants that were able to draw water from the soil, resist drying out, and reproduce without water.***

The appearance of plants on land changed the rest of life on Earth. New ecosystems emerged, and organic matter began to form soil. From the first pioneering land plants, one group developed into mosses. Another lineage gave rise to ferns, cone-bearing plants, and the most successful group of all—the flowering plants.

Figure 22-2

A Fossilized Plant

One of the earliest fossilized vascular plants was *Cooksonia*, which dates back 425 million years. This fossil shows the branched stalks that bore reproductive structures at their tips.



INTERACTIVITY

Figure 22-3

Plant Taxonomic Diagram

There are five main groups of plants in existence today. Note that the colors of the plant groups in the circle graph correspond to the colors of the same groups in the cladogram. **Ask Questions** What questions about plant evolution would you ask based on the data in the graph?

An Overview of the Plant Kingdom All plants are eukaryotes, have cell walls containing cellulose, and carry out photosynthesis using chlorophyll *a* and *b*. Botanists divide the plant kingdom into five major groups based on four important features: embryo formation, specialized water-conducting tissues, seeds, and flowers. The relationship of these taxonomic groups to one another is shown in **Figure 22-3**. Plants that form embryos are often referred to as "land plants," even though some of them now live in watery environments. Why was the development of these four features so important to plant evolution?

- Embryos that develop within a plant have protection from harsh elements on land.
- Plants with water-conducting tissue can draw water to greater heights than allowed by simple diffusion, allowing them to grow much larger.
- Seeds provide food and protection from drying out for the developing embryo. Seeds can be widely dispersed from the parent plant to grow in new locations.
- The successes of flowering plants, as shown in the circle graph in Figure 22-3, are due to the reproductive advantage they receive from their flowers and from the fruits they form around their seeds.

Plant scientists classify plants into finer groups within these major branches by comparing DNA sequences of various species.

READING CHECK **Review** What are the five major groups in the plant kingdom?

The Plant Life Cycle

Plants have a distinctive sexual life cycle that sets them apart from most other living organisms. ***The life cycle of plants has two alternating phases—a diploid (2N) phase and a haploid (N) phase.*** This shift between the haploid phase and the diploid phase is known as the **alternation of generations**.

The multicellular diploid (2N) phase is known as the **sporophyte** (SPOH ruh fyt), or spore-producing plant. The multicellular haploid (N) phase is known as the **gametophyte** (guh MEE tuh fyt), or gamete-producing plant. Recall from Chapter 12 that haploid (N) organisms carry a single set of chromosomes in their cell nuclei, while diploid (2N) organisms have two sets of chromosomes.

As shown in **Figure 22-4**, a sporophyte produces haploid spores through meiosis. These spores grow into multicellular structures called gametophytes. Each gametophyte produces reproductive cells called gametes—sperm and egg cells. During fertilization, a sperm and egg fuse with each other, producing a diploid zygote. The zygote develops into a new sporophyte, and the cycle begins again.

BUILD VOCABULARY

Suffixes The suffixes *-phyta* and *-phyte* come from the Greek word *phyton*, which means "plant."

READING TOOL

After reading this page, use Figure 22-4 to write a paragraph in your own words that describes alternation of generations. Start your paragraph with a sporophyte plant.

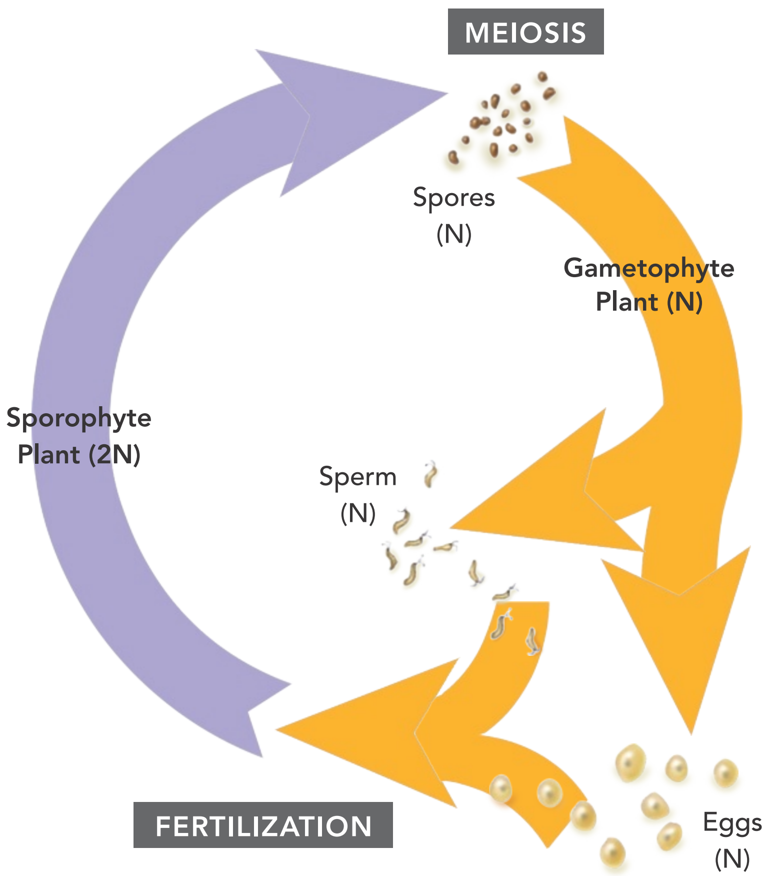


Figure 22-4

Alternation of Generations

Most plants have a life cycle with alternation of generations in which the haploid gametophyte phase alternates with the diploid sporophyte phase.

Haploid (N)
Diploid (2N)

Exploration Lab Guided Inquiry

Comparing Adaptations of Ferns and Mosses

Problem How are mosses and ferns able to survive on land?

In this lab, you will compare a moss and a fern to determine which plant is better adapted to grow when conditions become dry.

You can find this lab in your digital course.

Figure 22-5 shows an important trend in plant evolution—the reduction in size of the gametophyte and the increasing size of the sporophyte. Although many green algae have a diploid sporophyte phase, some do not; their only multicellular bodies are gametophytes. Mosses and their relatives consist of a relatively large gametophyte and smaller sporophytes. Ferns and their relatives have a small gametophyte and a larger sporophyte. Seed plants have an even smaller gametophyte.

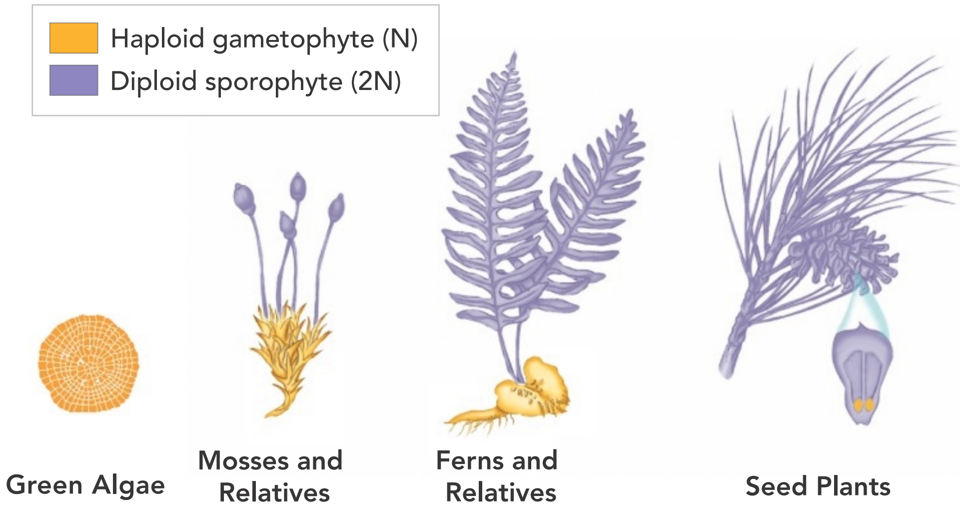


Figure 22-5

Trends in Plant Evolution

An important trend in plant evolution is the reduction in size of the gametophyte and the increase in size of the sporophyte. **Interpret Visuals** How does the relative size of the haploid and diploid stages differ between mosses and seed plants?

HS-LS1-1, HS-LS1-2, HS-LS4-1

LESSON 22.1 Review

KEY QUESTIONS

1. Why do plant cells need sunlight, carbon dioxide, and water?
2. How did the relative lack of water on land affect how plants evolved?
3. Use the terms *sporophyte* and *gametophyte* to describe the alternation of generations in plants.

CRITICAL THINKING

4. **Construct an Explanation** Most plants have their leaves aboveground and their roots buried in the soil. How does this organization of structures help the plant survive?
5. **Identify Patterns** What pattern is formed by sporophytes and gametophytes in plant evolution?
6. **CASE STUDY** List and describe the four main adaptations that helped plants to thrive on land.

Plant Diversity

LESSON 22.2

KEY QUESTIONS

- *What are the characteristics of green algae?*
- *What factor limits the size of bryophytes?*
- *How is vascular tissue important?*
- *What adaptations allow seed plants to reproduce without standing water?*

HS-LS1-4: Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

VOCABULARY

bryophyte
vascular tissue
archegonium
antheridium
sporangium
tracheophyte
tracheid
xylem
phloem
seed
gymnosperm
angiosperm
pollination
ovule

READING TOOL

Compare and contrast the different types of plants. List each plant's characteristics and describe their similarities on the table in your **Biology Foundations Workbook.**

Like the mosses clinging to the moist rocks in the photograph, the earliest land plants were seedless, were restricted to damp environments, and grew only a few centimeters tall. Even today, many groups of seedless plants are still around. How do these plants continue to thrive, and how do their reproductive patterns differ from plants that produce seeds?

Green Algae

What do you think of when you hear the word *algae*? As we use the word today, the algae are not a single group of organisms. Some algae are prokaryotes, like cyanobacteria, and some are protists, like the dinoflagellates. The *green algae*, however, are the ones that belong to the plant kingdom.

The First Plants Fossil evidence suggests that the green algae appeared well before plants first emerged on land. Fossil formations from more than 550 million years ago during the Cambrian Period show evidence of large mats of green algae. See **Figure 22-6**.

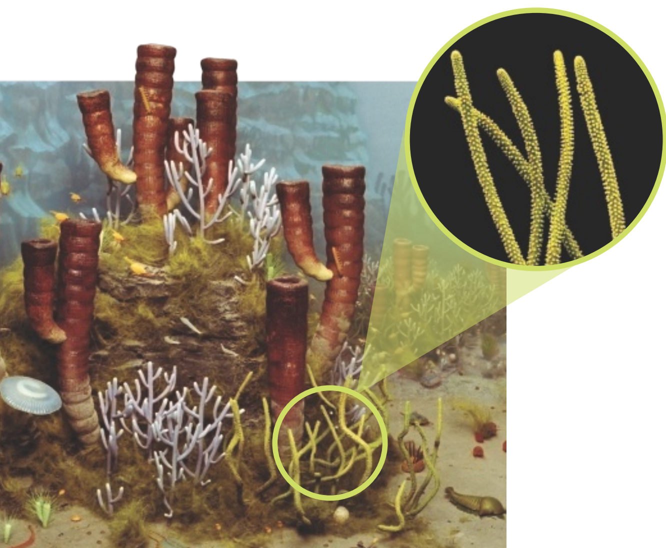


Figure 22-6

Early Plants and Animals

Primitive green algae shared the ocean floor with corals and sponges in the Middle Cambrian Period, about 500 million years ago.

The green algae share many characteristics—including their photosynthetic pigments and cell wall composition—with larger, more complex plants. ***Green algae are mostly aquatic. They are found in fresh and salt water, and in some moist areas on land.*** Because most green algae are single cells or branching filaments, they are able to absorb moisture and nutrients directly from their surroundings. Therefore, most green algae do not contain the specialized tissues found in other plants.

Life Cycle Like land plants, many green algae have life cycles that switch back and forth between haploid and diploid phases. For example, so long as living conditions are suitable, the haploid green alga *Chlamydomonas* reproduces asexually by mitosis, as shown in the left half of **Figure 22-7**. If environmental conditions become unfavorable, *Chlamydomonas* can switch to a stage that reproduces sexually, as shown in the right half of the figure.

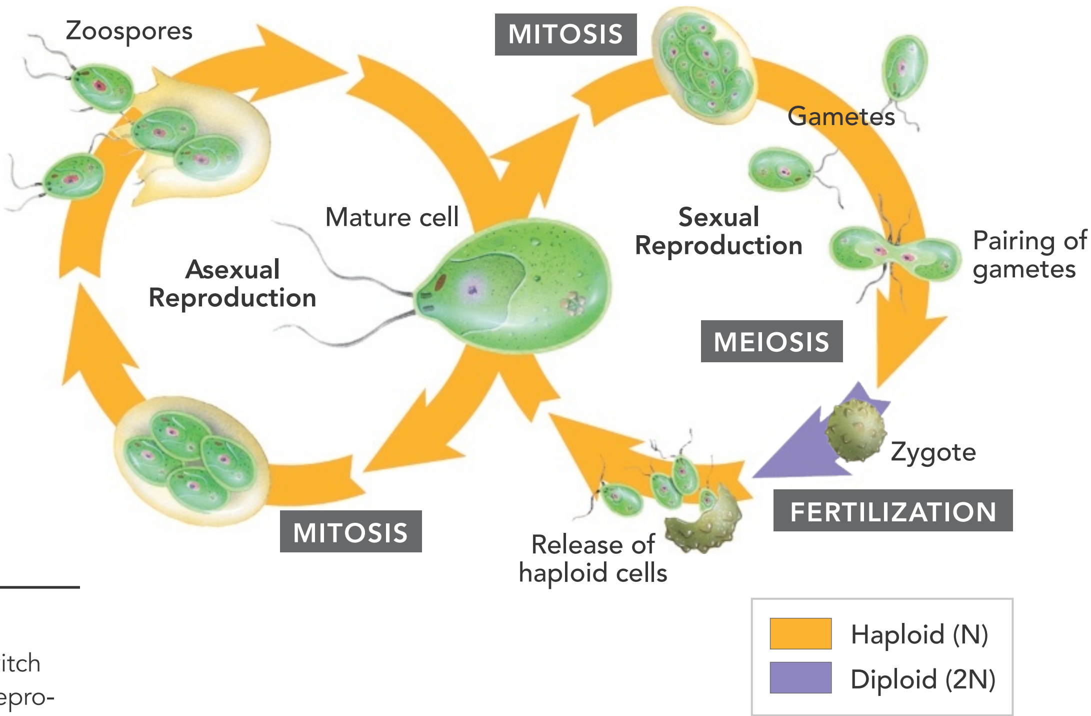


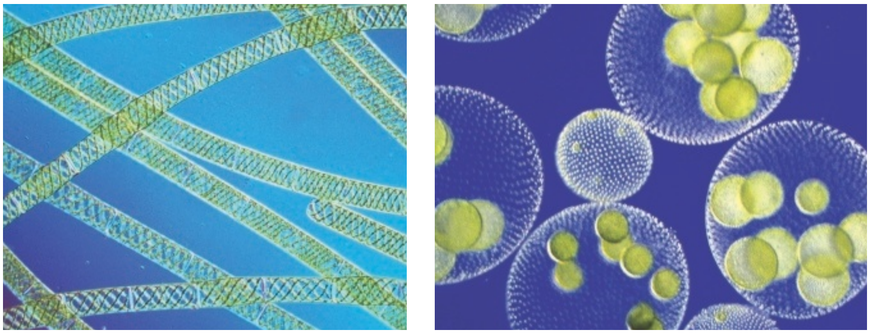
Figure 22-7

Life Cycle of *Chlamydomonas*

The green alga *Chlamydomonas* can switch from asexual to sexual reproduction as environmental conditions change. **Interpret Visuals** Which form of reproduction includes a diploid organism that can survive harsh conditions?

Multicellularity Many green algae form colonies, and they provide a hint about how the first multicellular plants may have evolved. Two examples of colonial algae are shown in **Figure 22-8**. The freshwater alga *Spirogyra* forms long, threadlike colonies constructed of filaments. The cells of a colony are stacked almost like soda cans placed end to end. *Volvox* colonies, shown on the right, are more complex than those of *Spirogyra*, consisting of as few as 500 to as many as 50,000 cells arranged to form hollow spheres.

READING CHECK Review How do green algae get moisture and nutrients?



Spirogyra (LM 80×) **Volvox** (LM 50×)

Figure 22-8

Multicellular Green Algae

Colonial algae such as *Spirogyra* and *Volvox* provide evidence that multicellular organisms could evolve from single-celled versions.

Mosses and Other Bryophytes

In the cool forests of the northern United States, the moist ground feels almost like a spongy green carpet. Look closely, however, and you will see clusters of short plants known as mosses. Mosses have a waxy coating that resists drying and thin filaments known as rhizoids (RY zoydz) that anchor them to the soil and absorb water and nutrients. **Figure 22-9** shows the common structure of a moss.

Mosses belong to a group of plants known as **bryophytes** (BRY oh fyts). Unlike algae, the bryophytes have specialized reproductive organs and grow from embryos. The bryophytes were among the first plants to become established on land. In addition to mosses, the bryophytes include two other groups, known as hornworts and liverworts. Bryophytes are generally small and found only in damp soil. This is because they lack water-conducting **vascular tissue**. Vascular tissue makes it possible for other plants to draw water up against the pull of gravity. ***The lack of vascular tissue limits the height of most bryophytes to just a few centimeters.***

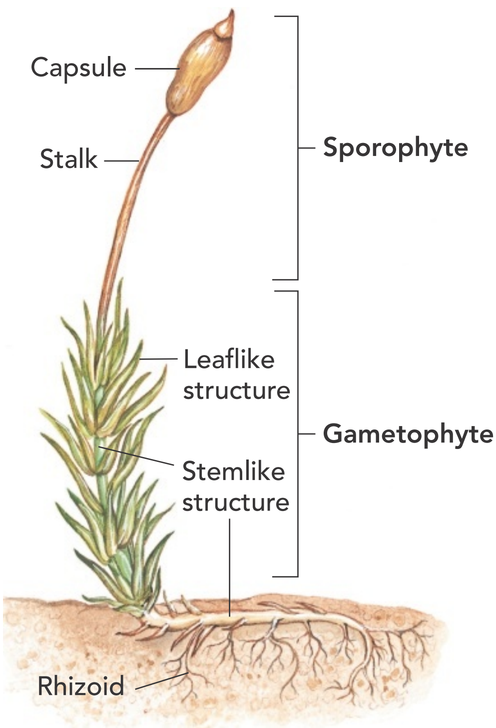


Figure 22-9

Structure of Moss

In bryophytes, the gametophyte is the dominant, more familiar stage of the life cycle.

INTERACTIVITY

Design a park by planning which types of plants will thrive in particular ecosystems.

Life Cycle Like all land plants, bryophytes display alternation of generations. In bryophytes, the gametophyte is the dominant stage of the life cycle. It also carries out most of the plant's photosynthesis. As shown in **Figure 22-10**, the sporophyte grows out of the body of the gametophyte and is dependent on it for water and nutrients. When a moss spore lands in a moist place, it sprouts and grows into a tangled mass of green filaments that develop into the familiar green moss plants. Gametes are formed in reproductive structures at the tips of the gametophytes. Eggs are produced in a type of organ called **archegonia** (ahr kuh GOH nee uh; singular: archegonium). Sperm are produced in **antheridia** (an thur ID ee uh; singular: antheridium) and need standing water to swim to the egg cells. When they meet, sperm and egg cells fuse to produce a diploid zygote.

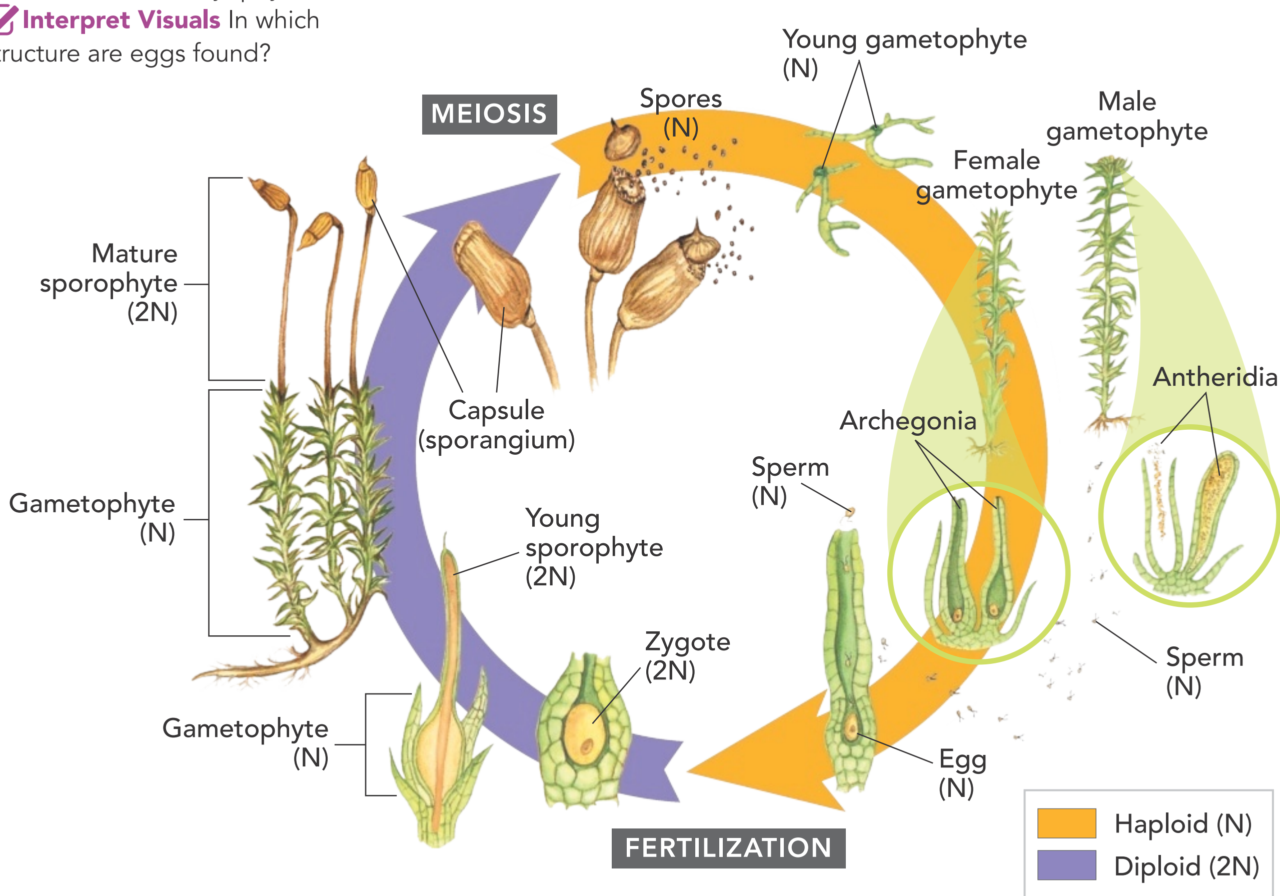
That zygote then grows into a sporophyte, capped by a spore capsule called a **sporangium** (spoh RAN jee um; plural: sporangia). Inside the capsule, haploid spores are produced by meiosis. When the capsule ripens, it opens, and haploid spores are scattered to the wind to start the cycle again.

READING CHECK **Cite Evidence** Identify evidence that supports the claim that the gametophyte carries out most of a bryophyte's photosynthesis.

Figure 22-10

Moss Life Cycle

This life cycle shows the dominance of the gametophyte stage that is typical of mosses and other bryophytes. **Interpret Visuals** In which structure are eggs found?



Ferns and Their Relatives

For millions of years, plants grew no taller than a meter because they lacked vascular tissue. Then, about 420 million years ago, something remarkable happened. The small, mosslike plants on land were joined by new plants, some as large as trees. What happened? Fossil evidence shows that these new plants were the first to have a transport system with true vascular tissue. For the first time, plants were able to grow high above the ground.

CASE STUDY

Figure 22-11

Vascular Tissue

Horsetails are among the most primitive plant species to have developed specialized vascular tissue. These tissues are able to carry water and nutrients against the pull of gravity. **Infer** How can height be an advantage to plants?

Evolution of a Transport System Vascular plants, such as the horsetails shown in **Figure 22-11**, are also known as **tracheophytes** (TRAEY kee uh fyts). They are named after a specialized type of water-conducting cell, called a **tracheid** (TRAY kee id). Tracheids are hollow tubelike cells with thick cell walls strengthened by lignin. They are one of the great evolutionary innovations of the plant kingdom.

Tracheids are found in **xylem** (ZY lum), a tissue that carries water upward from the roots to every part of a plant. Tracheids are long, slender cells with regions on the ends and sides known as pits. The cell walls in pit regions are extremely thin, which allows water to pass through from one tracheid to the next.

Vascular plants also have a second transport tissue called phloem. **Phloem** (FLOH um) transports nutrients and carbohydrates produced by photosynthesis. Like xylem, the main cells of phloem are long and specialized to move fluids throughout the plant body. ***Vascular tissues—xylem and phloem—make it possible for vascular plants to move fluids through their bodies against the force of gravity.*** Vascular plants can grow tall, but not indefinitely tall. One reason is the limits of vascular transport. Scientists estimate that the tissues can lift water to a maximum height of about 130 meters. That is about the height of the tallest trees.

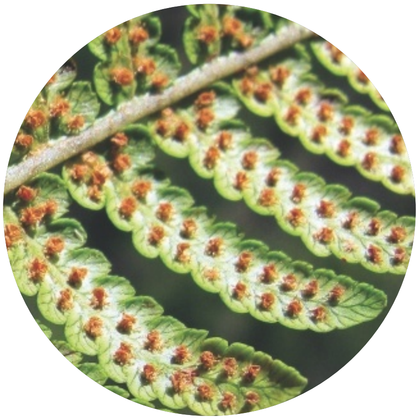
READING TOOL

Create a two-column chart that compares and contrasts xylem and phloem. You can add information to this chart throughout the chapter.

Figure 22-12

Fern Fronds and Sporangia

Fronds are the leaves of ferns. Sori, which are clusters of sporangia, often form on the underside of a frond.



Seedless Vascular Plants Although the tracheophytes include all seed-bearing plants, three groups of seedless vascular plants are alive today: club mosses, horsetails, and ferns.

The most numerous seedless plants, with 11,000 species, are the ferns. Ferns have true vascular tissues, strong roots, creeping or underground stems called rhizomes (RY zohmz), and large leaves called fronds, shown in **Figure 22-12**. Ferns can thrive in areas with little light. They are most abundant in wet, or at least seasonally wet, habitats.

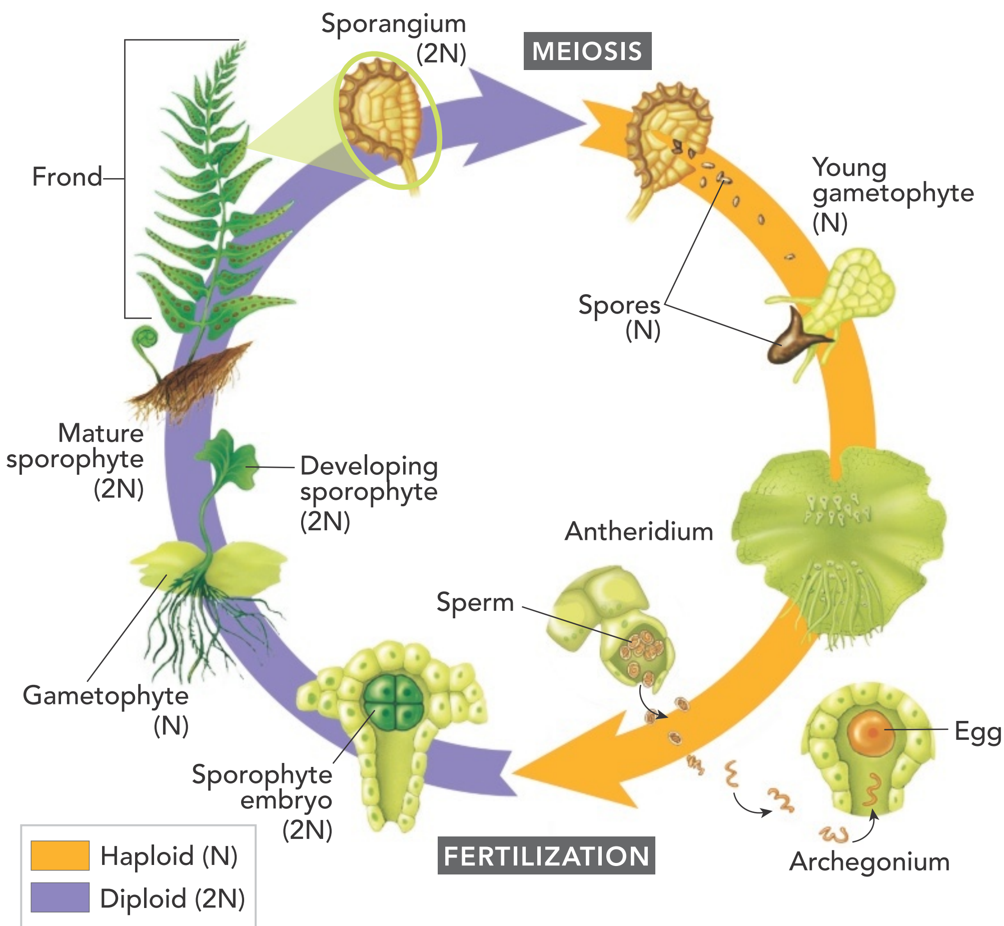
Life Cycle The large plants easily recognized as ferns are actually the diploid sporophyte phase of the fern life cycle. The fern life cycle is shown in **Figure 22-13**. Spores produced by these plants grow into thin, heart-shaped haploid gametophytes, which live independently of the sporophyte. As in bryophytes, sperm and eggs are produced on these gametophytes in antheridia and archegonia, respectively. Fertilization requires a thin film of water, so that the sperm can swim to the eggs. The diploid zygote produced by fertilization develops into a new sporophyte plant, and the cycle begins again.

READING CHECK **Cause and Effect** Why are ferns able to grow so much taller than bryophytes?

Figure 22-13

Fern Life Cycle

In the life cycle of a fern, the dominant and recognizable stage is the diploid sporophyte. **Interpret Visuals** Are the spores haploid or diploid?



CASE STUDY Analyzing Data

Keeping Ferns in Check

Dennstaedtia punctilobula is a fern that grows on the forest floor and often crowds out tree seedlings, blocking efforts to regrow trees after logging or other work in a forest. To understand the fern better, scientists measured the number of viable fern spores per square centimeter of soil at various distances from a plot of existing fern plants. They counted spores in the soil in July, as the ferns were just beginning to grow, and in November, after they had released their spores.

1. **Construct Graphs** Place the data from the table on a scatterplot showing the number of spores per square centimeter versus their distance from the plot. Use different colors for the before and after dispersal data points.
2. **Calculate** What percentage of the spores after dispersal are found within 4 meters of the parent plants?

Number of Spores in Soil

Distance From Plot of Ferns (meters)	Before Dispersal (July)	After Dispersal (November)
0	14	54
2	16	18
4	5	9
10	10	17
50	2	7

3. **Interpret Graphs** Are spore numbers higher before dispersal or after dispersal? Explain.
4. **Use Evidence to Construct an Argument** Would cutting down nearby clusters of ferns prevent ferns from invading patches of the forest that have just been cut for timber? Explain your reasoning on the basis of the data.

Seed Plants

Whether they are acorns, pine nuts, dandelion seeds, or the peas shown in **Figure 22-14**, seeds can be found everywhere. What are seeds? Are they gametes? Reproductive structures? Do they contain sperm or eggs? The truth is that they are none of the above.

A **seed** is a plant embryo and its food supply encased in a protective covering. Each and every seed contains a living plant ready to sprout as soon as it encounters the proper conditions for growth. The production of seeds has been one key to the ability of plants to colonize even the driest environments on land. The living plant within a seed is diploid and represents an early stage of the sporophyte phase of the plant life cycle.

Figure 22-14

Seeds

The seeds of pea plants develop in pea pods. If conditions are right, each pea could grow into a new plant.

The First Seed Plants

There exist fossils of seed-bearing plants that lived almost 360 million years ago. These fossils document several evolutionary stages in the development of the seed. The fossil record indicates that ancestors of seed plants evolved new adaptations that enabled them to survive in many environments on dry land. Similarities in DNA sequences from modern plants provide evidence that today's seed plants are all descended from common anscestors. Unlike mosses and ferns, the gametes of seed plants do not need standing water for fertilization. ***Adaptations that allow seed plants to reproduce without standing water include a reproductive process that takes place in cones or flowers, the transfer of sperm by pollination, and the protection of embryos in seeds.***

BUILD VOCABULARY

Word Origins The prefix *gymno-* comes from the Greek word *gymnos*, meaning "naked." The prefix *angio-* comes from the Greek word *angeion*, meaning "vessel." The suffix *-sperm* means "seed."

Cones and Flowers

In seed plants, the male gametophytes and the female gametophytes grow and mature directly within the sporophyte. The gametophytes develop inside reproductive structures known as cones or flowers. In fact, seed plants are divided into two groups on the basis of which of these structures they have.

Gymnosperms (JIM noh spurmz) bear their seeds directly on the scales of cones. These were the first seed-bearing plants to appear in the fossil record. Today, highly successful gymnosperms include trees such as pine, spruce, and fir that grow in the great forests of North America.

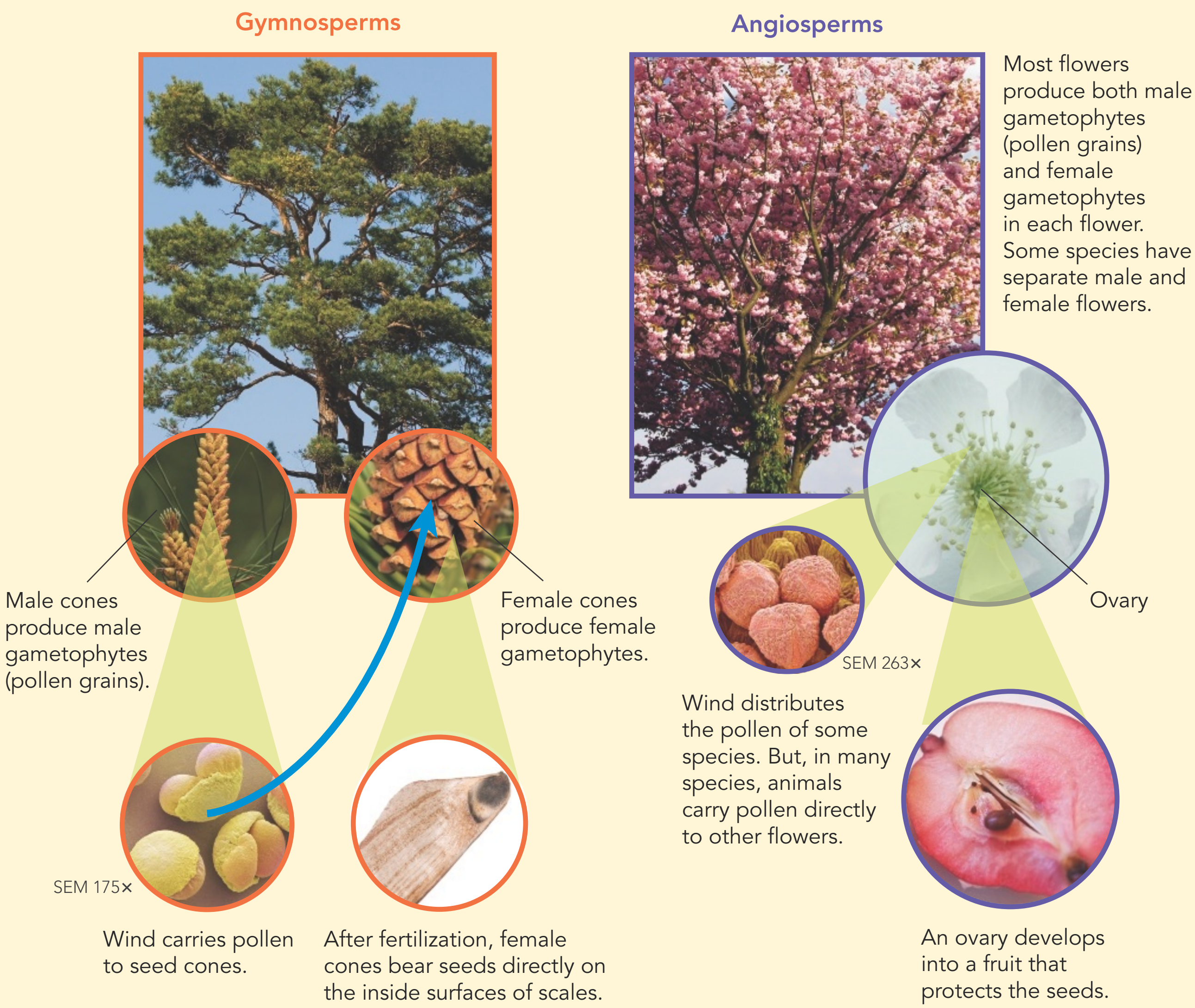
Angiosperms (AN jee oh spurmz), or flowering plants, bear their seeds in flowers inside a special layer of tissue that surrounds and protects the seed. **Figure 22-15** compares the reproductive structures of gymnosperms and angiosperms. Flowering plants include nearly all of the crops grown for food around the world, such as wheat, corn, and rice, as well as fruits like apples and oranges. While many flowers are large and colorful, others, like the flowers produced by grasses and many trees, have more subtle shapes and colors, and are easy to overlook.

Visual Summary

Figure 22-15

Gymnosperms and Angiosperms

The two major groups of seed plants can be distinguished by their reproductive structures.



Pollen The entire male gametophyte of a seed plant 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, pollen grains are carried to the female reproductive structure by wind or animals such as insects. The transfer of pollen from the male reproductive structure to the female reproductive structure is called **pollination**.

Seeds After fertilization, the zygote contained within a seed grows into a tiny plant—the sporophyte embryo. A tough seed coat surrounds and protects the embryo and keeps the contents of the seed from drying out. Seeds can survive long periods of bitter cold, extreme heat, or drought until it is time to sprout.

Figure 22-16
Pollen Cone

This pollen cone on a pine tree is shedding pollen, which will be carried by wind to seed cones.

The Life Cycle of a Gymnosperm

The word *gymnosperm* actually means "naked seed." The name reflects the fact that gymnosperms produce seeds that are exposed on the scales within cones. Gymnosperms alive today include relatively rare plants such as cycads and the much more abundant plants known as conifers, which include pines and firs.

Pollen Cones and Seed Cones Conifers produce two types of cones: pollen cones and seed cones. Meiosis takes place in pollen cones—also called male cones—to produce pollen grains, as shown in **Figure 22-16**. As tiny as it is, a pollen grain contains the entire male gametophyte stage of the life cycle.

Seed cones are larger than pollen cones and produce the female gametophytes. Near the base of each scale of the seed cones are two **ovules** (AHV yoolz). 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.

INTERACTIVITY

Explore the variations in the reproductive cycles of the major plant groups.

Pollination and Fertilization The conifer life cycle, shown in **Figure 22-17**, typically takes two years to complete. The cycle begins in the spring as male cones release enormous numbers of pollen grains carried away by the wind. Some of these pollen grains reach female cones. There, the pollen grains are caught in a sticky secretion produced by the ovules within the female cones and pulled inside the ovules.

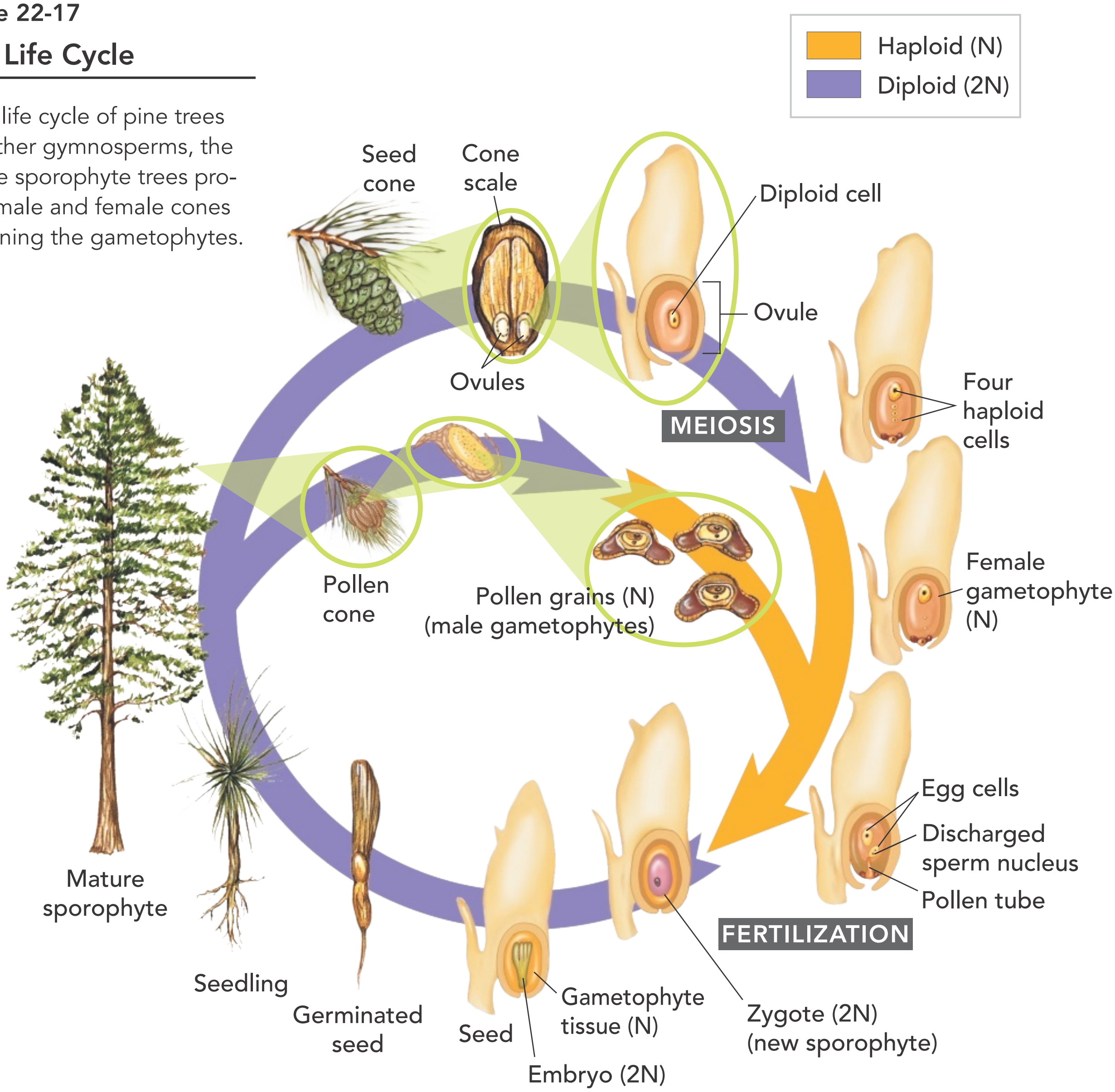
If a pollen grain lands near an ovule, the grain splits open and begins to grow a pollen tube. Once the pollen tube reaches the female gametophyte, one sperm nucleus disintegrates; the other fertilizes the egg contained within the female gametophyte. Fertilization produces a diploid zygote, which grows into an embryo. The embryo is then encased in a protective covering to form a seed that is ready to be scattered.

ANIMATION

Figure 22-17

Pine Life Cycle

In the life cycle of pine trees and other gymnosperms, the mature sporophyte trees produce male and female cones containing the gametophytes.



HS-LS1-4

LESSON 22.2 Review

KEY QUESTIONS

1. Describe the characteristics of green algae.
2. Why are bryophytes small?
3. How did the evolution of vascular tissue function in the success of land plants?
4. What is a seed?

CRITICAL THINKING

5. **Construct an Explanation** Why are ferns common in damp forests, but not in grasslands, deserts, and other dry environments?
6. **Classify** Make a table with two columns—labeled haploid and diploid—and assign each of the following structures from the pine life cycle to the appropriate column: pollen tube, seed cone, embryo, ovule, and seedling.
7. **CASE STUDY** How do seeds make angiosperms and gymnosperms more fit to reproduce on land than ferns and mosses?

Flowers, Fruits, and Seeds

LESSON 22.3

KEY QUESTIONS

- *How are different angiosperms classified?*
- *What are flowers?*
- *How does fertilization in angiosperms differ from fertilization in other plants?*
- *What is vegetative reproduction?*
- *How do fruits form?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS1-4: Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

VOCABULARY

ovary • fruit • cotyledon • monocot • dicot • embryo sac • pollination • double fertilization • endosperm • vegetative reproduction • dormancy germination

READING TOOL

Complete the chart in your **Biology Foundations Workbook** to compare and contrast monocots and dicots.

"Flower Power" may have been a slogan from the San Francisco "hippie" movement of the 1960s, but to biologists, flower power is a real thing. As a result of it, flowering plants dominate the land and are the most abundant organisms in the plant kingdom. What are the secrets of their success? As you will see, it all has to do with the unique way in which they reproduce.

Angiosperms

Angiosperms first appeared during the Cretaceous Period about 135 million years ago, making their origin the most recent of any phylum, plant or animal. Flowering plants originated on land and soon came to dominate Earth's plant life. Angiosperms make up the vast majority of plant species.

Angiosperms produce sexual reproductive organs known as flowers. Flowers contain **ovaries**, which surround and protect the seeds. The presence of an ovary gives angiosperms their name: *Angiosperm* means "enclosed seed." After fertilization, ovaries within flowers develop into fruits that surround, protect, and help disperse the seeds. The angiosperm **fruit** is a structure containing one or more matured ovaries. The wall of the fruit helps disperse the seeds inside it, carrying them away from the parent plant.

Angiosperm Classification For many years, flowering plants were classified according to the number of seed leaves, or **cotyledons** (kaht uh LEED uns), in their embryos. Those with one seed leaf were called **monocots**. Those with two seed leaves were called **dicots**. At one time, these two groups were considered classes within the angiosperm phylum, and all angiosperms were placed in one class or the other.

VIDEO

Learn about the two main categories of flowering plants.

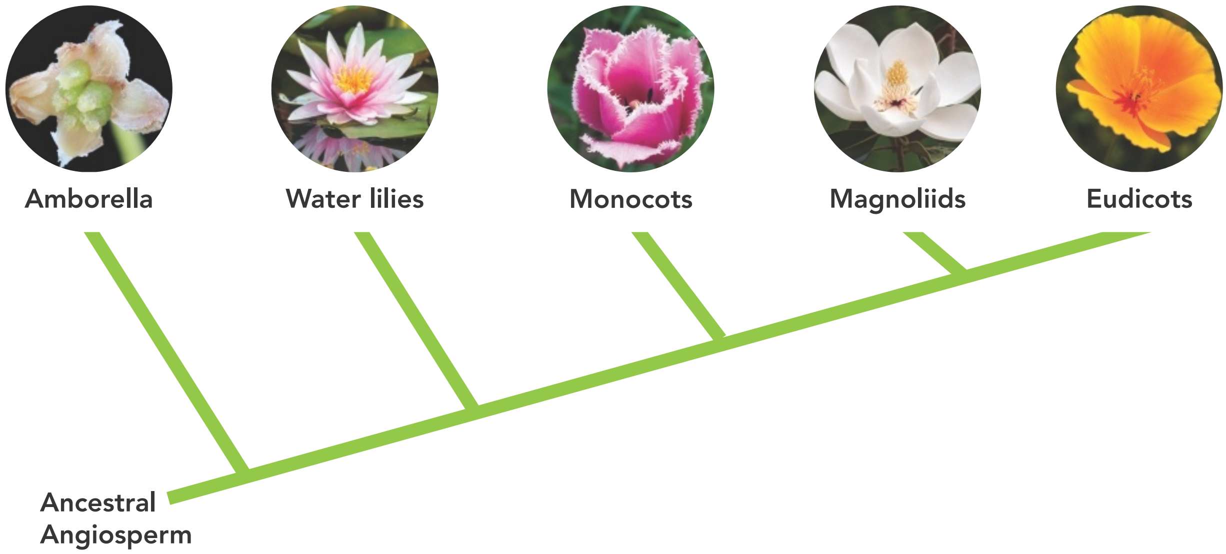


Figure 22-18

Angiosperm Clades

Five of the major clades of angiosperms are represented here. Scientists are still working out the relationships among these groups.

INTERACTIVITY

Investigate the great diversity of angiosperms.

More recent studies of plant genomes and new fossil discoveries have shown that things are actually a little more complicated. Around 135 million years ago, the oldest known angiosperm, *Archaefructus*, whose name means "ancient fruit," first appeared. While it is a true angiosperm, it is neither a monocot nor a dicot. Other evidence suggests that *Amborella*, a plant found on the Pacific island of New Caledonia, belongs to yet another lineage of flowering plants. Information gained from the *Amborella* discovery led scientists to place other plants, such as the water lilies, near the base of angiosperm evolution.

Figure 22-18 summarizes the modern view of angiosperm classification. While the monocots form a single group, the dicots fall into a number of different categories. This means, of course, that the term *dicot* is no longer used for classification. However, it can still be used to describe many of the characteristics of plant structure, and that is how it is used in this book.

Angiosperm Diversity The people who work with plants, including farmers, botanists, and foresters, categorize angiosperms according to a variety of characteristics. ***Angiosperms differ in the number of their seed leaves, the strength and composition of their stems, and the number of growing seasons they live.*** An iris, for example, has a single seed leaf, is a nonwoody plant, and may live for many years.

Monocots and Dicots Angiosperms are called either monocots or dicots based on the number of seed leaves they produce. They also differ in characteristics such as stem structure and the number of petals per flower. **Figure 22-19** illustrates the differences between monocots and dicots. Monocots include plants such as corn, wheat, lilies, orchids, and palms. Monocot grasses—especially wheat, corn, and rice—are cultivated in mass quantities for food. Dicots include roses, clover, tomatoes, oaks, and daisies.

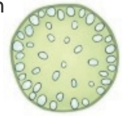
Characteristics of Monocots and Dicots					
	Seeds	**Leaves**	**Flowers**	**Stems**	**Roots**
Monocots	Single cotyledon 	Parallel veins 	Floral parts often in multiples of 3 	Vascular bundles scattered throughout stem 	Fibrous roots 
Dicots	Two cotyledons 	Branched veins 	Floral parts often in multiples of 4 or 5 	Vascular bundles arranged in a ring 	Taproot 

Figure 22-19

Comparing Monocots and Dicots

This table compares the characteristics of monocots and dicots. **Interpret Tables** How do the flowers of monocots and dicots typically differ?

Woody and Herbaceous Plants Flowering plants also differ in terms of the woodiness of their stems. Woody plants are made primarily of cells with thick cell walls that support the plant body. These include trees, shrubs, and vines. Shrubs are typically smaller than trees, and vines have stems that are long and flexible. Herbaceous (hur BAY shus) plants do not produce true wood, and therefore have nonwoody stems. Examples of herbaceous plants include dandelions, zinnias, petunias, and sunflowers.

Annuals, Biennials, and Perennials If you've ever planted a garden, you know that many flowering plants live for just a single season while others grow year after year. The life span of plants is determined by a combination of genetic and environmental factors. The types of plant life spans—annual, biennial, and perennial—are described in **Figure 22-20**.

READING CHECK **Review** How do woody plants differ from herbaceous plants?

Figure 22-20

Comparing Plants by Life Span

Categories of plant life spans include annuals, biennials, and perennials.

Annuals pass through their entire life cycle in one growing season.

Biennials live for two growing seasons. Seeds and flowers form in the second season.

Perennials regrow year after year.

Flower Structure

What makes a flower beautiful? Is it the symmetry of its petals, its rich colors, or its fragrance? These things may matter to us, but to a plant, the whole point of a flower is to bring gametes together for reproduction and to protect the resulting embryo.

Flowers are an evolutionary advantage to plants because they attract animals such as bees, moths, or hummingbirds. These animals—drawn by the color, scent, or even the shape of the flower—carry pollen with them as they leave. Because these animals go directly from flower to flower, they can carry pollen to the next flower they visit. This type of pollination is much more efficient than the wind pollination of most gymnosperms.

Flowers are reproductive organs, and their beauty reflects the stunning evolutionary success of the angiosperms. The basic structure of a angiosperm flower is shown in **Figure 22-21**. ***Flowers are reproductive organs that are composed of four different kinds of specialized leaves: sepals, petals, stamens, and carpels.***

Sepals

The outermost portion of a flower consists of modified leaves called sepals (SEE pulz). They enclose the bud before it opens and protect the flower as it develops. Petals, which are often brightly colored, are found just inside the sepals. The colors and shapes of petals help to attract insects and other pollinators to the flower.

Petals generally fall off a flower after several days. Losing petals also helps the plant reproduce. After pollination occurs, animal visitors are not useful until much later in the process.

Quick Lab **Guided Inquiry**

What Is the Structure of a Flower?

1. Examine a flower carefully. Make a detailed drawing of the flower and label as many parts as you can. Note whether the anthers are above or below the stigma.
2. Remove an anther and place it on a slide. While holding the anther with forceps, use a scalpel to cut one or more thin slices across the anther. **CAUTION:** *Be careful with sharp tools. Place the slide on a flat surface before you start cutting.*
3. Lay the slices flat on the microscope slide and add a drop of water and a coverslip. Observe the slices with the microscope at low power. Make a labeled drawing of your observations.
4. Repeat steps 2 and 3 with the ovary.

ANALYZE AND CONCLUDE

1. **Observe** Are the anthers in this flower located above or below the stigma? How could this location affect what happens to the pollen produced by the anthers? Explain your answer.
2. **Apply Concepts** What structures did you identify in the anther? What is the function of these structures?
3. **Apply Concepts** What structures did you identify in the ovary? What is the function of these structures?
4. **Draw Conclusions** Which parts of the flower will become the seeds? Which parts will become the fruit?

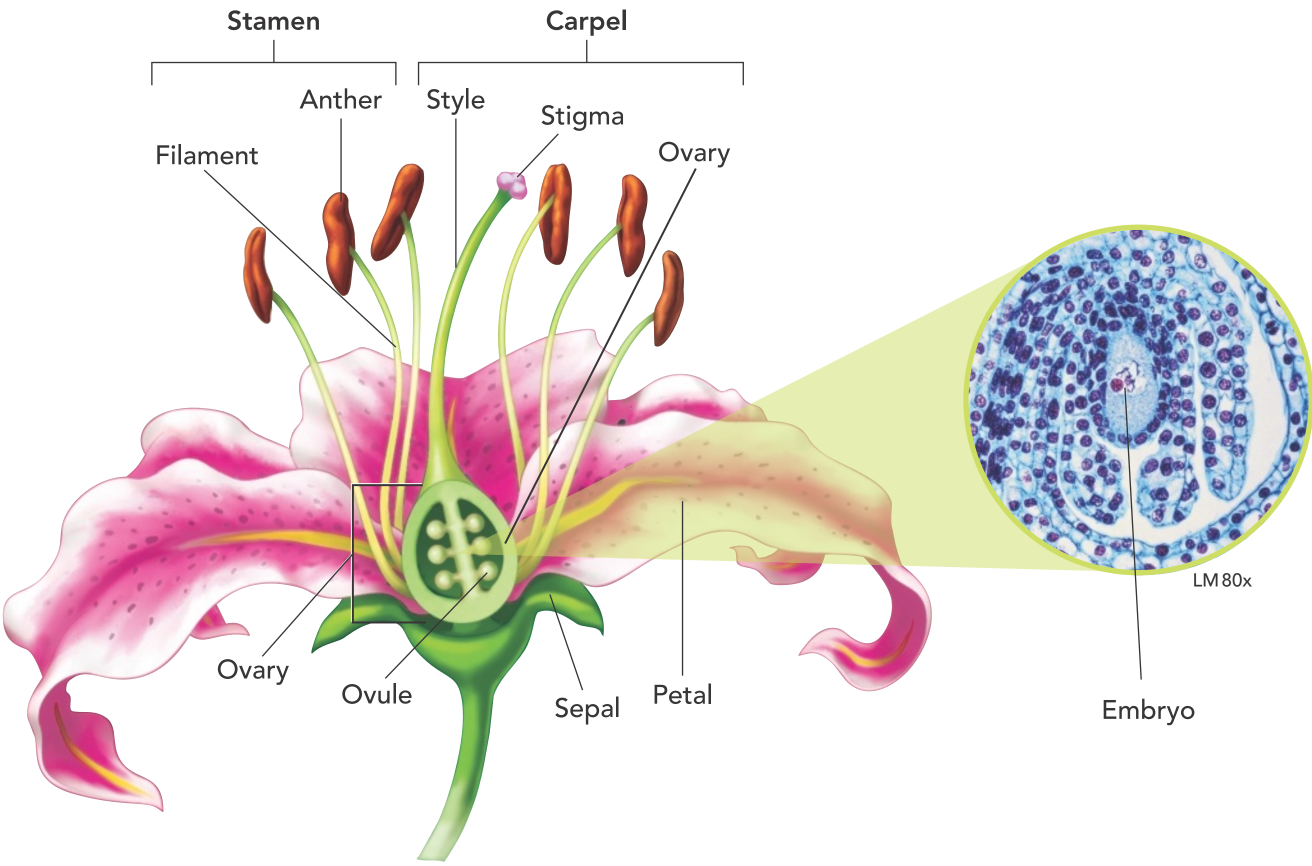


Figure 22-21

The Parts of a Flower

This diagram shows the parts of a typical flower. The flowers of some angiosperm species do not have all the parts shown here.

Stamens and Carpels Inside the ring of petals are organs that produce male and female gametophytes. The stamens are the male parts of the flower. Each stamen consists of a stalk called a filament with an anther at its tip. Anthers are the structures in which pollen grains—the male gametophytes—are produced. In most angiosperm species, the flowers have several stamens. If you rub your hand on the anthers of a flower, a yellow-orange dust may stick to your skin. This dust is made up of thousands of individual pollen grains.

The innermost floral parts are the carpels, which produce female gametophytes and, later, seeds. The carpels are fused into a broad base, forming an ovary where the female gametophytes are produced. The diameter of the carpel narrows into a stalk called the style. At the top of the style is a sticky or feathery portion known as the stigma, which is specialized to capture pollen. Botanists sometimes call a single carpel or several fused carpels a pistil.

READING CHECK **Classify** Make a two-column table with the columns labeled Male and Female. Then list and define the structures that make up a flower in the appropriate column.

Variety in Flowers

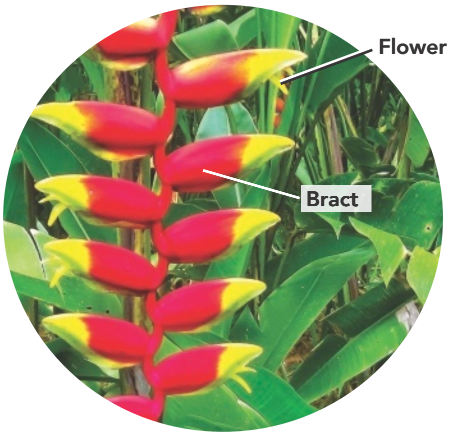
Variety in Flowers Flowers vary greatly in shape, color, and size, as shown in **Figure 22-22**. While most flowering plants produce both male and female gametophytes, in some species the male and female gametophytes are produced on different plants. In some plants, many flowers grow close together to form a composite structure that looks like a single flower. Other flowers might attract a wide variety of pollinators.

READING CHECK **Form a Hypothesis** How might it be an advantage for a plant to have many flowers clustered in a single structure? (Hint: Refer to the allium in **Figure 22-22**.)

Figure 22-22

Variety Among Flowers

Flowers vary greatly in structure. Some flowers have adaptations that are so specific that they can only be pollinated by one particular animal.



Lobster Claw Heliconia
Heliconia **flowers are protected within colorful leaf structures called bracts.**

Allium

Wild Rose

Passion flower

Kuri Squash

The Angiosperm Life Cycle

Like other plants, angiosperms have a life cycle that shows an alternation of generations. The diploid sporophyte produces haploid gametophytes inside the tissues of the flower.

READING TOOL

List the sequence of events that occur during the life cycle of an angiosperm.

Male Gametophytes Male gametophytes—the pollen grains—develop inside anthers, as shown in **Figure 22-23**. First, meiosis produces four haploid spore cells. Each spore then divides again to produce two cells, a generative cell and a tube cell. The male gametophyte with its two cells is then surrounded by a thick wall that protects it from damage.

Female Gametophytes Female gametophytes develop inside the carpels. The ovules—the future seeds—are enveloped in a protective ovary—the future fruit. A single diploid cell goes through meiosis to produce four haploid cells, three of which disintegrate. The remaining cell undergoes mitosis, producing eight nuclei. Next, cells walls form, which produce a total of seven cells, six with one nucleus and a seventh with two nuclei. These seven cells are the female gametophyte, also known as the **embryo sac**. One of the eight nuclei, near the base of the gametophyte, is the actual egg cell—the female gamete. If fertilization takes place, this egg cell will fuse with the male gamete to become the zygote that grows into a new sporophyte plant.

ANIMATION

Figure 22-23

The Development of Gametophytes

The diagrams show the development of the male gametophyte inside an anther and the development of the female gametophyte inside a single ovule.

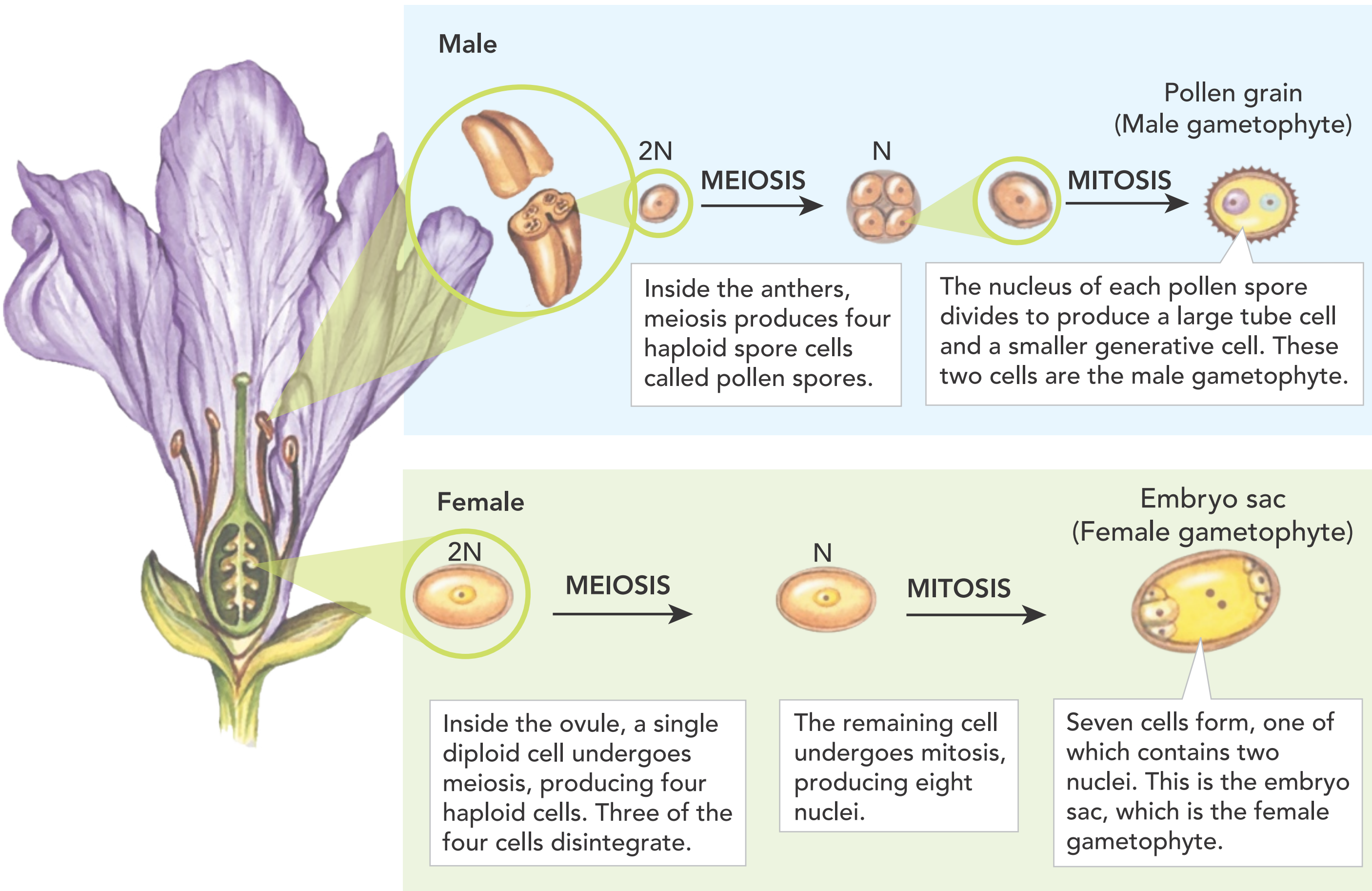


Figure 22-24

Pollination

The appearance of a flower often indicates how it is pollinated. The flowers of an animal-pollinated flower are often large and brightly colored. In contrast, the flowers of a slender meadow foxtail are typical of wind-pollinated flowers in that they are small and not very showy but produce vast amounts of pollen.

BUILD VOCABULARY

Related Word Forms Several word forms are derived from the word *pollen*. **Pollination** is the transfer of pollen from one flower to another. A *pollinator* is an animal that moves pollen.

Pollination

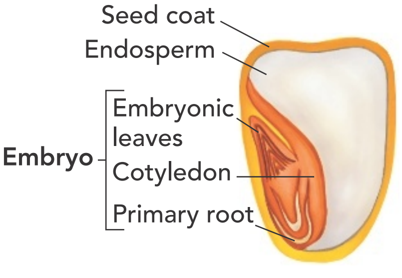
The transfer of pollen to the female portions of the flower is called **pollination**. Some angiosperms are wind pollinated. Most angiosperms, however, are pollinated by animals, such as the bee in **Figure 22-24**, that carry pollen from one flower to another. Animal-pollinated plants have adaptations such as bright colors and sweet nectar to attract and reward animals. In turn, many animals have evolved bodies that enable them to reach nectar deep within certain flowers. For example, hummingbirds have long, thin beaks that can probe deeply into flowers to reach their nectar.

Insect pollination is beneficial to insects such as bees because it provides a dependable source of food—pollen and nectar. Plants benefit because these insects take the pollen directly from flower to flower. The efficiency of insect pollination may be one of the main reasons angiosperms displaced gymnosperms as the dominant land plants over the past 130 million years. However, it also means that many plant species are highly dependent upon insect pollinators. When bee populations, for example, are threatened by diseases or insecticides, it can adversely affect plant populations and lower the productivity of agricultural crops.

Figure 22-25

Inside a Corn Kernel

Distinct fertilization events produce the two main parts of the seed: the plant embryo and the endosperm.



Fertilization

When a pollen grain lands on the stigma of a flower, it begins to grow a pollen tube. One of the pollen grain's two cells—the "generative" cell—divides and forms two sperm cells. The pollen tube grows into the style, where it eventually reaches the ovary and enters an ovule.

Inside the embryo sac, two distinct fertilizations take place in a process called **double fertilization**. First, one of the sperm nuclei fuses with the egg nucleus to produce a diploid zygote that becomes 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. ***The process of fertilization in angiosperms is distinct from that found in other plants. Two fertilization events take place—one that produces the zygote and the other that produces the endosperm within the seed.*** The structure of a seed is shown in **Figure 22-25**.

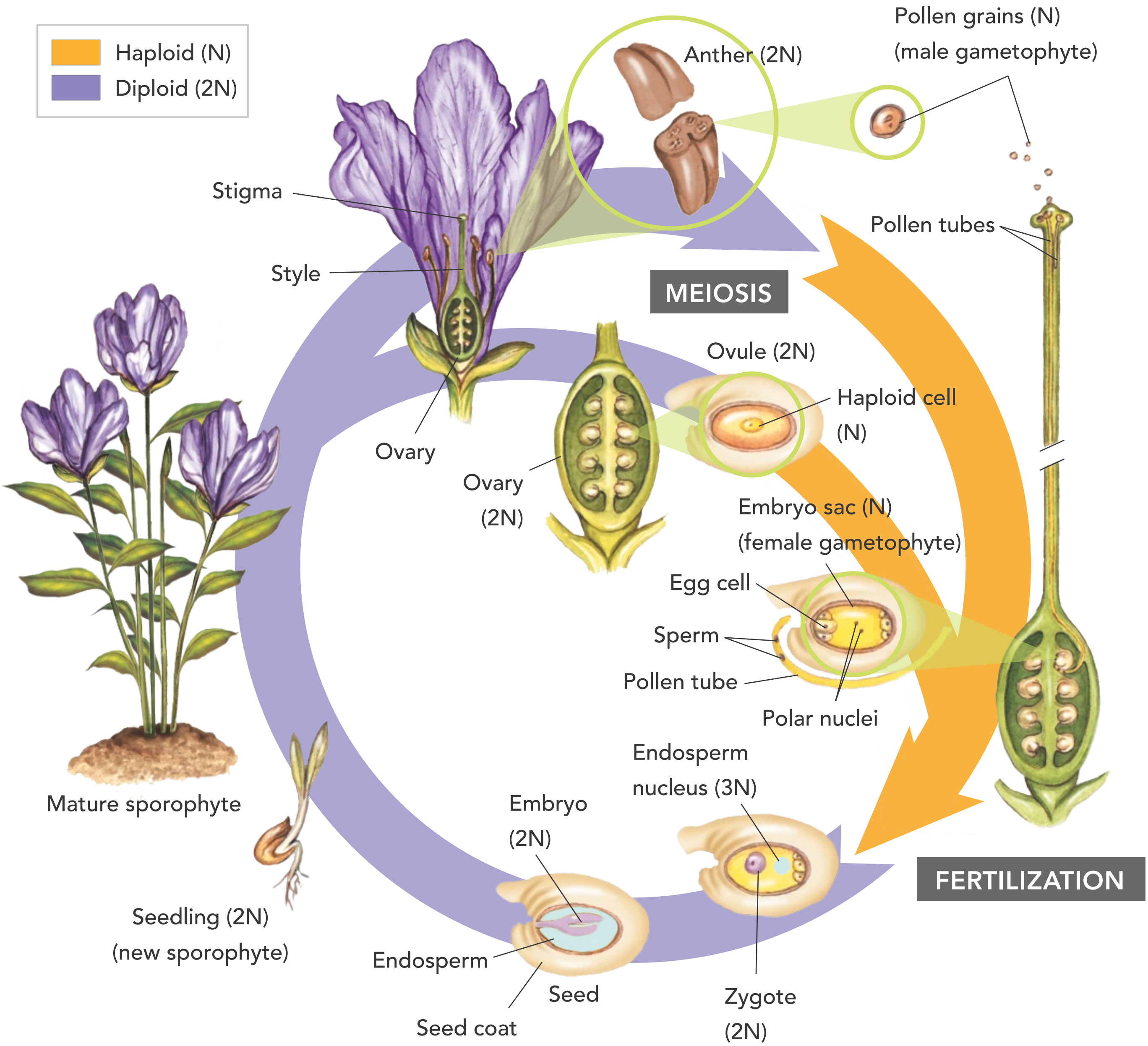


Figure 22-26

Angiosperm Life Cycle

In the life cycle of a typical angiosperm, the developing seeds of a flower are protected and nourished inside the ovary.

Double fertilization may be another reason why the angiosperms have been so successful. By using endosperm to store food, the flowering plant spends very little energy producing seeds from ovules until double fertilization has actually taken place. The energy saved can be used to make many more seeds. **Figure 22-26** summarizes the life cycle of a typical angiosperm.

READING CHECK **Cause and Effect** What are the products of double fertilization?

Vegetative Reproduction

Many flowering plants can also reproduce asexually by a process known as **vegetative reproduction**. This process takes place naturally in many plants, and horticulturists also use it as a technique to produce many copies of an individual plant. ***Vegetative reproduction is the formation of new individuals by mitosis. It does not require gametes, flowers, or fertilization.***

Sprouting potato

Cholla cactus

Strawberry plant

Figure 22-27

Examples of Vegetative Reproduction

Stem adaptations play a role in the vegetative reproduction of these plants. A potato is an underground stem called a tuber that can grow whole new plants from buds, called eyes. Some cacti can grow new plants from existing stems that fall from the plant. Strawberry plants send out long, trailing stems called stolons, or runners. Nodes that rest on the ground produce roots and upright stems and leaves.

Vegetative reproduction takes place in a number of ways, as shown in **Figure 22-27**. Because vegetative reproduction does not involve seed formation, a single plant can reproduce quickly. In addition, asexual reproduction allows a single plant to produce genetically identical offspring. This enables well-adapted individuals to rapidly fill a favorable environment.

Horticulturists often take advantage of vegetative reproduction by using cuttings or grafting to make many identical copies of a plant or to produce offspring from seedless plants. A grower may simply cut a length of stem containing meristem tissue and bury it in a sterile medium such as perlite or sand to encourage root formation.

Grafting is used to reproduce seedless plants and varieties of woody plants that will not grow from cuttings. A grower cuts a piece of stem or a lateral bud from a parent plant and attaches it to another plant, as shown in **Figure 22-28**. Grafting works best when the two plants are closely related, such as when a bud from a lemon tree is grafted onto an orange tree.

READING CHECK **Apply Concepts** Describe how asexual reproduction might allow a plant to become rapidly established in a new area.

Figure 22-28

Grafting

When just starting to bud, a branch from a lemon tree is grafted onto the branch of an established orange tree. Months later, the mature branch bears lemon fruit. Grafting can lead to a single plant bearing more than one type of fruit.

Fruits and Seeds

Would it surprise you to learn that if you ate a meal of corn on the cob and baked beans, from the point of view of a biologist, you were actually eating fruits? The development of the seed, which protects and nourishes the plant embryo, contributed greatly to the success of plants on land. But the *angiosperm* seed, protected by a fruit, was an even better adaptation, as we will see.

Fruit and Seed Development Once fertilization of an angiosperm is complete, nutrients flow from the vascular system into the flower to support the growing embryo within the seed. ***As angiosperm seeds mature, ovary walls thicken to form a fruit that encloses the developing seeds.*** A fruit is simply a matured angiosperm ovary, usually containing seeds. An exception is found in commercially grown fruits that are selectively bred to be seedless, such as some varieties of grapes. Examples of fruits are shown in **Figure 22-29**.

In everyday language, the term *fruit* applies to sweet plant products such as apples, grapes, and strawberries. However, think about foods such as string beans, corn, beans, cucumbers, and tomatoes, which we commonly call vegetables. Since these vegetables contain the seeds of plants, they are also fruits. The ovary wall surrounding a fruit may be fleshy, as it is in grapes and tomatoes, or tough and dry, like the shell that surrounds peanuts. The peanuts themselves are seeds.

While fruits and seeds are developing, it generally benefits the plant to keep animals away. Bright flower petals have fallen away, and the appearance of the remains of the flower generally blends in with the rest of the plant. The developing fruits and seeds are also not especially tasty. In many cases, they are tough and bitter. Many fruits, including tomatoes, oranges, and bananas, begin with green rinds that match the colors of the plant leaves. When they ripen, they take on brighter colors.

Figure 22-29

Variety Among Fruits

Like the flowers from which they develop, fruits vary in structure.

Pomegranate

Maple

Plum

Peanut

Lychee

INTERACTIVITY

Investigate the conditions that could make flowers suddenly bloom in a hot, dry landscape.

Seed Dispersal Fruits are not there to nourish the seedling—the endosperm does that. So why should plants have seeds that are wrapped in an additional layer of nutrient-packed tissue? 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 animals. What good is such sweetness if all it does is get the seed eaten? Well, believe it or not, that's exactly the point.

The seeds of many plants, especially those encased in sweet, fleshy fruits, are often eaten by animals. The seeds are covered with tough coatings, allowing them to pass through an animal's digestive system unharmed. The seeds then sprout in the feces eliminated from the animal. 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 plant. Several mechanisms of seed dispersal are shown in **Figure 22-30**.

Animals are not the only means by which plants can scatter their seeds. Seeds are also adapted for dispersal by wind and water. A dandelion seed, for example, is attached to a dry fruit that has a parachute-like structure. This adaptation allows the seed to glide a considerable distance away from the parent plant. Some seeds, like the coconut, are dispersed by water. Coconut fruits are buoyant enough to float in seawater for many weeks, enabling them to reach remote islands.

CASE STUDY

Figure 22-30

Mechanisms of Seed Dispersal

Angiosperm seeds are dispersed in a variety of ways. **Construct an Explanation** How did the adaptations that lead to a variety of seed dispersal methods contribute to the success of angiosperms on land?

Birds and other animals may drop seeds as they eat the fruit.

The wind carries the tiny seeds of dandelions.

Palm trees colonize tropical islands because of their floating fruit—the coconut.

The burrs on this goat are the fruits of the burdock plant. The sticky fruits hitch a ride to new places.

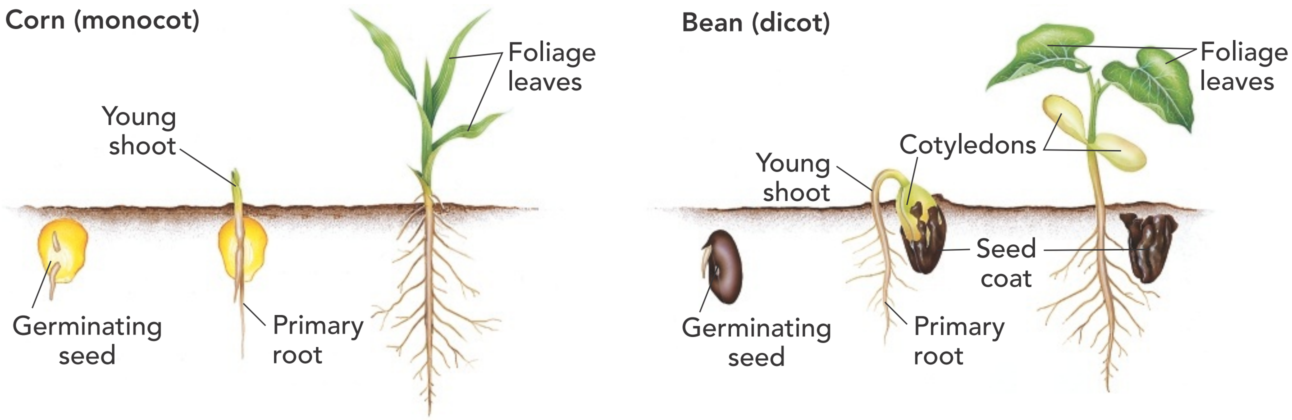


Figure 22-31

Germination: A Comparison

The monocot corn seedling (left) grows directly upward, protected by a sheath of tissue that surrounds the developing leaves. In contrast, the garden bean (right) forms a hook in its stem that gently pulls the new plant tissues out of the soil.

Seed Germination All seeds contain plant embryos in a state of **dormancy**, during which the embryo is alive but not growing. **Germination** takes place when growth of the embryo resumes and the seed sprouts into a plant. The seeds of some plants may remain dormant for many weeks or even months. The timing of germination can be critical for a plant, especially in climates where growing conditions change with the seasons. The seeds of many temperate plants, for example, germinate only in the spring, when conditions are best for growth. In some species, the seeds depend on a period of cold temperatures. The seeds are dormant while cold, and then begin growing when temperatures warm. Dormancy also can allow for long-distance seed dispersal, making it possible for seeds to germinate under ideal conditions.

When germination does begin, the growing plant unfolds its first leaves, the cotyledons. Some cotyledons, like those of garden beans, store nutrients during dormancy. Then they transfer the nutrients to the rest of the plant as the seed germinates. **Figure 22-31** compares germination in a monocot and a dicot.

HS-LS1-1, HS-LS1-2, HS-LS1-4

LESSON 22.3 Review

KEY QUESTIONS

1. Describe three general ways that angiosperms may differ from one another.
2. What are the functions of stamens and carpels?
3. Describe the features of fertilization that are characteristic of angiosperms.
4. What is the result of vegetative reproduction?
5. Describe how fruits form.

CRITICAL THINKING

6. **Construct an Explanation** How does the life cycle of some angiosperms depend on animals? Include two specific examples to support your answer.
7. **Compare and Contrast** How is vegetative (asexual) reproduction similar to sexual reproduction in angiosperms? How is it different?

CASE STUDY WRAP-UP

How did plants conquer the land?

A forest fire may kill thousands of trees all at once, but the destruction is not permanent. Trees, like other plants, have a variety of adaptations that allow them to survive on land—and to repopulate the land when the opportunity arises.

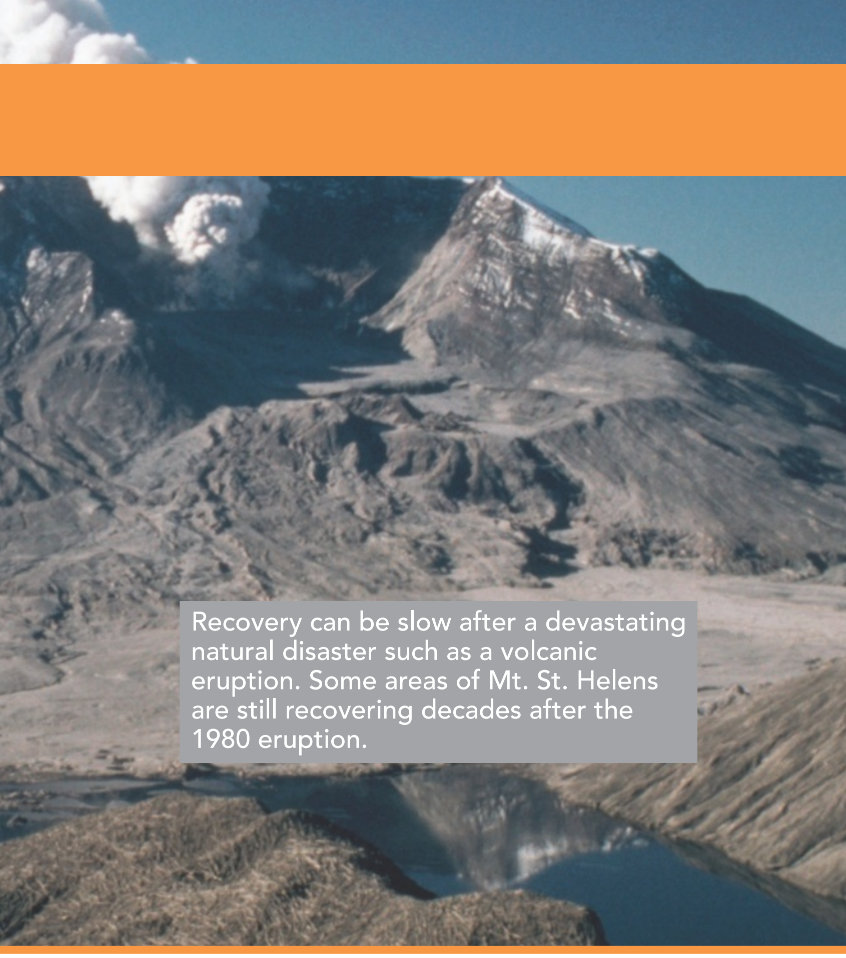
HS-LS1-1, HS-LS1-2, CCSS.ELA-LITERACY.RST.9-10.2, CCSS.ELA-LITERACY.WHST.9-10.1

Make Your Case

Green algae are small organisms that live only in the water or very moist environments. However, step by step, the descendants of algae became towering trees, vines with delicious fruit, and all the other diverse plants that live across the land today. The adaptations that evolved in plants are an amazing story. The story also involves the evolution of animals. Many plant parts, such as showy flowers and sweet fruits, are adaptations for attracting help in reproduction.

Construct an Explanation

1. **Compare and Contrast** How do the structures and functions of a typical land plant, such as a lodgepole pine, compare and contrast with green algae?
2. **Synthesize Information** Based on your knowledge of plants, and additional research if necessary, describe in order the important events in the evolution of plants. Include at least five events in your history.



Recovery can be slow after a devastating natural disaster such as a volcanic eruption. Some areas of Mt. St. Helens are still recovering decades after the 1980 eruption.

Careers on the Case

Work Toward a Solution

In natural ecosystems, plants are distributed and grow in patterns that nature determines. In some careers, however, people work with plants directly.

Landscaper

Landscapers apply their own ideas to choose and arrange plants. They work to place plants in yards and parks, along sidewalks, and in other public spaces. To be successful, landscapers need to combine a sense of design, and a knowledge of a variety of plants and how they grow.

VIDEO

Learn more about landscaping and related careers.

Society on the Case

Of Lawns and Elms

When Europeans began settling North America, they brought their ideas about lawns with them. Today, grassy lawns surround houses and other buildings across the United States. Lawns can be attractive, but they displace the natural ecosystem, which may have been a forest, prairie, wetland, or desert. Lawns also require maintenance that has consequences for the environment. In hot, dry climates, a healthy lawn might require watering as often as once a day. The fertilizer that is spread on lawns may wash into lakes and streams where it can spur the growth of algae. Fertilizer can also pollute groundwater.

Some popular plants in landscaping have led to unintended results. For example, elm trees were once very popular for lining city sidewalks. The tall, arching branches of the elms formed green canopies over the streets. By 1930, North America was home to more than 70 million elm trees. Then they were ravaged by Dutch elm disease. Beetles spread this fungal-borne disease from tree to tree. By 1989, more than three quarters of the elms in North America were dead.

The best way to make a landscape sustainable is to use plants that are native to the region. In California and Arizona this could mean planting native succulents, which are plants that have fleshy parts that hold water. Southern Florida is home to many native grasses that grow in the sandy soil without excess fertilizer. Many people who live by forests choose to forgo any type of a lawn at all. They let the forest grow around their houses and clear trees only when they pose safety hazards.

CHAPTER 22
STUDY GUIDE

Lesson Review

Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

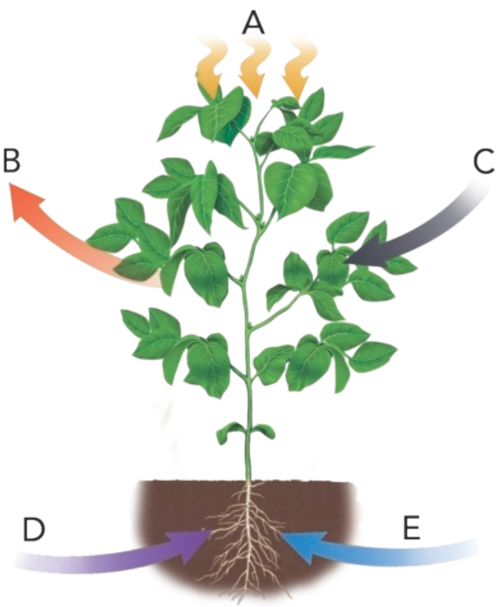
22.1 What Is a Plant?

Plants depend upon sunlight, gas exchange, water, and minerals. Plants use the energy from sunlight to carry out photosynthesis. They require oxygen to support cellular respiration as well as carbon dioxide to carry out photosynthesis. Plants also need a way to access water and minerals.

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.

Most plant life cycles have two alternating phases, a diploid and a haploid phase. The multicellular diploid phase is the sporophyte, or spore-producing plant. The multicellular haploid phase is the gametophyte, or gamete-producing plant. The cycle is known as the alternation of generations.

- alternation of generations
- sporophyte
- gametophyte



Interpret Visuals Identify each of the labeled needs of a plant and explain the function of each.

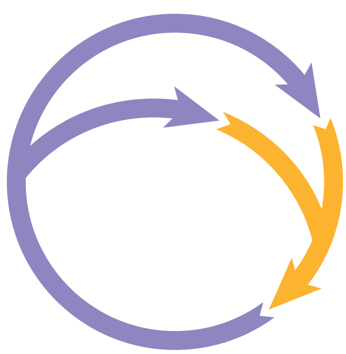
22.2 Plant Diversity

Fossil evidence suggests that the first plants were similar to modern-day green algae. The first land plants were bryophytes, which include mosses, hornworts, and liverworts. Because they lack water-conducting vascular tissue, they grow in damp soil and low to the ground.

About 420 million years ago, plants with true vascular tissue evolved. Vascular plants are known as tracheophytes, because they contain tracheids. Tracheophytes include all seed-bearing plants as well as seedless vascular plants: club mosses, horsetails, and ferns. Seedless vascular plants produce spores. They require a thin film of water to carry out fertilization.

Gymnosperms and angiosperms are seed plants. A seed is a plant embryo and food supply encased in a protective covering. In seed plants, the male and female gametophytes grow and mature directly in the sporophyte, within structures known as cones or flowers. Gymnosperms bear their seeds in cones. Angiosperms bear their seeds in flowers.

- bryophyte
- vascular tissue
- archegonium
- antheridium
- sporangium
- tracheophyte
- tracheid
- xylem
- phloem
- seed
- gymnosperm
- angiosperm
- pollination
- ovule



Identify Patterns Does this life cycle follow the pattern of green algae, seedless plants, or seed plants? Explain.

22.3 Flowers, Fruits, and Seeds

Scientific classification best reflects evolutionary relationships among flowering plants. However, people that work with flowering plants, or angiosperms, categorize them in different ways. Angiosperms are often grouped by the number of their seed leaves—plants with one seed leaf are called monocots; those with two seed leaves are called dicots. Flowering plants can have woody or herbaceous stems (which are smooth and non-woody). Angiosperms are also classified by their life span. Annuals grow, flower, and die in one season; biennials grow over two seasons before they die; perennials continue to flower from year to year.

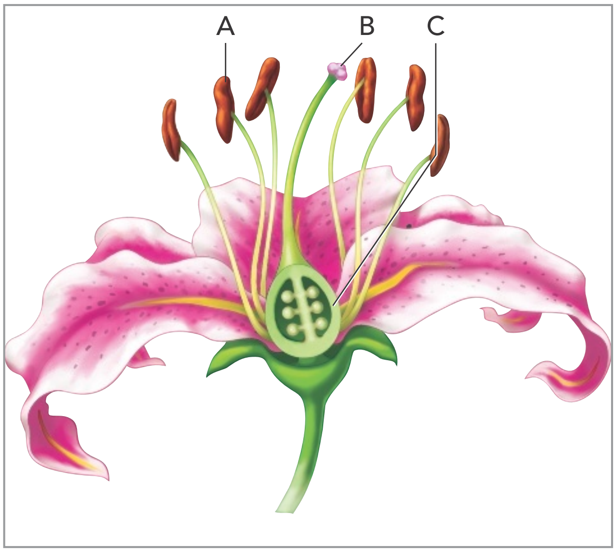
Flowers are reproductive organs that are composed of four different kinds of specialized leaves: sepals, petals, stamens, and carpels. Sepals protect the bud before it opens and protect the flower while it is developing. Petals are the bright-colored leaves that attract pollinators. The stamens are the male part of the flower and contain the anthers. Carpels are the innermost part of the flower that houses the ovules.

The process of fertilization in angiosperms is distinct from that found in other plants. Two fertilization events take place—one produces the zygote and the other a tissue, called the endosperm, within the seed.

Vegetative reproduction is the formation of new individuals by mitosis. It does not require gametes, flowers, or fertilization.

As angiosperm seeds mature, the ovary walls thicken to form a fruit that encloses the developing seeds. The seeds contained within the fruit are often dispersed by animals. Other methods of seed dispersal include wind and water.

- ovary
- fruit
- cotyledon
- monocot
- dicot
- embryo sac
- pollination
- double fertilization
- endosperm
- vegetative production
- dormancy
- germination



Infer Explain how the three lettered structures are involved in fertilization.

Organize Information

Complete the table by indicating if each group of plants exhibits the listed characteristics.

Group of plant	Green algae	Mosses and relatives	Ferns and relatives	Cone-bearing plants	Flowering plants
Seeds?	1.	2.	3.	4.	5.
Vascular tissue?	6.	7.	8.	9.	10.
Fruit?	11.	12.	13.	14.	15.

PERFORMANCE-BASED ASSESSMENT

Keeping the Buzz On

Communicate a Solution

HS-LS4-6, HS-ETS1-2, CCSS.ELA.LITERACY.WHST.9-10.1, CCSS.ELA.LITERACY.WHST.9-10.7

STEM Do you like almonds? They're healthy and they taste great, but did you know they couldn't be produced without the help of insects? Central California produces 80 percent of the world's supply of almonds. Each year, millions of bees are transported to that region to pollinate the almond groves. Honeybees also pollinate scores of other food crops throughout the country, from tomatoes and peppers to watermelons and cantaloupes. But all is not well in the world of bees.

Increasingly, honeybees in North America are threatened by colony collapse disorder, a condition in which worker bees abandon their hives and eventually die. According to the Department of Agriculture, nearly 42 percent of U.S. bee colonies died off in 2015, many due to colony collapse disorder. Concern is now so great that a Presidential Task Force was established to recommend a plan to prevent the loss of these essential insects and the crops that depend upon them.

Researchers think that a number of factors may be contributing to colony collapse disorder. These include climate-induced changes in the growing season, loss of natural habitat, parasitic mites that attack the bees' nervous systems, and the use of a class of pesticides known as neonicotinoids. Worries about the survival of these critical insects have prompted governments around the world to propose programs of habitat conservation and to consider banning pesticides that may be dangerous to bee populations.

A honeybee heads for an almond flower.

SCIENCE PROJECT

This mobile apiary is transporting bees to a grove or farm that needs pollinators.

Possible Causes of Colony Collapse Disorder

Possible Cause	Leads to ...
Pesticides (specifically, neonicotinoids)	Death of some bees that consume pollen or nectar tainted with the pesticide
Climate change	Alteration of seasonal timing for flowering
Habitat loss	Reduction in the abundance of wildflowers and other sources of nectar for bees
Parasitic mites (such as *Varroa*)	Death of bees by infestation
Stress from beekeeping practices such as transportation across the country	Weakened bees that are more susceptible to other stressors

1. **Define the Problem** What food crops depend on bees and other pollinating insects? What would be the result if these pollinators disappeared?
2. **Ask Questions** What actions have U.S. government agencies, such as the Department of Agriculture, taken to study colony collapse disorder?
3. **Conduct Research** Use print and online reference sources to research the possible causes of colony collapse disorder, as well as possible solutions. Be sure to evaluate the credibility and accuracy of the reference sources.
4. **Develop an Argument** Choose the possible cause that you think is a likely explanation for colony collapse disorder. Then, based on the evidence you researched, develop an argument to support the explanation, as well as an action plan to address the problem.
5. **Communicate** Present your argument in a speech to classmates. Try to convince them that your action plan is worthwhile. Be sure to describe the following:
    - The specific nature of the threat to the bee population
    - Areas of the United States where this threat may be most severe
    - How your plan of action would counteract this threat, and help to improve the health of bees and other pollinating insects

As you listen to the arguments of classmates, evaluate their points of view, reasoning, and use of evidence and rhetoric. Try to identify any faulty reasoning or distorted evidence.

CHAPTER 22

ASSESSMENT

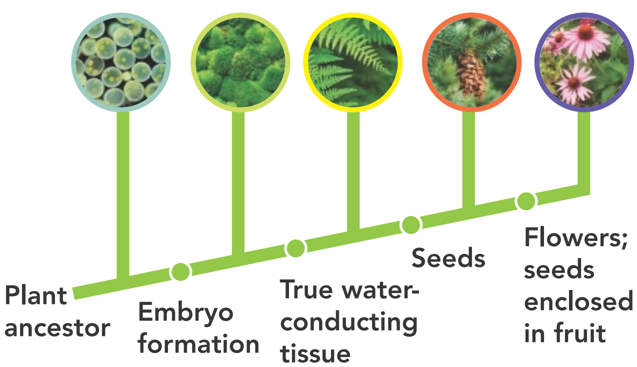
KEY IDEAS AND TERMS

22.1 What Is a Plant?

HS-LS1-1, HS-LS1-2, HS-LS4-1

1. The ancestors of land plants likely evolved from
   a. mosses that lived in the water.
   b. an organism similar to green algae.
   c. a protist that lived on land.
   d. prokaryotes that carried on photosynthesis.
2. Recent changes in the classification of the plant kingdom are based on
   a. studies comparing DNA sequences.
   b. comparison of physical structures.
   c. differences and similarities in life cycles.
   d. whether or not a plant uses seeds to reproduce.
3. What is the basic difference between a sporophyte and a gametophyte?
   a. A sporophyte is a reproductive structure, while a gametophyte is not.
   b. A sporophyte undergoes sexual reproduction, while a gametophyte undergoes asexual reproduction.
   c. A sporophyte is the diploid phase, while a gametophyte is the haploid phase of the plant life cycle.
   d. A sporophyte is much smaller than a gametophyte.
4. What do plants need to survive?

Use the following diagram to answer questions 5 and 6.



5. Which group of plants is most closely related to the ancestor of all plants?
6. What distinguishes the mosses group from the fern group of plants?

22.2 Plant Diversity

HS-LS1-4

7. Which answer describes a reason that bryophytes need to live in moist areas?
   a. Bryophytes need the extra water for photosynthesis.
   b. The sperm of bryophytes need water to swim to an egg.
   c. Gas exchange is more efficient in wet areas.
   d. Without moisture, rhizoids cannot anchor the plants.
8. Water is carried upward from the roots to every part of a vascular plant by
   a. rhizoids.
   b. phloem.
   c. cuticle.
   d. xylem.
9. Seed-bearing plants differ from all other plants in that
   a. they have only xylem and no phloem.
   b. they have a gametophyte generation.
   c. their gametes do not require water for fertilization to occur.
   d. they have true roots, stems, and leaves.
10. In the life cycle of a moss, what environmental conditions are necessary for fertilization?
11. How was the ability to produce lignin significant to the evolution of plants?
12. Why does the conifer life cycle take two years to complete?
13. Describe a fern gametophyte.

22.3 Flowers, Fruits, and Seeds

HS-LS1-1, HS-LS1-2, HS-LS1-4

14. In angiosperms, the structures that produce the male gametophyte are called the
    a. anthers.
    b. sepals.
    c. pollen tubes.
    d. stigmas.
15. The process in which a single plant produces many offspring genetically identical to itself is
    a. sexual reproduction.
    b. agriculture.
    c. dormancy.
    d. vegetative reproduction.
16. The thickened ovary wall of a plant may join with other parts of the flower to become the
    a. fruit.
    b. seed.
    c. endosperm.
    d. cotyledon.

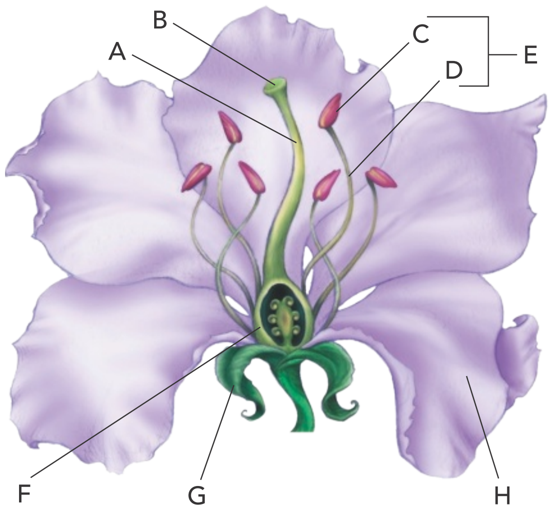
17. What is a carpel? Where is it located in a typical flower?

18. What are the products of double fertilization? Describe them.

19. Give examples of seed dispersal by animal, wind, and water.

20. What is the function of dormancy?

21. The diagram shows the parts of a typical flower.
   a. Inside which structure is pollen produced?
   b. What structure does label A represent? What is its function?
   c. In which structure do seeds develop?
   d. What is the name of structure G?



CRITICAL THINKING

22. **Classify** How do botanists classify the five major groups of plants?

23. **Draw Conclusions** If all you know about a plant is that it lives almost all of its life as a multicellular haploid organism, what can you conclude about the kind of plant it is?

24. **Construct an Explanation** How does alternation of generations differ among the various types of plants, such as mosses and flowering plants?

25. **Compare and Contrast** How are green algae similar to other plants? How are they different?

26. **Compare and Contrast** Moss plants are small, but ferns can grow as tall as small trees. Explain why this is so.

27. **Apply Scientific Reasoning** How is it helpful for vascular plants to have two transport systems—xylem and phloem—instead of just one system?

28. **Construct an Explanation** Why are seeds not classified as the reproductive structures of a plant?

29. **Cite Evidence** During the age of the dinosaurs, the vast majority of land plants were ferns and mosses. Today, the vast majority of land plants are seed plants. Cite evidence from the text and provide an explanation for this change based on the basic requirements of plants.

30. **Apply Concepts** A friend of yours lives in one of the desert areas of New Mexico and wants to grow a garden of bryophytes. What environmental conditions would your friend need to provide the garden for it to be successful?

31. **Construct an Explanation** The seeds of lupines, a tundra plant, can remain dormant for thousands of years, and still germinate when conditions are favorable. How might this trait provide an advantage to lupines in their environment?

32. **Revise Models** A student is developing a model of the life cycle of gymnosperms. The model includes a pine cone, such as the one shown here. How could adding a second pine cone improve the model?

33. **Predict** Some plants form flowers that produce stamens but no carpels. Could fruit form on one of these flowers? Cite textual evidence to support your answer.

34. **Integrate Information** Pollen and seeds are the most reliable plant-related evidence at archaeological sites and at modern-day crime scenes because they are long-lasting. Relate this quality to their structure and function in living plants.

CHAPTER 22

ASSESSMENT

CROSSCUTTING CONCEPTS

35. **Structure and Function** At first glance, an oak tree and a zebra hardly seem similar in any way. Describe the characteristics that they do share. What are the characteristics of the oak tree that distinguish it from organisms in the other kingdoms of living things?

36. **Stability and Change** Compare the benefits and drawbacks of sexual reproduction and vegetative reproduction for a plant.

MATH CONNECTIONS

Analyze and Interpret Data

CCSS.MATH.CONTENT.MP2, CCSS.MATH.CONTENT.HSS.IC.B.6

Refer to the text and data table to answer questions 37 and 38. In a laboratory experiment, fruits from 5 different types of trees were dropped from a height of 4 meters. The falling time was measured and recorded in the data table shown here. Assume that for every second that a fruit falls, the wind carries it 1.5 meters away from the parent tree.

Fruit Type Versus Dispersal Time

Type of Tree	Average Time (s) for Seed to Fall 4 m
Norway maple 	5.2
Silver maple 	4.9
White ash 	3.1
Shagbark hickory 	0.9
Red oak 	0.9

37. **Analyze Data** Given the same wind, which of the fruits shown in the table is most likely to be carried farthest from the parent tree? Explain.

38. **Draw Conclusions** Based on the data and illustrations of the fruit structures, which of the following conclusions is most reasonable?

a. Winged seeds carry more nutrition for the growing embryo than seeds without wings.

b. Wind is not very effective in carrying seeds away from the parent plant.

c. Acorns are more likely to germinate if they fall close to the parent plant.

d. Red oak and hickory depend on factors other than wind to achieve dispersal.

For several years, a homeowner notices moss growing in the backyard in areas where grass otherwise would grow. Half of the yard receives direct sunlight, while the other half is shady. The table shows the data that the homeowner collects. Use the table to answer questions 39 and 40.

Growth of Moss in Sun and Shade

	Year					
	1	2	3	4	5	6
Area of Moss in Sun (m^2)	0	0	1	2	1	1
Area of Moss in Shade (m^2)	0	2	5	7	6	9

39. **Draw Conclusions** What conclusion about the growth of moss does the data support?

40. **Apply Scientific Reasoning** The area of moss in the shade ranges from none to 9 square inches. What are some possible explanations for this range of values?

LANGUAGE ARTS CONNECTIONS

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.2

41. **Write Explanatory Texts** Describe how seeds form from a process of double fertilization.

42. **Write Procedural Texts** Write a step-by-step procedure for distinguishing the major types of plants: green algae, mosses and their relatives, ferns, gymnosperms, and angiosperms.

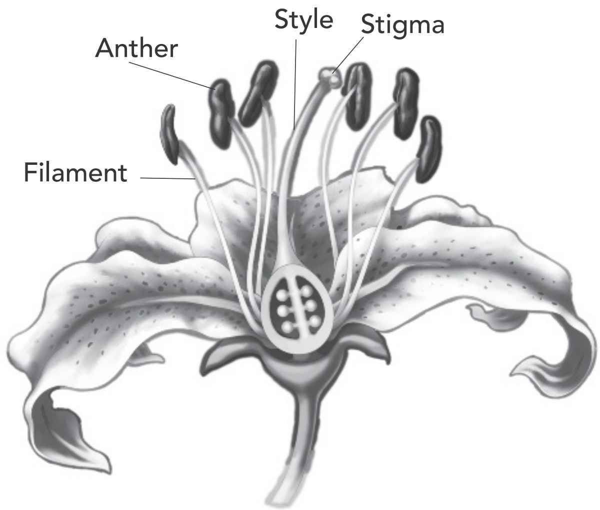
Read About Science

CCSS.ELA-LITERACY.RST.9-10.2

43. **Summarize Text** Trace the text's explanation of why flowers are the key to the evolutionary success of the angiosperms.

END-OF-COURSE TEST PRACTICE

Questions 1–2



1. A student wants to determine whether or not the flower is pollinated by an animal, such as an insect or bird. Which property of the flower would be most useful for making this inference?
   A. Number of stamens
   B. Location of the style
   C. Color and shape of the petals
   D. Location and size of the ovary
   E. Amount of pollen that it produces

2. In an experiment, Marlene removes the six anthers from the flower shown here. What best describes the ability of the altered flower to form seeds?
   A. The flower cannot form seeds because it cannot be pollinated.
   B. The flower cannot form seeds because it cannot produce male gametophytes.
   C. The flower may form seeds because the stigma produces pollen.
   D. The flower may form seeds if it receives pollen made by another flower.
   E. The flower may form seeds if it receives enough nutrients from the soil.

3. Mosses and other bryophytes never grow taller than a few centimeters. The height of bryophytes is limited because they lack which of these structures?
   A. Haploid gametophytes
   B. Diploid sporophytes
   C. Flowers and cones
   D. Cells that perform photosynthesis
   E. Vascular tissue

4. The life cycle of a plant includes two alternating phases: a diploid (2N) phase and a haploid (N) phase. As plants evolved in many stages from green algae to seed plants, what trend occurred in the alternating phases?
   A. The haploid phase became larger.
   B. The diploid phase became larger.
   C. The two phases became more alike.
   D. The two phases each became smaller.
   E. The two phases became less dependent on one another.

5. When the first seed plants evolved, they became the first plants to complete which of these tasks?
   A. Transporting water against gravity
   B. Growing directly out of the soil
   C. Reproducing without flowers
   D. Reproducing without cones
   E. Reproducing without standing water

6. A cucumber is often called a vegetable because of the way it is used as a food. What property of the cucumber shows that it is properly classified as a fruit?
   A. It has a rounded shape.
   B. It develops aboveground.
   C. It has a fleshy, edible center.
   D. It contains the seeds of the plant.
   E. It develops from the sepals of a flower.

ASSESSMENT

For additional assessment practice, go online to access your digital course.

If You Have Trouble With...						
Question	1	2	3	4	5	6
See Lesson	22.3	22.3	22.2	22.1	22.2	22.3