Many organisms on Earth, including humans, depend on the diversity of plants and their traits for survival.

20.1 Origins of Plant Life  TEKS 7A, 7E, 8C, 12A
20.2 Classification of Plants  TEKS 5B, 7D, 8B, 8C
20.3 Diversity of Flowering Plants  TEKS 7B, 7D, 8B

Data Analysis
MEAN, MEDIAN, AND MODE  TEKS 2G

20.4 Plants in Human Culture

ONLINE BIODIVERSITY

ONLINE Labs
- QuickLab  Classifying Plants as Vascular or Nonvascular
- Habitat Clues
- Comparing Monocots and Dicots
- Investigating Medicinal Plants
- Plants and Pollinators

- Phytoremediation
- Video Lab  Plant Diversity
- Video Lab  Monocot and Dicot Seeds
How have flowering plants come to dominate Earth’s landscapes?

From the mosses that live in Antarctica to these flowering protea plants of South Africa, the plant kingdom is diverse. Proteas are native to one region of South Africa, called the Cape floristic region, which can go through long periods of drought. This small region is home to over 9000 plant species, including at least 6000 that are found nowhere else on Earth.

**Using Language**

**Classification** As you read the chapter, make distinctions between general words that describe categories and specific words that describe individuals within a category. Words that name categories are more general than words that describe individuals.

**Your Turn**

Use information that you read in the chapter to answer the following questions.

1. What are two types of seedless vascular plants?
2. What is the general term identifying the category that includes mosses, liverworts, and hornworts?
Origins of Plant Life

**KEY CONCEPT** Plant life began in the water and became adapted to land.

**VOCABULARY**
- plant
- cuticle
- stomata
- vascular system
- lignin
- pollen grain
- seed

**MAIN IDEAS**
- Land plants evolved from green algae.
- Plants have adaptations that allow them to live on land.
- Plants evolve with other organisms in their environment.

**Connect to Your World**
The flowering proteas shown on the previous page are not just plants with beautiful flowers. Various birds, rodents, and insects rely on protea nectar and pollen as food sources. Green protea beetles even live inside of protea flowers. Without plants, animal life as we know it would not exist on land.

**MAIN IDEA**

**TEKS 7A, 8C**

Land plants evolved from green algae.

All green algae share certain characteristics with plants. Plants are multicellular eukaryotes, most of which produce their own food through photosynthesis and have adapted to life on land. Like plants, green algae are photosynthetic eukaryotes. They have chlorophyll that captures energy from sunlight during photosynthesis. Chlorophyll is what makes these algae—and most of the plants that we are familiar with—green. Green algae and plants have the same types of chlorophyll. Another feature both green algae and plants share is that they use starch as a storage product. Most green algae also have cell walls that contain cellulose, a complex carbohydrate that is found in the cell walls of all plants.

Evidence from genetic analysis points to one ancient species of green algae that is the common ancestor of all plants. If it were alive today, this species would be classified as a member of the class Charophyceae, like the algae in **Figure 1.1**. Several other important plant characteristics likely originated in charophyceans.

- A multicellular body, which led to the specialization of cells and tissues
- A method of cell division that produces cells with small channels in their walls, which allows cells to communicate with each other chemically
- Reproduction that involves sperm traveling to and fertilizing an egg cell

Today, charophyceans are common in freshwater habitats. Scientists hypothesize that the ancestral charophycean species may have grown in areas of shallow water that dried out from time to time. Natural selection likely favored individuals that could withstand longer dry periods. Eventually, the first true plant species evolved, as shown in **Figure 1.2**. True plants have multicellular embryos that remain attached to the female parent as they develop.
The earliest plant fossils date to more than 450 million years ago. The first true plants probably grew on the edges of lakes and streams. Like modern-day mosses, they relied on droplets of water that brought sperm to eggs to produce the next generation of plants. They also had a fairly simple structure similar to that of moss, keeping low to the ground to retain moisture. Over time, the descendants of these plants were able to live in even drier areas.

Apply: What evidence suggests that green algae are close relatives of land plants?

**TEKS 7A**

**MAIN IDEA TEKS 7E**

Plants have adaptations that allow them to live on land.

Life on land presents different challenges than does life in the water. Unlike land plants, algae are constantly surrounded by water, which is needed for photosynthesis. The buoyancy of water supports the weight of most algae. For algae, water provides a medium through which sperm and spores can travel, allowing for reproduction and dispersal. Finally, water prevents sperm, eggs, and developing offspring from drying out.

The challenges of living on drier land have acted as selective pressures for plant life on Earth. In turn, many land plants have evolved adaptations that allow them to retain moisture, transport water and other resources between plant parts, grow upright, and reproduce without free-standing water.
Retaining Moisture
Plants will die if they dry out from exposure to air and sunlight. The surfaces of plants are covered with a cuticle. A cuticle is a waxy, waterproof layer that helps hold in moisture. As Figure 1.3 shows, there are tiny holes in the cuticle, called stomata (singular, stoma). Special cells allow stomata to close to prevent water loss, or to open to allow air to move in and out. Without stomata, the movement of air would be prevented by the cuticle.

Transporting Resources
Taller plants often have more access to sunlight than do shorter plants, but growing tall presents another challenge. While plants must get sunlight and carbon dioxide from the air, they must also get water and nutrients from the soil. A structure for moving these resources to different parts of the plant evolved in the form of a vascular system. A vascular system is a collection of specialized tissues that bring water and mineral nutrients up from the roots and disperse sugars down from the leaves. A vascular system allows a plant to grow higher off the ground.

Growing Upright
Plant height is also limited by the ability of a plant to support its own weight. Plants need structure to support their weight and provide space for vascular tissues. This support comes from a material called lignin (LIHG-nihn), which hardens the cell walls of some vascular tissues. Lignin is also responsible for the strength of wood and provides stiffness to the stems of other plants. As a result, plants can retain their upright structure as they grow toward the sun.

Reproducing on Land
In all plants, eggs are fertilized within the tissue of the parent plant. There, the fertilized egg develops into an embryo, the earliest stage of growth and development for a plant. Some plants reproduce with the help of rainwater or dew, while others do not need free-standing water to reproduce. Pollen and seeds are adaptations that allow seed plants to reproduce completely free of water.

A pollen grain is a two-celled structure that contains a cell that will divide to form sperm. Pollen can be carried by wind or animals to female reproductive structures. A seed is a storage device for a plant embryo. A seed has a hard coat that protects the embryo from drying wind and sunlight. Once a seed encounters the right conditions, the embryo can develop into an adult plant.

Analyze Discuss why the four challenges on this page do not apply to most algae.
Why is lignin especially important in the cell walls of vascular tissues?
Plants evolve with other organisms in their environment.

Plants have coevolved with other terrestrial organisms for millions of years. Some of these relationships are cooperative, while others have evolved between plant species and the animal species that eat them.

**Mutualisms**

Mutualism describes an interaction between two species in which both species benefit. Mutualistic relationships exist between plant roots and certain types of fungi and bacteria. Roots provide a habitat for these fungi and bacteria, while the fungi and bacteria help the plant get mineral nutrients from the soil.

Many flowering plants depend on specific animal species for pollination or seed dispersal. In turn, these animals are fed by the plant’s pollen, nectar, or fruit. For example, in Madagascar, Darwin noticed a variety of orchids with long, tubular flower parts. He predicted that a nocturnal moth with a tongue 30 and 35 cm (10–14 in.) long must be the pollinator. That very moth, shown in **FIGURE 1.4**, was discovered 40 years after Darwin’s prediction.

**Plant-Herbivore Interactions**

Plants have a variety of adaptations that discourage animals from eating them. The spines on a cactus and the thorns on a rose stem are examples. Other plants produce defensive chemicals that act as pesticides against plant-eating predators. Natural selection favors herbivores that can overcome the effects of defensive plant adaptations. In turn, natural selection favors plants that produce even sharper spines or thorns or even more toxic chemicals.

Some insects use defensive chemicals produced by plants to their advantage. The larvae of monarch butterflies, for example, feed exclusively on milkweed species. Milkweed plants produce a chemical that makes monarch larvae, adults, and even eggs taste bad to potential predators. In this way, the butterfly has a type of chemical protection as a result of eating milkweed leaves during its development.

**Synthesize**

Describe how defensive chemicals in plant leaves may have evolved.

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**20.1 Formative Assessment**

**REVIEWING MAIN IDEAS**

1. What characteristics do land plants share with green algae? **TEKS 8C**
2. What adaptations allow plants to thrive on dry land? **TEKS 7E**
3. Describe two ways in which plants evolve with other organisms.

**CRITICAL THINKING**

4. **Synthesize** Describe how a cuticle could have evolved through natural selection. **TEKS 7E**
5. **Evaluate** For plants, what are the advantages and disadvantages of growing tall?

**CLASSIFICATION**

6. Some scientists think that certain species of green algae should be in the kingdom Plantae. What reasons might these scientists use to defend their position? **TEKS 8C**
Classification of Plants

**KEY CONCEPTS** Plants can be classified into nine phyla.

**MAIN IDEAS**
- Mosses and their relatives are seedless nonvascular plants.
- Club mosses and ferns are seedless vascular plants.
- Seed plants include cone-bearing plants and flowering plants.

**Connect to Your World**
How many different types of plants can you think of? You are probably familiar with the plants that grow in your neighborhood and in places you regularly visit. Scientists have described about 300,000 plant species, and many more probably remain to be found. All plants belong to the kingdom Plantae. However, DNA analysis continues to reveal new relationships that keep taxonomists updating the plant family tree.

**MAIN IDEA** **TEKS** 7D, 8B, 8C

**Mosses and their relatives are seedless nonvascular plants.**

In a damp forest, mosses lend an emerald green color to the landscape. These plants do not produce seeds. They have no vascular systems. Instead, they grow close to the ground or on surfaces such as tree trunks, where they can absorb water and nutrients directly. They also rely on free-standing water to allow their sperm to swim to and fertilize eggs. Mosses belong to Bryophyta, one of the three phyla of nonvascular plants. The other phyla in this category are Hepatophyta, the liverworts, and Anthocerophyta, the hornworts.

**Liverworts**
Most liverworts live in damp environments and get moisture directly from the surface of the soil. They are often found growing on wet rocks, in greenhouse flowerpots, and in other areas with plenty of moisture. Liverworts can have one of two basic forms: thallose or leafy. The name liverwort refers to thallose liverworts, which look like the lobes of a liver flat on the ground. Eggs are produced on umbrella-like structures of the thallose liverwort, shown in Figure 2.1. Though thallose liverworts may be easier to recognize, leafy liverworts are much more common. Leafy liverworts have stemlike and leaflike structures. These leaflike structures are most often arranged in three rows.

**FIGURE 2.1** Thallose liverworts, like the one shown here, can grow from 2 mm to 25 cm in length.
**Hornworts**

Hornworts are a widespread group of plants that are found in tropical forests and along streams around the world. Hornworts grow low to the ground, and the main plant body has a flat, lobed appearance similar to that of thallose liverworts. Little green horns rising above the flat plant body, as shown in **FIGURE 2.2**, produce spores.

**Mosses**

Mosses are the most common nonvascular plants. Some look like clumps of grass, others look like tiny trees, and still others look like strands of green yarn. Mosses do not have true leaves. Instead, they have leaflike structures that are just one cell thick. While they lack vascular systems, some moss species do have cuticles, and most of them have stomata. Mosses can anchor themselves to surfaces such as soil, rocks, or tree trunks, as shown in **FIGURE 2.3**, with structures called rhizoids (RY-zoydz).

Mosses are often tolerant of harsh weather conditions and nutrient-poor soils. They can grow in many places where other plants are unable to grow. Some mosses can survive in deserts and tundras by entering a stage of dormancy until water is available. In fact, mosses are often among the first plants to colonize bare land and begin the soil-making process in the early stages of primary succession.

One moss that is commonly used by humans is sphagnum (SFAG-nuhm), which grows in acidic bogs. Sphagnum does not decay when it dies, so thick deposits of this dead moss, called peat, build up over time. Peat can be cut from the ground and burned as fuel. Dried peat can absorb water, and it has antibacterial properties. In fact, dried peat has been used in products such as diapers and bandages. Peat also has an important role in the carbon cycle, as a reservoir that holds carbon in an organic form.

**Apply** Why can't nonvascular plants grow tall?
Club mosses and ferns are seedless vascular plants.

About 300 million years ago, during the Carboniferous period, shallow swamps were home to enormous seedless vascular plants. Over time, the dead remains of these plants were pressed and heated underground, where they gradually turned into coal. This is why we call coal a fossil fuel.

Club mosses (phylum Lycophyta) and ferns (phylum Pterophyta) are modern seedless vascular plants. Like nonvascular plants, they depend on water for reproduction. However, a vascular system allows these plants to grow higher above the ground and still get materials they need from the soil.

**Club Mosses**

Club mosses, which are not true mosses, belong to the oldest living group of vascular plants. Some ancient species looked like modern trees, growing more than ten stories tall. These giant plants were wiped out when the Carboniferous climate cooled, but some of the smaller species survived. One common living genus of club moss is *Lycopodium*. Some *Lycopodium* species, such as the one shown in Figure 2.4, look like tiny pine trees and are sometimes called “ground pines.”

**Whisk Ferns, Horsetails, and Ferns**

Ferns and their relatives, whisk ferns and horsetails, can be grouped together in one phylum. Whisk ferns grow mostly in the tropics and subtropics. Although they lack true roots and leaves, DNA analysis indicates that whisk ferns are closely related to ferns.

Horsetails grow in wetland areas and along rivers and streams. They have tan, scalelike leaves that grow in whorls around a tubular stem. Like club mosses, horsetails were much larger and more common in the Carboniferous period. Because horsetails’ cell walls contain a rough compound called silica, colonial settlers used the plant, also called “scouring rush,” to scrub pots.

Ferns are the most successful survivors of the Carboniferous period, with about 12,000 species alive today. Most ferns grow from underground stems called rhizomes (RY-zohmz). Their large leaves, shown in Figure 2.5, are called fronds. Newly-forming fronds, called fiddleheads, uncurl as they grow. Some ferns are grown as houseplants. Others, called tree ferns, live in the tropics and can grow over three stories tall.

**Infer** Why do most seedless vascular plants live in moist areas?
Seed plants include cone-bearing plants and flowering plants.

You may be familiar with seeds as the small plant parts that, when sown and tended, will produce another plant. From an evolutionary viewpoint, seed plants have several great advantages over their ancestors.

- **Seed plants can reproduce without free-standing water.** Seedless plants depend on water through which sperm swim to fertilize an egg. However, seed plants do not depend on water in this way. Seed plants, such as the pine tree in **FIGURE 2.6**, produce pollen. Pollen can be carried by the wind or on the body of an animal pollinator, such as a bee. **Pollination** occurs when pollen meets female reproductive parts of the same plant species. Each pollen grain has a cell that will then divide to form sperm. Fertilization occurs when a sperm meets an egg. The ability to reproduce without free-standing water allows many seed plants to live in drier climates.

- **Seeds nourish and protect plant embryos.** A seed consists of a protective coat that contains a plant embryo and a food supply. A seed can survive for many months, or even years, in a dormant state. During this time, the seed can withstand harsh conditions, such as drought or cold, that might kill an adult plant. When conditions are right, the embryo will begin growing, using the food supply provided by the seed.

- **Seeds allow plants to disperse to new places.** Wind, water, or animals often carry seeds far from the individual plant that produced them. In fact, many seed plants have adaptations that aid in the dispersal of seeds, such as the “wings” that carry maple seeds in the wind. Because seeds can remain dormant, the embryo will not begin to develop until it reaches a suitable environment.
Scientists hypothesize that seed plants evolved as Earth’s climate changed from warm and moist to hot and dry during the Devonian period, 410 to 360 million years ago. Fossil evidence suggests that seed plants evolved about 360 million years ago. Seed plants can be grouped according to whether their seeds are enclosed in fruit.

- A **gymnosperm** (JIHM-nuh-spurm) is a seed plant whose seeds are not enclosed in fruit.
- An **angiosperm** (AN-jee-uh-spurm) is a seed plant that has seeds enclosed in some type of fruit.

Most gymnosperms are cone-bear- ing and evergreen, such as pine trees. A woody **cone** is the reproductive structure of most gymnosperms. It contains hard protective scales. Pollen is produced in male cones, while eggs are produced in female cones. Seeds also develop on the scales of female cones, which protect fertilized eggs.

There are three living phyla of gymnosperms: cycads (phylum Cycadophyta), *Ginkgo biloba* (phylum Ginkgophyta), and conifers (phylum Coniferophyta).

**Cycads**

Cycads look like palm trees with large cones, as shown in **FIGURE 2.7**. Huge forests of cycads grew during the Mesozoic era, 248 million to 65 million years ago. These plants provided food for dinosaurs. In fact, the Jurassic period of this era is commonly called the Age of the Cycads. Today, cycads grow in tropical areas in the Americas, Asia, Africa, and Australia. Many cycad species are endangered because of their slow growth and loss of habitat in these tropical areas.

**Ginkgo**

Like cycads, ginkgoes were abundant while the dinosaurs lived. Only one species lives today, *Ginkgo biloba*, shown in **FIGURE 2.8**. This species is native to China, and it has survived in part due to its cultivation by Buddhist monks since the year 1100. Because it so closely resembles its fossil ancestors, Darwin called this species a living fossil. In fact, the ginkgo may be the oldest living species of seed plants. Today, it is grown around the world in gardens and used in urban landscaping.

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**VOCABULARY**

- **Gymnosperm** comes from the Greek words gumnos, which means “naked,” and sperma, which means “seed.”
- **Angiosperm** comes from the Greek words angos, which means “vessel,” and sperma, which means “seed.”
Conifers

By far, the most diverse and common gymnosperms alive today are the conifers—familiar trees with needlelike leaves, such as those in Figure 2.9. Pines, redwood, spruce, cedar, fir, and juniper all belong to this phylum. Conifers supply most of the timber used for paper, cardboard, housing lumber, and plywood. They grow quickly, and large tree farms help produce enough wood to meet demand.

Many conifers are evergreen, or green all year-round. However, a few lose their needles in the winter. Conifers are well adapted to high altitudes, sloping hillsides, and poor soil. These characteristics allow conifers to thrive in mountainous regions.

Conifers tend to grow old and grow tall. Two known conifers hold world records. At more than 9550 years of age, one spruce tree in the Dalarna province of Sweden is the oldest known living tree. And a giant sequoia tree in Sequoia National Park in California is the world’s most massive living thing. It has a mass of 1.2 million kilograms, which is about the mass of 40 buses.

Flowering Plants

Angiosperms belong to a phylum of their own (phylum Anthophyta) and are commonly called flowering plants. A flower is the reproductive structure of flowering plants. Flowers protect a plant’s gametes and fertilized eggs, as woody cones do for most gymnosperms. A fruit is the mature ovary of a flower. Fruit can take the form of a juicy peach, the wings attached to a maple seed, or the fluff surrounding dandelion seeds. As you will learn in the next section, flowers and fruits have played a large role in the dominance and diversity of flowering plants today.

Apply What adaptation of seed plants allows sperm to reach and fertilize an egg in the absence of water?

20.2 Formative Assessment

REVIEWING MAIN IDEAS
1. What are the habitat requirements for seedless nonvascular plants?
2. What are the evolutionary advantages of a vascular system? TEKS 7D
3. What are the evolutionary advantages of seeds? TEKS 7D

CRITICAL THINKING
4. Infer In what type of environment might you find nonvascular plants, seedless vascular plants, and seed plants growing together? Explain.
5. Apply Consider the characteristics of pollen grains. Why do people with pollen allergies find it difficult to avoid exposure to pollen?

CONNECT TO
HISTORY OF LIFE
6. According to the fossil record, seed plants date back to 360 million years ago, when Earth’s climate was becoming hotter and drier. What role did this global climate change likely play in the evolution of seed plants? TEKS 7D
Need for Seeds

Endangered Plants
Explore a plant in your area that is threatened or endangered, and determine how to keep it from going extinct.

Cotton-Ball Bats
Have you ever wondered what bats are up to at night? Watch as bats are tracked through the rain forest and discover the crucial role they play in the ecosystem.

Plant and Pollinator Matching Game
Examine the adaptive features of flowers and animals, and use them as clues to match flowers to their animal pollinators.
Diversity of Flowering Plants

**VOCABULARY**
cotyledon  
monocot  
dicot  
wood

**MAIN IDEAS**
- Flowering plants have unique adaptations that allow them to dominate in today’s world.
- Botanists classify flowering plants into two groups based on seed type.
- Flowering plants are also categorized by stem type and lifespan.

**Connect to Your World**

Sunflower seeds in the shell aren’t just a tasty snack. They are an example of one of the great adaptations of flowering plants. Like all flowering plants, sunflowers produce fruits. Technically, the fruit is the shell surrounding the sunflower seed. As you will soon learn, fruits can take many forms beyond the juicy apple or peach that may first come to mind.

**Flowering plants have unique adaptations that allow them to dominate in today’s world.**

Up until about 65 million years ago, there were far fewer flowering plants than there are today. After the mass extinction event that ended the Cretaceous period, the fossil record reveals that a major shift took place in species that dominated Earth. Dinosaurs disappeared, as did many seedless plant species. These plant extinctions left open niches into which flowering plants, such as the dogwoods in **Figure 3.1**, could radiate and prosper. Their diversification happened quickly in geologic terms and was closely tied to the diversification of land animals such as insects and birds. The same adaptations that were important to the success of flowering plants long ago continue to be important today.

**Flowers and Pollination**

Flowers allow for more efficient pollination than occurs in most gymnosperms, which rely on wind for pollination. You have probably observed a bee or a butterfly hovering around the center of a flower. These insects and other animals feed on pollen, which is high in protein, or on nectar, a sugary solution produced in the flowers of some plant species. As an animal feeds from a flower, it gets pollen on itself. Then, when it moves to another flower for more food, some of the pollen brushes off onto the new flower. Thus, animal pollinators transfer pollen from flower to flower in a very targeted way. For this reason, flowering plants pollinated by animals don’t need to produce nearly as much pollen as do plants that rely on the wind to randomly transfer their pollen.
Fruits and Seed Dispersal

The many types of fruits include some very unlike the kinds you see in a grocery store. In biological terms, a fruit is a flower’s ripened ovary, which surrounds and protects the seed or seeds. For example, the shells of sunflower seeds and peanuts are fruits. Fruit play an important role in seed dispersal. As shown in Figure 3.2, the more familiar fleshy fruits are tasty food sources for animals, which digest the fruit tissue but not the seeds. Seeds pass through the animal and are deposited along with a convenient supply of fecal fertilizer that is helpful during germination. Others take the form of burrs that cling to passing wildlife, or fibers that help spread seeds by wind.

Infer Why is pollination by animals more efficient than wind pollination?

Botanists classify flowering plants into two groups based on seed type.

There are at least 300,000 identified flowering plant species. Compared with other living plant phyla—the three gymnosperm phyla have a total of 720 species—the number of flowering plants is impressive.

Botanists classify flowering plants into two basic kinds of seed: seeds with one or two cotyledons. A cotyledon (kaht-uhl-EED-uhn) is an embryonic leaf inside a seed. For this reason, cotyledons are often called “seed leaves.” As an embryo develops into a seedling, the seed leaf of some species remains inside the seed coat. In other species, cotyledons break out of the seed and turn green.
Monocots

Flowering plants whose embryos have one seed leaf are called monocotyledons, or **monocots** (MAHN-uh-kahts). As **FIGURE 3.3** shows, monocot plants generally have parallel veins in long, narrow leaves, such as those of an iris or lily. Their flower parts usually occur in multiples of three, and bundles of vascular tissues are scattered throughout the stem. The cereal plants we depend on—corn, wheat, rice—are monocots, as are all other grasses, irises, and lilies.

Dicots

Dicotyledons, or **dicots** (DY-kahts), are flowering plants whose embryos have two seed leaves. In contrast to monocots, dicots have leaves with netlike veins. Flower parts in dicots usually occur in multiples of four or five, and bundles of vascular tissue are arranged in rings. Most deciduous trees, which lose their leaves in the fall, are dicots. Peanuts are also dicots. Each “half” of a peanut that has been removed from its shell is a cotyledon.

**Predict** Would you expect that cotyledons are green inside a seed? Explain.

**MAIN IDEA**

**TEKS BB**

Flowering plants are also categorized by stem type and lifespan.

Flowering plants can also be categorized by stem type and lifespan, as shown in **FIGURE 3.4**. These characteristics help describe mature flowering plants and are commonly used by botanists, gardeners, landscape designers, and horticulturists.
Herbaceous or Woody Stems
Some flowering plants develop woody stems, while others do not. **Wood** is a fibrous material made up of dead cells that are part of the vascular system of some plants. High concentrations of lignin and cellulose make the cell walls of these cells thick and stiff. Woody plants therefore have stiff stems and branches. Wood also accounts for the thickness of many woody plant stems. Trees, shrubs, and most vines have woody stems. Plants that do not produce wood, such as cucumbers, cacti, and marigolds, are called herbaceous plants.

Three Types of Lifespans
It is helpful for biologists to classify plants in terms of their lifespans, since lifespan is an important life history trait.

- **Annual**  Flowering plants that mature from seeds, produce flowers, and die all in one year are called annuals. Corn and lettuce are common annuals, as are some garden flowers such as zinnias.

- **Biennial**  Flowering plants that take two years to complete their life cycle are called biennials. During the first year, a biennial produces a short stem, leaves that grow close to the ground, and underground food reserves. During the second year, these reserves are used to produce a taller stem, leaves, flowers, and seeds. Carrots are common biennial garden plants.

- **Perennial**  Any flowering plant that lives for more than two years is a perennial. Most woody plants, including trees, are perennials. The stems and leaves of some herbaceous perennials, such as some grasses and dandelions, die at the end of the fall and grow back in the spring.

**Contrast**  How do the lifespans of annuals, biennials, and perennials differ?

### 20.3 Formative Assessment

**REVIEWING MAIN IDEAS**

1. What adaptations give flowering plants a reproductive advantage over gymnosperms?  
   - **TEKS 7D**

2. What are the primary differences between monocots and dicots?

3. Name three ways in which flowering plants can be categorized.  
   - **TEKS 8B**

**CRITICAL THINKING**

4. **Contrast**  In what ways does pollination in gymnosperms differ from pollination in angiosperms?

5. **Apply**  How would you take plant lifespan type into account when planning a garden?

**CONNECT TO MASS EXTINCTIONS**

6. The fossil record reveals a mass extinction at the end of the Cretaceous period. Discuss why mass extinctions are commonly followed by a period of adaptive radiation, in this case, of flowering plants.  
   - **TEKS 7B**
Mean, Median, and Mode

One way to analyze data is to use measures of central tendency, which are measures that indicate the center of a data set. The three most common measures of central tendency are the mean, median, and mode. It is often helpful to look at all three of these measures because they may each point out different characteristics of a data set.

The mean is calculated by adding all of the data points together and dividing by the number of data points. The mean considers the full range of data and is therefore affected by outliers—data points that vary greatly from all of the other points in the data set.

The median is the data point that falls in the middle when all of the data points are ordered from least to greatest. If there is an even number of data points, the median is the average of the two middle numbers. Since outliers do not affect the median, this may be a good measure to use with a data set that includes outliers.

The mode is the value that occurs most frequently. It is not affected by outliers. Some data sets have more than one mode. If there are several modes that dominate the data set, it is a good idea to study these data points more closely.

Model

A class counted the number of seeds found in some common fruits. These data are shown in Table 1.

- **Oranges** The mean is an appropriate measure to use for this data set because there are no obvious outliers.
- **Watermelons** The mean is affected by an outlier, 582 seeds. The median is a good measure to represent this data set.
- **Apples** The two modes represent a trend in these results that the students may want to investigate further.

<table>
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<th>Fruit</th>
<th>Number of Seeds per Fruit</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
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<td>5</td>
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<td>219</td>
<td>180</td>
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</tr>
</tbody>
</table>

**Practice** Choose an Appropriate Measure of Central Tendency

Use the data for the number of seeds counted in each of ten strawberries to answer the questions below.

1. **Calculate** Find the mean, median, and mode for this set of data.
2. **Evaluate** Which measure of central tendency best represents this data set? Why?
**20.4 Plants in Human Culture**

**VOCABULARY**
- botany
- ethnobotany
- pharmacology
- alkaloid

**KEY CONCEPTS** Humans rely on plants in many ways.

**MAIN IDEAS**
- Agriculture provides stable food supplies for people in permanent settlements.
- Plant products are important economic resources.
- Plant compounds are essential to modern medicine.

**Connect to Your World**

Books are made from plants. The pages are pulverized wood from trees, the ink contains plant oil, and the glue that binds them together is made from petroleum—the ancient leftovers of algae and plants. Humans rely on plants for nearly everything in daily life. Today, crop plants are so important to our economy that their changing prices are reported in the media alongside those of stocks and bonds.

**MAIN IDEA**

**Agriculture provides stable food supplies for people in permanent settlements.**

Some of the plants that are considered important by humans have changed over time, but plants have always been used to fill the basic needs of our species: food, shelter, clothing, and medicine. While botany is the study of plants, ethnobotany explores how people in different cultures use plants.

For most of human history, people survived by hunting and gathering. This requires a very thorough understanding of local botany—plant locations, life cycles, and characteristics. Hunting and gathering also requires people to change locations if resources are diminished by weather, disease, or overuse. People then must become familiar with the resources of the new area.

**FIGURE 4.1** Agriculture has become an important part of our global economy. Many river deltas, such as the Sacramento River delta in California, are used for farmland because of their nutrient-rich soils and water.
Archaeological evidence suggests that people started intentionally planting for harvest about 10,000 years ago. Over the centuries, ancient farmers “tamed” wild species by a process of artificial selection, as shown in FIGURE 4.2. They chose plants with the best traits, saved their seeds, and planted them the next year. Most of the world’s staple foods—corn, rice, and wheat—were developed from wild grasses in this way. These farmers became more closely tied to particular areas.

Because farming requires people to stay in one place, agriculture gave rise to more socially complex centers of human populations. A benefit of farming was a more reliable source of food that could support a growing population. Eventually, farmers grew enough excess food to sell it to neighbors as a cash crop. In this way, farming became part of a culture’s economy.

**Summarize** What does an ethnobotanist study?

**Main Idea**

**Plant products are important economic resources.**

Plant products have been traded among various regions for thousands of years. Spices such as pepper, cinnamon, and cloves were so valuable that they were commonly used as a form of currency during the early Middle Ages. In fact, many of the seafaring explorations to Asia and the Americas during the 1400s and 1500s were prompted by the value of spices, like those shown in FIGURE 4.3. Columbus, Magellan, and da Gama were all in search of a new route to the valuable commodities of the East.

Today, plants are important economic resources on a global scale. The values of rice, grains, soybeans, coffee, sugar, and cotton traded in world markets every year are each billions of dollars. Paper, textiles, and lumber are just a few of the plant-derived products that contribute to our economy.

**Connect** What plants were used to make the clothes that you are wearing and the contents of your backpack?
Plant compounds are essential to modern medicine.

The study of drugs and their effects on the body is called pharmacology. Many of the drugs used today are derived from plants, and much of the knowledge of these plants comes from traditional cultures. We still use some plants medicinally in the same way they have been used for thousands of years. For instance, the aloe vera gel you can buy to soothe sunburn was used for the same purpose by the Egyptians 3500 years ago.

As shown in FIGURE 4.4, scientists continue to look for and find new uses for plants that have been used medicinally for centuries. For example, Native Americans have long used the Pacific yew to treat a variety of conditions. In the 1960s, scientists isolated a compound called taxol from the tree, which has been used as a cancer treatment since 1993. Salicin, which comes from willow trees, is another plant compound that you are likely familiar with. It is the active ingredient in aspirin, the most widely used medicine in the world.

While plant oils and resins are common in traditional medicines, other plant compounds, including gums, steroids, and alkaloids, have found their way into modern medicines. Alkaloids are potent plant chemicals that contain nitrogen. In small amounts, many alkaloids are medicinal. By interfering with cell division, some alkaloids—such as taxol—have anti-cancer properties. Two alkaloids produced by the Madagascar periwinkle are used to treat childhood leukemia and Hodgkin's disease. Other alkaloids have been identified to treat conditions ranging from a nasty cough to high blood pressure.

Today, much medical research focuses on the chemical properties of various plant compounds—especially compounds from plants that have been used medicinally in traditional cultures. Chemists also work to develop synthetic drugs based on the structure of these natural compounds, often changing the structures slightly to increase effectiveness and reduce side effects.

Infer Why might certain plant compounds have healing effects in small quantities but be dangerous in larger doses?

### 20.4 Formative Assessment

#### REVIEWING MAIN IDEAS

1. How has agriculture affected the day-to-day life of humans?
2. In what ways are plants an important part of our culture today?
3. Why is a knowledge of plants so important to pharmacology?

#### CRITICAL THINKING

4. Analyze How did the average person's knowledge of plants change in societies that adopted agriculture? Explain your answer.
5. Connect Aside from food and medicine, in what ways are plants used in your life?

#### CONNECT TO

- **CELLS**
  - Some alkaloids help stop the spread of cancer by interfering with mitosis. Recall from the chapter Cell Growth and Division that mitosis is the phase of the cell cycle when the duplicated chromosomes separate so that two new cells form.

- **HUMAN IMPACT ON ECOSYSTEMS**
  - Many plants harvested for medicinal purposes grow in rain forests of developing countries. How might this fact affect the ecosystems and economies of these countries?
20 Summary

KEY CONCEPTS

20.1 Origins of Plant Life
Plant life began in the water and became adapted to land. The common ancestor of plants is an ancient species of green algae. Green algae called charophyceans are the closest living relatives to this common ancestor. Over time, the first true plant species evolved as they adapted to life on land. Land plants have evolved mechanisms to retain moisture, transport resources, grow upright, and reproduce on land. They have also coevolved with other organisms that inhabit dry land.

20.2 Classification of Plants
Plants can be classified into nine phyla. Mosses and their relatives make up three phyla of seedless nonvascular plants. These plants rely on water for reproduction and must grow low to the ground to absorb water and nutrients. Club mosses and ferns make up two phyla of seedless vascular plants. Vascular tissue allows these plants to grow higher above the ground. Seed plants, which include three phyla of cone-bearing plants and one phylum of flowering plants, do not rely on water for reproduction. Sperm of seed plants are produced by pollen grains. Seeds nourish and protect the embryos of these plants.

20.3 Diversity of Flowering Plants
The largest phylum in the plant kingdom is the flowering plants. Flowers and fruit are two adaptations that have allowed flowering plants to become the dominant plant group on Earth today. Flowers often allow for more efficient pollination by animals, while fruit can aid in seed dispersal. Botanists classify flowering plants into two groups based on the number of cotyledons inside the seed. Flowering plants can also be categorized based on stem type and lifespan.

20.4 Plants in Human Culture
Humans rely on plants in many ways. Plants are essential to human existence. All of the food that we eat comes either directly or indirectly from plant life. Agriculture provides stable food supplies for most people today. Many agricultural products are important economic resources on a global scale. Plants also provide us with clothing, paper, textiles, lumber, and medicines.

 Three-Column Chart  Use a three-column chart to take notes about the nine divisions of plants. Use the columns to write the scientific names of each division, the common names, and details about the plants.

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Details</th>
</tr>
</thead>
</table>

Concept Map  Use a concept map to review how flowering plants can be classified.

flowering plants can be classified by

- which can be
- which can be
- which can be
CHAPTER 20 Review

CHAPTER VOCABULARY

20.1 plant
   cuticle
   stomata
   vascular system
   lignin
   pollen grain
   seed

20.2 pollination
   gymnosperm
   angiosperm
   cone
   flower
   fruit

20.3 cotyledon
   monocot
   dicot
   wood

20.4 botany
   ethnobotany
   pharmacology
   alkaloid

Reviewing Vocabulary

Vocabulary Connections

For each group of words below, write a sentence or two to clearly explain how the terms are connected. For example, for the terms cuticle and stomata, you could write “Together, the cuticle and stomata prevent water loss while allowing for gas exchange.”

1. lignin, wood
2. pollen grain, pollination
3. gymnosperm, seed, cone
4. angiosperm, seed, flower, fruit
5. cotyledon, monocot, dicot
6. pharmacology, alkaloid

7. Cuticula is the Latin word for “skin.” How does this meaning relate to the definition of the word cuticle?

8. In Greek, the word stoma means “mouth.” How does this meaning relate to its botanical meaning?

9. In Latin, the word pollen means “dust” or “fine flour.” How does this meaning relate to its botanical meaning?

10. The word conus is a Latin word that means “wedge” or “peak.” How does this meaning relate to the definition of the word cone?

11. Frui is a Latin verb meaning “to enjoy.” How does this meaning relate to the role that various fruits play in human culture?

12. The prefix mono- means “one” in Latin, while the prefix di- means “two.” How do these meanings relate to the words monocot and dicot?

Reviewing MAIN IDEAS

13. Summarize the evidence supporting the statement that modern plants evolved from an ancient species of green algae. TEKS 7A

14. Discuss four major challenges that early plants faced while adapting to life on dry land. TEKS 7A

15. The 30-centimeter tongue of the hawk moth is long enough to reach the nectar—and reproductive organs—of the night-blooming orchid. What can be concluded about the evolution of plants from these types of relationships? Explain. TEKS 7D

16. Describe the structural features that limit the height of mosses and their relatives.

17. Explain why most seedless vascular plants live in moist environments.

18. What is the main difference between the seeds of cone-bearing plants and the seeds of flowering plants? TEKS 8B

19. Summarize two of the adaptations of flowering plants that allow them to flourish in today’s world. TEKS 8B

20. Describe the system that botanists use to classify flowering plants into two main groups. TEKS 8B

21. Compare and contrast annual, biennial, and perennial lifespans.

22. What role does agriculture play in the stability and survival of modern human populations?

23. How can plants play a role in developing modern medicines, even if they are not used as ingredients?
Critical Thinking

24. **Analyze** Aquatic plants, which evolved from land plants, have adaptations that allow them to live in the water. Some aquatic plants grow completely submerged in water. What challenges might these plants face that do not apply to plants that live entirely on land? **TEKS 7E**

25. **Analyze** The sperm of seedless plants are flagellated, while those of seed plants are not. How do the sperm of seed plants reach eggs without flagella? **TEKS 8B**

26. **Compare** When a plant reproduces, it is important for its offspring to disperse so that they do not compete directly with the parent plant. Compare the structures that allow seedless plants and seed plants to disperse to new locations. **TEKS 8B**

27. **Synthesize** Some experts predict that the Amazon rain forest will be completely destroyed within the next century due to human activities. What resources would potentially be lost along with this ecosystem?

28. **Infer** Some types of flowers have special markings on their petals that act as guides to the pollen or nectar for their pollinators. How could such markings have evolved through natural selection? **TEKS 7D**

29. **Analyze** What evolutionary advantage do the seeds of dandelions have over the seeds of pine trees? **TEKS 7E**

30. **Synthesize** How might an increase in the use of insecticides affect flowering-plant populations in the area?

Interpreting Visuals

Use the illustration below to answer the next two questions.

31. **Analyze** What parts of this plant could you examine to determine whether it is a monocot or a dicot?

32. **Apply** Is this plant likely a monocot or a dicot? Explain your reasoning.

Analyzing Data Measure Central Tendency

Valencia oranges, which likely originated in Spain or Portugal, are now the most widely planted orange variety in the world. Use the data below on the number of California Valencia oranges per tree to answer the next three questions.

<table>
<thead>
<tr>
<th>CALIFORNIA VALENCIA ORANGES PER TREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>596, 402, 489, 708, 374, 548, 640, 585, 518, 450</td>
</tr>
</tbody>
</table>

Source: California Agricultural Statistics Service

33. **Calculate** What are the mean, median, and mode for this data set? Round the mean to the nearest whole number.

34. **Analyze** Does this data set contain outliers? Explain your answer.

35. **Evaluate** Which measure of central tendency best represents this data set? Explain your answer.

Making Connections

36. **Write About Seeds** From the viewpoint of a plant embryo, write about the importance of a seed. What does the seed provide for you? In what ways does it help you? What advantages do you have over nonseed plants?

37. **Synthesize** The flowering proteas of South Africa are adapted to a dry climate that receives as little as 600 mm (23.6 in) of rain each year. However, plants must retain moisture in order for photosynthesis to occur. Describe the adaptations that allow these plants to retain moisture in their leaves while still allowing for air to move in and out. **TEKS 7E**
Record your answers on a separate piece of paper.

**MULTIPLE CHOICE**

**TEKS 2C, 3F**
1 In the 1940s, Barbara McClintock observed patterns of inheritance in corn plants that could not be explained by the current gene theory. The conclusions of her work were not widely accepted for years until further supported by the work of other scientists. What does this scenario demonstrate about science?
   A Data that are more than 50 years old should be discarded.
   B Data that do not fit a scientific theory should be discarded.
   C Theories may be modified as additional data leads to new conclusions.
   D The repetition of results by many scientists is not necessary to validate a theory.

**THINK THROUGH THE QUESTION**
Think about the process by which plants produce sugars. You can eliminate any answer choices that would result in plants with less sugar.

**TEKS 2G, 11B**
2

<table>
<thead>
<tr>
<th>Tomato Plant Growth Per Week (cm)</th>
<th>Plot</th>
<th>Condition</th>
<th>Average Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>full sun</td>
<td>9 cm</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>part sun</td>
<td>7 cm</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>full shade</td>
<td>2 cm</td>
</tr>
</tbody>
</table>

Gardeners are testing three plots of land with similar soil to find out which is best for growing tomato plants. Which of the following conclusions is best supported by their data?
   A Plot 1 received the most nutrients.
   B Tomato plants grow best in full sun.
   C Tomato plants cannot grow in the shade.
   D The data are not reliable because there is no control.

**TEKS 2G, 6D**
3 The sugar in corn quickly converts to starch after the corn has been picked. After picking, corn that has the Sh2 gene in its DNA was found to have more sugar and less starch than corn without this gene. Which of the following statements is most likely true about corn with this gene?
A Corn that expresses this gene cannot convert sugar to starch.
B This gene causes corn to convert sugar to starch when picked.
C Plants with this gene produce less sugar.
D This gene works in conjunction with other genes to convert sugar to starch.

**TEKS 7E**
4 The beak shape shown below likely evolved as a result of the birds that could get food most efficiently with this adaptation —
   A dying in the absence of long, tubular flowers
   B not attracting a mate
   C being able to eat a wide variety of food, such as nuts, insects, and berries
   D being more likely to survive and reproduce

**TEKS 7B, 7E, 11B**
5 Rock from the Cretaceous period contains the fossils of a variety of dinosaurs and seedless plants. The fossil record afterwards includes the fossils of many flowering plants and smaller animals, but no dinosaurs. Which of the following statements is supported by this evidence?
A Dinosaurs had begun to die out during the Cretaceous period.
B A mass extinction at the end of the Cretaceous period made new niches available for flowering plants.
C The Cretaceous environment was less favorable to seedless plants than to flowering plants.
D Dinosaurs evolved around the end of the Cretaceous period.