CHAPTER 24

Plant Growth and Development



An oak forest is home for many different animals. Some eat the acorns produced by oaks, others make their home in tree trunks, and still others find safety in the lush oak foliage.

You have probably heard the old saying, "Mighty oaks from tiny acorns grow." But have you ever thought about the amazing changes that take place during the long life of such a tree? A tiny embryo oak plant sits within an acorn for months, maybe even years. Then one spring, it sprouts. Its roots grow deep into the soil in search of water and nutrients. Its leaves reach toward the sun—toward the light energy that powers the life of the plant. In autumn, growth slows. The oak's leaves turn color and fall to the ground. The entire plant undergoes the changes necessary to survive the approaching cold winter weather.

Many years later, the tree matures. Suddenly it produces hundreds, perhaps even thousands, of flowers. Some of the flowers produce seeds that mature into acorns. When the acorns ripen, they fall to the ground, where they may be buried or eaten by squirrels. With luck, the process of growth begins again.

CHAPTER OUTLINE

24–1 Patterns of Growth
- Annuals, Biennials, and Perennials
- Growth of Stems
- Growth in Dicot Stems
- Growth in Monocot Stems
- Growth of Roots

24–2 Control of Growth and Development
- Hormones and the Control of Plant Growth
- The Nature of Hormone Action
- The Role of Auxin
- Cytokinins
- Gibberellin
- Tropisms
- Winter Dormancy
- Day Length and Flowering

24–1 Patterns of Growth

Section Objectives

- Compare annual, biennial, and perennial plants.
- Compare the growth of monocot and dicot stems.
- Explain how roots increase in length.

Plants grow in different ways. If you have ever grown plants from seeds, you may be aware that some plants mature and produce flowers in the same year they are sown. Other plants take longer. **Plants are classified into three main groups—annuals, biennials, and perennials—depending on how long it takes them to produce flowers and how long they live.**

Annuals, Biennials, and Perennials

Some plants grow from seed to maturity, flower, produce seeds, and die all in the course of one growing season. These plants are called **annuals** (from the Latin word *annus*, which means year). Many common plants—such as marigolds, corn, and peas—are annuals.

Biennials (*bi* is the Latin word for two) are plants that usually live for two years. During the first growing season, biennials grow roots, stems, and leaves. The leaves and stems die back to the ground in winter, but the below-ground roots remain alive. The following season, new leaves and stems grow from the roots. In this second season, however, the plant produces flowers. Once the flowers produce seeds, the plant dies. Common biennial plants include some species of foxglove, sugar beets, carrots, and turnips.

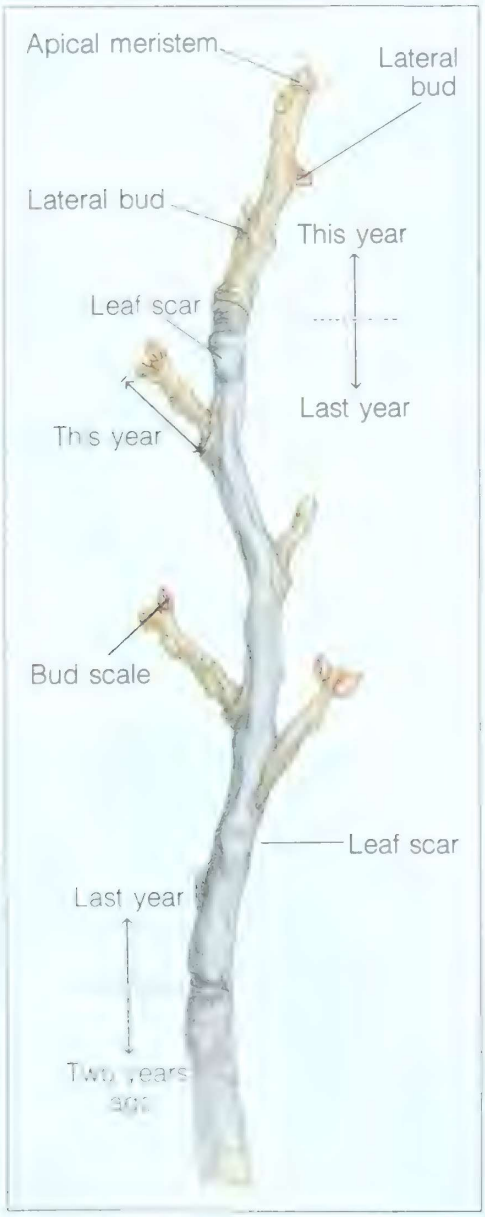
Perennials are plants that live for more than two years. Peonies, popular perennial garden plants, often outlive the person who planted them. Other perennials, such as dawn redwoods, have trunks and branches that live and grow larger for hundreds, even thousands, of years. Trees and shrubs are



Figure 24–1 *The zinnia (left) is one of the many plants that live for only one growing season. Plants such as the foxglove (right) take two growing seasons to complete their life cycle.*



Figure 24–2 *The chrysanthemum (left) and the peony (right) are perennials, which means they are able to grow for many years. Cold winter temperatures cause the top parts of the plants to die down to the ground. The roots, locked in the frozen soil, remain alive and will begin to grow again with the warmth of spring.*



perennials because they live for indefinite periods of time. Trees and shrubs whose stems contain woody tissue are called woody plants.

Plants whose stems have little or no woody tissue are called **herbaceous** (her-BAY-shuhs) plants. In cold climates, herbaceous plants die back to their roots every year. For example, perennials such as chrysanthemums and tulips grow new leaves and stems every spring. In tropical climates, the above-ground parts of both woody and herbaceous plants can grow throughout the year.

Growth of Stems

As you may recall from Chapter 23, stems grow longer at their tip as cells in the apical meristem divide. These newly formed cells then grow larger in an area behind the meristem called the **zone of elongation**. Farther back from the zone of elongation is the **zone of maturation**. Here cells differentiate into the various cells that make up a plant stem. In herbaceous plants, almost the entire stem is composed of tissue produced by the apical meristem. Tissue produced by the apical meristem is called **primary tissue**.

It should be clear to you that if a perennial plant is to grow larger year after year, its stems must increase in thickness as well as in length. Yet, as you may remember, only meristematic tissue can produce new cells for growth. In perennial plant stems, new tissue is added by special meristematic tissues called the vascular cambium and cork cambium. The addition

Figure 24–3 *A twig taken from a tree in winter shows how the apical meristem—the place where plant cells divide—is protected from the cold by thick bud scales. Twigs from different plant species have different markings, which can be used by botanists to identify the species—even without the benefit of leaves.*

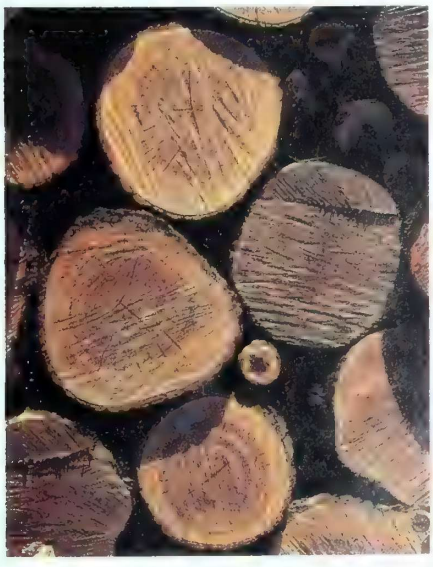
of new tissue in these cambium layers increases the thickness of the stem, which is needed to support a larger plant.

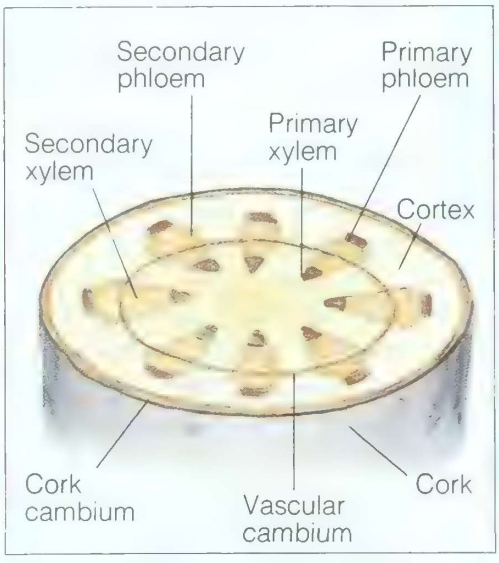
Growth in Dicot Stems

In woody dicot stems, a layer of vascular cambium located between the xylem and phloem tissues remains alive through the plant's first winter. In the following spring, this vascular cambium becomes active as its cells begin to divide. Xylem cells are formed on the surface of the vascular cambium that faces the center of the stem. Phloem cells are formed on the surface that faces the outside of the stem. These new layers of vascular tissue are called **secondary xylem** and **secondary phloem**. Both secondary layers spread sideways from each vascular bundle in the cambium layer, soon uniting the circle of vascular bundles into a solid ring. The xylem tissue is on the inside of the ring, and the phloem tissue is on the outside. The vascular cambium remains between the xylem and phloem.

XYLEM GROWTH The new ring of xylem tissue formed during every growing season plus the older xylem become the wood of trees. Although the cells of the older xylem layers are dead, they still conduct water for several years. Xylem is called **sapwood** as long as it conducts water. After some time, however, the oldest xylem cells become clogged with tars and resins and are no longer able to conduct water. This xylem tissue, which no longer conducts water but gives strength and support to the tree, is called **heartwood**.

You have probably seen tree rings, or **annual rings**, in the wood of trees. Tree rings are formed because the vascular cambium makes large xylem cells during the spring and smaller xylem cells during late summer and fall. The large cells of spring wood look lighter than the smaller cells of summer wood. Thus the tree accumulates set after set of alternating light and dark rings, one set for every year the tree is alive.





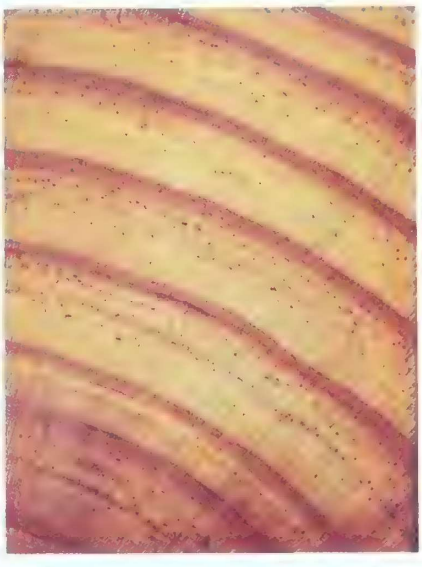


Figure 24–4 *Each tree ring represents a season's growth. During a single growing season, secondary xylem and phloem are produced by the vascular cambium. Note the variations in the sizes of the rings.*



Figure 24–5 Beavers are known for their sharp teeth, which have produced the results you see here. The bark and the delicate underlying phloem tissue of the tree have been gnawed away. The tree has been girdled and will eventually die.

PHLOEM GROWTH The vascular cambium makes new phloem cells at the same time it makes new xylem cells. These secondary phloem cells are added to the inner surface of the previous year's phloem. The phloem layer, however, never becomes as thick as the xylem layer. One reason for this is that the cambium makes only one new phloem cell for every six or eight xylem cells. Another reason is that phloem cells have thinner walls than xylem cells and are crushed as the stem grows thicker.

Phloem tissue forms the inner half of tree bark. Here it carries sugars and other products of photosynthesis from leaves to those plant parts that do not make their own food. For this reason, a tree will die if the phloem in tree bark is damaged or removed in a ring around the trunk.



Growth in Monocot Stems

Recall that in monocots (corn and lilies, for example) xylem and phloem tissues are arranged in vascular bundles scattered throughout the stem. In most monocots, these bundles lack a vascular cambium, so no new xylem and phloem cells can be produced. This means that once the apical meristem of a monocot produces a stem, that stem cannot grow thicker. Few monocots grow more than several meters tall.

But there are a few tall monocots. Palms are one example. The few monocot trees remain short for several years. During this time, they produce leaf after leaf, without growing very tall. While they are producing leaves, however, the apical meristem as well as the stem below it grow wider. Finally, the meristem produces a stem strong enough to serve as a trunk. At that point, the monocot tree starts to grow taller. Unlike dicot stems, the stem of a palm does not increase greatly in width once the tree begins to grow tall.

Growth of Roots

Roots, like stems, grow in length as their apical meristem produces new cells near the root tip. The fragile new cells are covered by a tough **root cap** that protects the root as it forces its way through the soil. As the root grows, the root cap secretes a slippery substance that lubricates the progress of the root through the soil. Because cells at the very tip of the root cap are constantly being scraped away, new root cap cells are continually added by the meristem.

Figure 24–6 Palms are one of the few monocot trees. Palms remain short for a time, as their apical meristem increases in width (inset). However, the tiny palm will eventually grow tall.

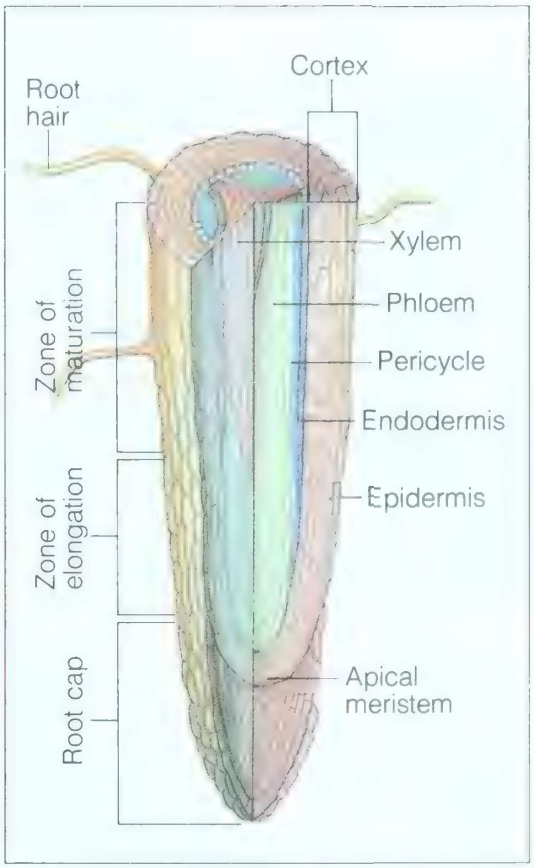


Figure 24–7 *Only the cells in the root tip divide. In the area just behind the root tip, the newly divided cells increase in length, pushing the root tip farther into the soil. The root cap, located just ahead of the root tip, protects the dividing cells as they are pushed forward.*

Most of the actual increase in root length occurs in the zone of elongation immediately behind the meristem. There, the small cells produced by the meristem grow longer. In the zone of maturation, these cells take on the structures and functions of mature root cells.

24-1 SECTION REVIEW

1. How does an annual plant differ from a perennial plant?
2. Why don't most monocot stems grow thicker?
3. How do stems and roots grow in length?
4. The tallest humans stop growing eventually, yet a tall tree increases its height year after year. Why are plants able to continue to grow taller as long as they live?

24–2 Control of Growth and Development

Section Objectives

- Describe the effects and importance of hormones on plant growth.
- Identify several plant tropisms.
- Compare long-day, short-day, and day-neutral plants.

Plants grow in response to important environmental factors such as light, moisture, temperature, and gravity. But just how do roots "know" to grow down and stems "know" to grow up toward light? The answers to these questions involve the actions of special chemicals that direct, or control, the growth of a plant.

Hormones and the Control of Plant Growth

In plants, as in animals, the division, growth, maturation, and differentiation of cells is controlled by a diverse group of chemical substances called hormones. A **hormone** is a substance produced in one part of an organism that affects another part of the organism. Plant hormones are manufactured primarily in apical meristems, in young leaves, and in growing seeds and developing fruits. Plant hormones control a plant's branching pattern, the rate at which its stems elongate, and its responses to environmental conditions.

How does a stem respond if a plant is knocked over? How do roots grow when they come up against a rock in the soil? How does a plant adjust its growth rate when winter or a dry season approaches? How do plants flower at the proper season? All these phenomena are controlled by hormones.

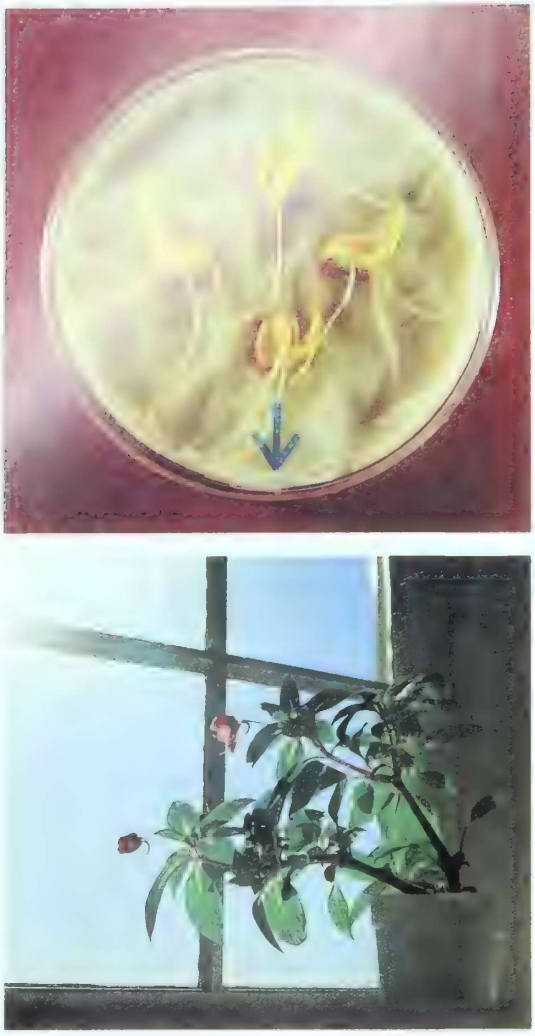


Figure 24–8 The roots of the corn seeds in this petri dish are growing in the same direction even though the seeds have been planted upside down (top). Stems grow toward the light (bottom). Why is it important that roots and stems grow the way they do?

The Nature of Hormone Action

The part of the organism affected by a hormone is known as the target tissue or **target organ**. The effects of a given hormone on a target tissue or target organ can vary a great deal for several reasons.

One reason is that the same concentration of a particular hormone can have two different effects on two different target tissues. For example, the identical concentration of a hormone can stimulate growth in stem tissues but inhibit growth in root tissues. Another reason is that different concentrations of a particular hormone can produce different effects on the same target organ. For example, low concentrations of a hormone can cause meristematic cells to divide, but high concentrations of that same hormone can prevent division. This phenomenon will help explain branching in plants. And a third reason is that two or more hormones can interact in a variety of ways. For example, the effect of one particular hormone may depend on whether or not another particular hormone is present. Systems of interacting hormones are important in regulating reproduction in plants.

The Role of Auxin

One well-known plant hormone is indoleacetic acid, commonly called **auxin**. Auxin can produce different effects on different plant tissues. High concentrations of auxin stimulate elongation of stem cells and inhibit elongation of root cells. Let us see how auxin directs the growth of stems and roots.

AUXIN AND STEM GROWTH Auxin produced in the apical meristem of a stem causes the stem to grow toward light and away from the pull of gravity. This effect was first noticed by Charles Darwin and his son Francis in experiments they performed in the 1880s. The Darwins observed that light caused "some influence" (they did not know what the influence was) to be transmitted from the tip of a growing stem down to the zone of cell elongation. This mysterious influence, the Darwins felt, caused the stem to bend and grow toward the source of light.

Other experiments performed between 1910 and 1920 by the Danish scientist P. Boysen-Jensen and the Hungarian researcher A. Paal showed that the "influence" the Darwins had observed was a chemical manufactured in the apical meristem. This chemical, the hormone we call auxin, is produced in the apical meristem and moves down the stem.

Today we understand that high concentrations of auxin stimulate young stem cells to elongate. If the source of light is directly overhead, and if the stem is growing vertically, the concentration of auxin will be the same on all sides of the stem. All the cells in the zone of elongation will grow at the same rate and the stem will grow straight up.

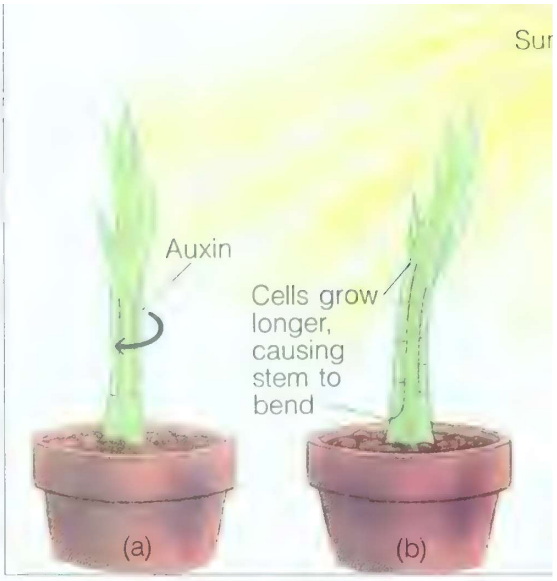


Figure 24–9 *Plants will bend toward a source of light. This fact is explained by the stimulating effect of plant hormones on cell growth. How do plant hormones cause a plant stem to bend?*

If the source of light is to one side of the stem, however, auxin will move away from the light to the shaded part of the stem. The higher concentration of auxin in the shaded side of the stem will stimulate cells in that side to elongate more than cells in the lighted side. This will cause the stem to bend toward the light.

If a plant is knocked on its side, auxin will accumulate in the lower side of the stem, or the side along the ground, because this side is darker than the upper side. It is the shaded side of the stem. The auxin-stimulated cells in the lower side will elongate more than the cells in the upper side. The stem will curve up, even in the absence of light.

AUXIN AND ROOT GROWTH Auxin produced in the apical meristem of roots causes the roots to grow away from light and toward the pull of gravity. If a growing root is exposed to light, auxin will concentrate in the shaded side of the root, just as it did in the shaded side of the stem. But high concentrations of auxin inhibit the elongation of root cells. Thus cells in the side of the root where auxin concentration is high will not elongate. Cells in the lighted side of the root will elongate normally, causing the root to bend away from the light.

If a growing root is directed sideways by an obstacle in the soil such as a rock, auxin will accumulate in the lower side of the root. Once again, high concentrations of auxin inhibit root cell elongation. The uninhibited root cells will elongate more than the auxin-inhibited root cells, and the root will bend downward.

AUXIN AND BRANCHING In addition to controlling cell elongation, auxin can also cause cell division in meristematic regions to stop or start. As a stem grows in length, cells in its apical meristem periodically produce other meristematic areas. These meristematic areas, called **lateral buds**, are on the sides of the stem. See Figure 24–11 on page 524. If these lateral buds begin to grow, they give rise to side branches that grow from the main stem.

If you grow plants at home or in the classroom, you know that most lateral buds do not start growing right away. Instead, they begin to grow only after the main growing tip of the plant has grown a distance above them. However, you can force these lateral buds into growth at any time by "pinching," or removing, the apical meristem. Why should this be the case?

Again, the action of auxin provides an explanation for the growth of lateral buds. Scientists have learned that high concentrations of auxin inhibit the growth of lateral buds, whereas low concentrations of auxin stimulate growth. Thus the high

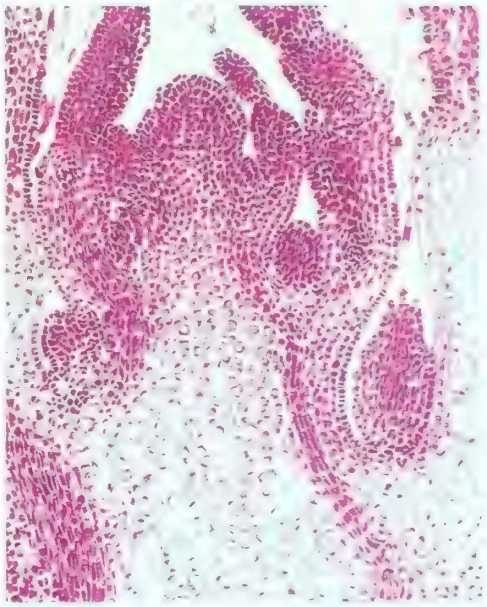


Figure 24–10 *A longitudinal section through the tip of a plant stem can be seen in this photomicrograph. Lateral buds can be seen just behind the apical meristem. These lateral buds will remain dormant as long as the tip of the plant remains intact nearby.*

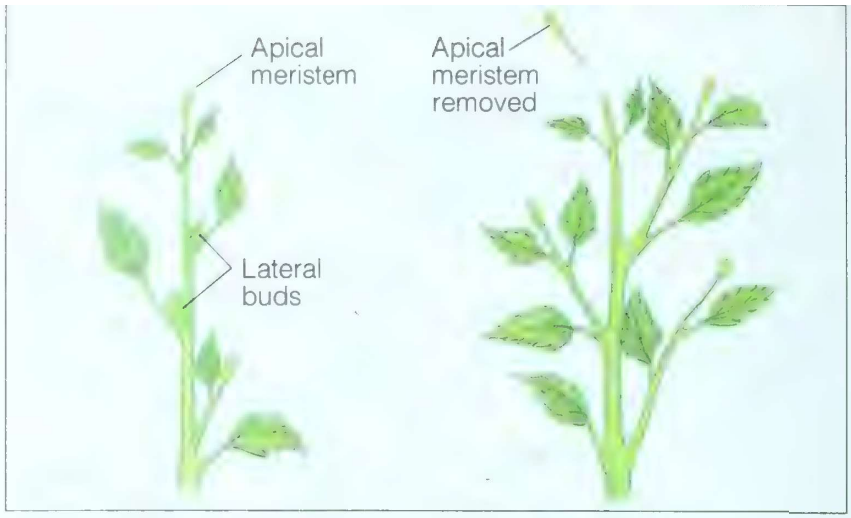


Figure 24–11 *The dormant lateral buds are kept from growing because of the production of hormones by the apical meristem. If the apical meristem is removed, however, the lateral buds will begin to grow. Pinching the apical meristem is one way a plant can be made to grow more bushy.*

concentration of auxin produced by the apical meristem inhibits the growth of lateral buds near the tip of the shoot. This inhibition is called apical dominance. When the apical meristem grows away from the lateral buds, or when it is removed, the auxin concentration in the lateral buds drops. Apical dominance ends, and the lateral buds begin to grow.

Cytokinins

Growing roots manufacture hormones called **cytokinins**. These hormones move upward in plants. Some cytokinins are also produced in developing fruits and seeds. Cytokinins stimulate cell division and cause dormant seeds to sprout. Several of the effects produced by cytokinins are the opposite of the effects produced by auxins. For example, whereas auxins stimulate cell elongation, cytokinins inhibit elongation and cause cells to grow thicker. Whereas auxins inhibit the growth of lateral buds, cytokinins stimulate lateral bud growth. Cytokinins have different effects on different tissues.

In growing plants, therefore, the relative concentrations of auxin, cytokinin, and other hormones determine how the plant will grow. You will learn in later chapters that the interactions of hormones are common in animals as well as in plants.

Figure 24–12 *The effects produced by the growth hormone gibberellin are dramatic. The short seedlings have not been treated with the hormone; the tall seedlings have.*



Gibberellin

In the 1920s, Japanese biologists studying certain rice plants made an important discovery. The rice plants they were observing seemed to be afflicted by a "disease" that made them grow unusually tall and spindly. Eventually the rice plants grew so tall that they could no longer be supported by their stems, and so they fell over. The scientists found that the plants' extraordinary growth was caused by a substance produced by the fungus *Gibberella fujikuroi.* They named the growth-producing substance **gibberellin** (jihb-er-EHL-ihn) after the fungus that produced it. Later, researchers learned that there are several different gibberellins. They also learned that gibberellins are hormones manufactured by all higher plants.

Tropisms

The responses of plants to environmental stimuli are called **tropisms** (TROH-pihz-uhmz) from the Greek word that means turning. If a plant grows toward a stimulus, it is said to have a positive tropism. If it grows away from a stimulus, it is said to have a negative tropism. There are several different kinds of tropisms. A plant's response to light is called **phototropism**. A response to gravity is called **gravitropism**. A response to touch is called **thigmotropism**.

For example, as soon as the primary root emerges from a germinating seed, it grows down and away from light. The root thus shows negative phototropism (away from the stimulus, light) and positive gravitropism (toward the stimulus, gravity). The stem, on the other hand, immediately starts growing toward the surface of the soil and toward light. The stem has a positive phototropism (toward the stimulus, light) and a negative gravitropism (away from the stimulus, gravity). From the very beginning of a plant's life, these positive and negative tropisms direct the plant's growth. And as you learned, these relatively simple responses of plants are controlled by hormones.

Winter Dormancy

Auxin and other hormones work together to control the growth, dormancy, and death of leaves in deciduous plants. During the growing season, auxin is produced in the leaves. At summer's end, days become shorter and nights become longer. The change in the length of light and dark periods causes a change in the chemistry of a protein called phytochrome. This change in phytochrome causes several things to happen to the plant's production of hormones. Auxin production drops, but the production of the hormones abscisic (ab-SIHS-ihk) acid and ethylene gas increases.

These changes in hormone production have several effects. One is that the cells that join leaf petioles to their stems become weak, forming a band called the **abscission layer**. Another effect is that chlorophyll synthesis in leaves slows down and stops. The chlorophyll that remains in the leaves is slowly broken down by the plant or destroyed by sunlight. When this happens, brightly colored accessory pigments (such as those you learned about in the chapter on algae) become visible. During the summer, the green color of chlorophyll hides these pigments. But when the chlorophyll is no longer present in the leaves, these once-hidden pigments appear, providing the beautiful colors we associate with autumn foliage.

A third effect of changes in hormone production is that cell division in apical meristems changes. Instead of producing leaves, the meristems produce thick, waxy **bud scales**. These bud scales wrap around the apical meristems, protecting the terminal buds. Enclosed in its coat of scales, a terminal bud can

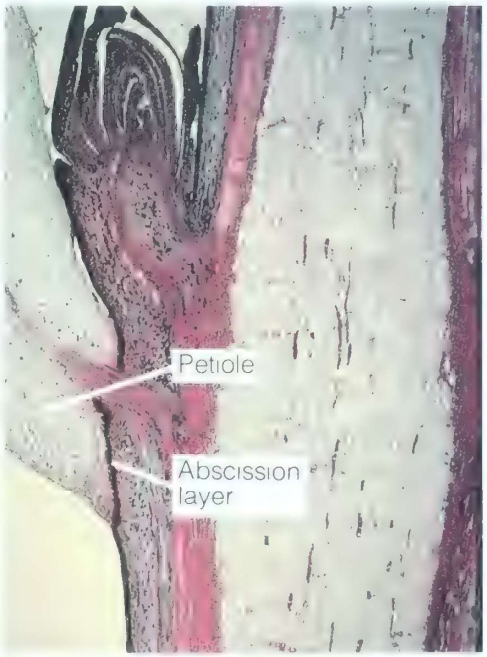


Figure 24–13 *In the fall, when winter's chill approaches, a tree prepares to shed its leaves. Here you can see the formation of the abscission layer at the base of a leaf petiole. When the abscission layer is complete, even the most gentle breeze will cause the cells to tear and the leaf to fall to the ground.*

survive the coldest winter days. At the onset of winter, xylem and phloem tissues pump themselves full of ions and organic compounds. These molecules act like antifreeze in a car, preventing the tree's sap from freezing.

During this time, the abscission layers at the bases of the leaves continue to develop. Eventually only a network of fragile vascular bundles holds the leaves on the stems. Sooner or later, a gust of wind or a rainstorm breaks the delicate abscission layers apart and the leaves fall. Where the leaves were once attached to the stems, only leaf scars remain as evidence of a season of growth.

SCIENCE, TECHNOLOGY, AND SOCIETY **APPLICATION**

Flowering by the Clock

For many people, flowers have special meanings. Flowers are often given as gifts, as tokens of affection, and to wish friends well. But the life of a grower of gift plants and flowers is not an easy one. In addition to the problem of insects and diseases that may harm the crop, there is the question of timing. A plant produced for Valentine's Day would be of little use if it flowered even a day late. Poinsettia plants grown for winter holiday decoration would be worthless if they flowered in June. Fortunately, you can buy roses on February 14 and poinsettias on December 25. Like clockwork, these flowers and plants are ready when they can be sold most profitably. How does this happen?

Growers of plants take advantage of day length to produce their plants at the proper times. For example, the poinsettia is a plant that flowers in nature during the winter. It is, as you might suspect, a short-day plant because it flowers naturally at the time of the year when nights are longest. In order to coax poinsettias into flowering at the "correct" time of the year, horticulturists cover the plants with thick cloths called blackout cloths during late-fall afternoons. The cloths prevent light from reaching the plants and interrupting the flowering cycle. In effect, the plants are tricked into believing that the days are short.

By covering some plants and adding additional light to others, horticulturists can almost guarantee that they will have plants and flowers available at suitable times. By taking advantage of the natural cycles of plant growth and flowering, consumers can be assured that they will have plants and flowers when they want them.

Long after the sun has ceased to shine, the plants in this greenhouse receive supplemental lighting to encourage, or in some cases delay, flowering.



Day Length and Flowering

"To everything there is a season," a popular song tells us, and nowhere is this more evident than in the regular cycles of growth in plants. Year after year, some plants flower in the spring, others in summer, and still others in the fall. How do plants time their flowering so precisely?

You know that there are fewer hours of daylight in winter than there are in summer. In the Northern Hemisphere, the shortest day occurs on or about December 21 and the longest day occurs on or about June 21. This means that from mid-winter through spring, days increase in length.

In the early 1920s, W. W. Garner and H. A. Allard, of the United States Department of Agriculture, learned that tobacco plants time their flowering according to the number of hours of light and darkness they receive. It soon became clear that many other plants also respond to periods of light and darkness. This response is called **photoperiodicity**.

At first, researchers assumed that plants respond primarily to the number of hours of light they receive. Plants such as chrysanthemums and poinsettias, which flower when days are short, were called short-day plants. Petunias, clover, and hollyhocks, which flower when days are long, were called long-day plants. The flowering of some plants, such as corn and tomatoes, did not seem to be affected by day length to any great extent. These plants were called day-neutral plants.

Today we know that the important factor in photoperiodicity is the length of the night or darkness period, not the length of the day or light period. Short-day plants actually flower because the nights are long. Long-day plants flower because the nights are short.

How do changes in the length of night cause plants to flower? As you learned earlier, changes in the length of light and darkness periods cause changes in compounds called phytochromes. In a manner that is still not understood, these changes in phytochrome chemistry stimulate plants to flower.



Figure 24–14 *During the winter, tight, thick bud scales encase the apical meristem on a twig (top). Most deciduous plants that grow in cold winter areas need a period of below-zero temperatures before their buds will begin to grow. However, when warm spring days encourage new growth, the bud scales open to reveal the new year's leaves and flowers (bottom).*

24–2 SECTION REVIEW

1. What are hormones? What is their role in plant growth and development? Where are most plant hormones produced?
2. How do different auxin concentrations affect cell elongation in stems? In roots? How do these effects explain phototropism and gravitropism in roots and stems?
3. What is the role of auxin in branching?
4. What environmental cue do plants use to time their flowering? How is this cue related to short-day plants and long-day plants?

LABORATORY INVESTIGATION

UNDERSTANDING PLANT TROPISMS

PROBLEM

How do roots find water and how do leaves find light?

MATERIALS *(per group)*

aluminum foil	2 index cards
2 150-mL beakers	medicine dropper
transparent tape	milk carton
15 corn seeds	petri dish
cotton	scissors
filter paper	potting soil

PROCEDURE

1. Place some water in a beaker. Add 15 corn seeds. Soak the seeds for 2 days.
2. Select 4 swollen corn seeds and place them in the bottom of a petri dish. Arrange the seeds in a straight line across the center of the dish, with each seed at right angles to the adjacent seed. See the accompanying illustration.



3. Put a piece of wet filter paper over the seeds. Cover the filter paper with enough wet cotton so that when the petri dish is closed, the seeds are held tightly in place. Cover the petri dish and tape it closed.
4. Make a stand for the petri dish from two index cards, as shown in the accompanying illustration. Fold the index cards in half. Then bend the cards so that the folds form right angles. Tape the cards together back to back. Slip the petri dish between the cards.
5. Fill the other 150-mL beaker with potting soil. Select 6 swollen corn seeds. Plant the seeds just below the surface of the soil, as far away from each other as possible. Moisten the soil.
6. Place the petri dish and the beaker in a dark place until the seeds have sprouted. This will take 2 or 3 days. Keep the soil evenly moist.
7. Examine the seeds in the petri dish after they have sprouted. Observe the directions in which the roots and leaves grow.
8. Make 3 small caps by wrapping small pieces of aluminum foil around the tip of a pen or pencil. Gently place these caps on half of the corn seedlings in the beaker.
9. Use scissors to cut the top off the large milk carton. Turn the milk carton upside down. Cut a small window on one side of the carton. Cut the window so that its base will be at the same level as the top of the beaker.
10. Place the beaker in a brightly lighted spot. Cover it with the milk carton. Position the carton so that light can reach the seedlings.
11. Leave the corn seedlings in bright light for about 4 days. During this time, water the plants with a medicine dropper if necessary.

OBSERVATIONS

1. In which direction are the leaves of the corn seeds in the petri dish growing? The roots?
2. In which direction are the leaves of the covered corn plants in the beaker growing?
3. In which direction are the leaves of the uncovered plants in the beaker growing?

ANALYSIS AND CONCLUSIONS

1. Why were the seeds in the petri dish grown in the dark?
2. What was the main influence on the direction of growth of the leaves and the roots of the corn plants in the petri dish?
3. How did the aluminum caps influence the direction of leaf growth in the corn plants?
4. What influenced the direction of growth of the leaves of the corn plants in the beaker?

STUDENT STUDY GUIDE

SUMMARIZING THE CONCEPTS

The key concepts in each section of this chapter are listed below to help you review the chapter content. Make sure you understand each concept and its relationship to other concepts and to the theme of this chapter.

24–1 Patterns of Growth

- There are three main groups of plants: annuals, biennials, and perennials.
- Stems increase in length as cells in their tip divide. These cells elongate in the zone of elongation behind the stem tip. The same cells differentiate in the zone of maturation, which occurs farther back from the tip.
- Roots increase in length as cells in the apical meristem in the root tips divide. These newly formed root cells elongate in a zone of elongation immediately behind the root tip. And they differentiate in a zone of maturation that is found farther from the tip.

24–2 Control of Growth and Development

- Hormones—special chemicals made by plants—direct the growth of plants.
- Auxin is an important plant hormone. High concentrations of auxin stimulate stem cells to grow longer. The same high concentrations of auxin can inhibit the elongation of root cells. Auxin also controls plant branching, since auxin inhibits the growth of lateral buds.
- Cytokinins are hormones produced in plant roots and developing fruits and seeds. These hormones stimulate cell division and cause seeds to sprout.
- Gibberellins are hormones produced by all plants.
- A tropism is the response of a plant to an environmental stimulus. A positive tropism is a response toward the stimulus. A negative tropism is a response away from the stimulus.
- During cold winters, many plants are dormant. Dormancy in plants is coordinated by the actions of several hormones. Dormancy is a reaction to environmental conditions that do not favor active plant growth.

REVIEWING KEY TERMS

Vocabulary terms are important to your understanding of biology. The key terms listed below are those you should be especially familiar with. Review these terms and their meanings. Then use each term in a complete sentence. If you are not sure of a term's meaning, return to the appropriate section and review its definition.

24–1 Patterns of Growth

annual
biennial
perennial
herbaceous
zone of elongation
zone of maturation
primary tissue
secondary xylem
secondary phloem
sapwood
heartwood
annual ring
root cap

24–2 Control of Growth and Development

hormone
target organ
auxin
lateral bud
cytokinin
gibberellin
tropism
phototropism
gravitropism
thigmotropism
abscission layer
bud scale
photoperiodicity

CHAPTER REVIEW

CONTENT REVIEW

Multiple Choice

Choose the letter of the answer that best completes each statement.

1. The response of plants to periods of light and dark is called
   a. gravitropism. c. thigmotropism.
   b. photoperiodicity. d. gibberella.
2. A plant that grows, matures, makes seeds, and dies within one year is a (an)
   a. biennial. c. annual.
   b. tree. d. perennial.
3. A part of a plant that shows positive phototropism and negative gravitropism is a
   a. leaf. b. root. c. flower. d. stem.
4. One way to coax a plant to branch is to
   a. fertilize it.
   b. trim the roots.
   c. remove the growing tip.
   d. keep the plant in the dark.
5. A plant that is laid on its side will
   a. die.
   b. grow very slowly.
   c. flower.
   d. bend its stem upward.
6. A chemical that directs the growth of a plant is called a (an)
   a. apical meristem. c. sapwood.
   b. hormone. d. heartwood.
7. An example of a monocot tree is a
   a. pine. c. palm.
   b. lily. d. maple.
8. A band of weak cells that forms where a leaf petiole joins a stem is called a (an)
   a. chlorophyll layer. c. abscission layer.
   b. meristem. d. cambium layer.

True or False

Determine whether each statement is true or false. If it is true, write "true." If it is false, change the underlined word or words to make the statement true.

1. The hormone that makes cells in the apical meristem divide is called acetic acid.
2. Brightly colored accessory pigments appear in the autumn when chlorophyll in the leaves breaks down.
3. Cells increase in length in the zone of maturation.
4. Bud scales protect the apical meristem from cold temperatures.
5. The response of plants to the length of day and night is called phototropism.
6. In autumn, the layer of weak cells that forms between the leaf petiole and the stem is called the abscission layer.
7. A hormone is a substance made in one part of an organism that affects another part.
8. The trunks of most trees increase in width as cells in the apical meristem divide.

Word Relationships

In each of the following sets of terms, three of the terms are related. One term does not belong. Determine the characteristic common to three of the terms and then identify the term that does not belong.

1. xylem, auxin, gibberellin, cytokinin
2. marigold, corn, dawn redwood, peas
3. breakdown of chlorophyll, formation of abscission layer, increase in the number of water molecules in xylem and phloem, formation of bud scales
4. summer, long days, short nights, long nights

CONCEPT MASTERY

Use your understanding of the concepts developed in the chapter to answer each of the following in a brief paragraph.

1. What is a tropism? Give an example of both a positive tropism and a negative tropism for a stem. For a root.
2. What is a herbaceous plant? Give an example of one.
3. How does auxin make a plant grow toward a light source?
4. What is photoperiodicity? How does it affect flowering plants?
5. What is a biennial? How does a biennial plant differ from a perennial plant?
6. What happens in the zone of maturation in a plant stem?
7. What is primary plant tissue?

CRITICAL AND CREATIVE THINKING

Discuss each of the following in a brief paragraph.

1. **Designing an experiment** One of your classmates suggests that all root cells have the ability to increase their length. Another classmate suggests that the cells in a root increase in length only in the zone of elongation just behind the root tip. Design an experiment to show which hypothesis is correct.
2. **Applying concepts** The sweet bay in the photograph was grown as a "standard." As you can see, a standard plant is grown to resemble a small tree. Next to it is a "normal" sweet bay plant. Use your knowledge of plant growth to determine the techniques used in growing a standard sweet bay.
3. **Applying concepts** People grow houseplants on windowsills. Many books advise giving houseplants a quarter turn every week. Why is this good advice to follow if you want to grow attractive plants?
4. **Relating cause and effect** Some dormant plants need an extended period of cold before their buds begin to grow. Some dormant plants even have to undergo two periods of freezing temperatures before their buds start growing again. Why is an extended period of cold or two freezing periods necessary for growth to resume?
5. **Making inferences** The black walnut tree grows in the northeastern part of the United States. Scientists have observed that few plants grow near the trunk of a black walnut. Offer an explanation for this observation.
6. **Using the writing process** Plants use the energy of light to make food. The flowering of some plants is affected by the length of day and night. Suppose light affected people in similar ways. Write a story about a person whose growth was affected by light.



