Botany Basics

1

Plants are unique and essential to life on earth. Unlike most living things, plants make their own food from sunlight and water. Either directly or indirectly, they are the primary food source for humans and other animals. Additionally, they provide fuel, replenish the earth's oxygen supply, prevent soil erosion, slow down wind movement, cool the atmosphere, provide wildlife habitat, supply medicinal compounds and beautify our surroundings.

Many plants are familiar to us, and we can identify and appreciate them based on their external structures. However, their internal structures and functions often are overlooked. Understanding how plants grow and develop helps us capitalize on their usefulness and make them part of our everyday lives.

This chapter focuses on *vascular* plants. Vascular plants contain xylem and phloem, which are the water, nutrient and food conducting tissues. Ferns and seed-producing plants fall into this category. We will distinguish between *monocotyledonous* and *dicotyledonous* plants. Sometimes called monocots and dicots for short, these plants have important distinguishing characteristics. For example, monocots (e.g., grasses) produce only one seed leaf (cotyledon)

Topics in this chapter

- Plant life cycles
- Internal plant parts
- External plant parts
- Plant growth and development
- Environmental factors affecting growth
- Plants in communities
- Plant hormones and growth regulators

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Table 1.—Comparison between monocots and dicots.

Structure	Monocots	Dicots
Seed leaves (cotyledons)	One	Two
Vascular system	Xylem and phloem are paired in bundles, which are dispersed throughout the stem.	Xylem and phloem form rings inside the stem. The phloem forms an outer ring, the xylem an inner ring.
Floral parts	Usually in threes or multiples of three.	Usually in multiples of four or five.
Leaves	Often parallel-veined.	Generally net-veined.

Botany terminology

Anther—The pollen sac on a male flower.
Apex—The tip of a shoot or root.
Apical dominance—The tendency of an apical bud to produce hormones that suppress growth of buds below it on the stem.
Axil—The location where a leaf joins a stem.
Cambium—A layer of growing tissue that separates the xylem and phloem and continuously produces new xylem and phloem cells.
Chlorophyll—The green pigment in leaves that is responsible for trapping light energy from the sun.
Chloroplast—A specialized component of certain cells; contains chlorophyll and is responsible for photosynthesis.
Cortex—Cells that make up the primary tissue of the root and stem.
Cotyledon—The first leaf that appears on a seedling. Also called a seed leaf.
Cuticle—A relatively impermeable surface layer on the epidermis of leaves and fruits.
Dicot—Having two seed leaves.
Epidermis—The outermost layer of plant cells.
Guard cell—Epidermal cells that open and close to let water, oxygen and carbon dioxide pass through the stomata.
Internode—The space between nodes on a stem.
Meristem—Specialized groups of cells that are a plant's growing points.
Mesophyll—A leaf's inner tissue, located between the upper and lower epidermis; contains the chloroplasts and other specialized cellular parts (organelles).
Monocot—Having one seed leaf.
Node—An area on a stem where a leaf, stem or flower bud is located.
Ovary—The part of a female flower where eggs are located.
Petiole—The stalk that attaches a leaf to a stem.
Phloem—Photosynthate-conducting tissue.
Photosynthate—A food product (sugar or starch) created through photosynthesis.
Photosynthesis—The process in green plants of converting carbon dioxide and water into food (sugars and starches) using energy from sunlight.
Pistil—The female flower part; consists of a stigma, style, and ovary.
Respiration—The process of converting sugars and starches into energy.
Stamen—The male flower part; consists of an anther and a supporting filament.
Stigma—The top of a female flower part; collects pollen.
Stoma (pl. stomates, stomata)—Tiny openings in the epidermis that allow water, oxygen and carbon dioxide to pass into and out of a plant.
Style—The part of the female flower that connects the stigma to the ovary. Pollen travels down the style to reach the ovary, where fertilization occurs.
Transpiration—The process of losing water (in the form of vapor) through stomata.
Turgor—Cellular water pressure; responsible for keeping cells firm.
Vascular tissue—Water-, nutrient- and photosynthate-conducting tissue (xylem and phloem).
Xylem—Water- and nutrient-conducting tissue.

while dicots (broadleaf plants) have two. The vascular systems, flowers and leaves of the two types of plants also differ (Table 1). These differences will be important in our discussion of plant growth and development.

Plant life cycles

A plant is classified as either an annual, biennial or perennial based on its life cycle or how many years it takes to produce flowers and seeds.

An *annual,* such as a marigold, completes its life cycle in 1 year. Annuals go from seed to seed in 1 year or growing season. During this period, they germinate, grow, mature, bloom, produce seeds and die. Summer annuals complete their life cycle during spring and summer; most winter annuals complete their growing season during fall and winter. There are both winter and summer annual weeds, and understanding a weed's life cycle is important in controlling it. Of course, in most locations in Alaska the temperature does not allow for winter annuals. Some plants that are winter annuals in warmer climates act as summer annuals in Alaska.

A *biennial* completes its life cycle in 2 years. During the first season, it produces vegetative structures (leaves) and food storage organs. The plant overwinters and then produces flowers, fruit and seeds during its second season. Swiss chard, carrots, beets, sweet William and parsley are examples of biennials.

Biennials can sometimes go from seed germination to seed production in one growing season. This phenomenon is referred to as bolting. It is a common occurrence in Alaska due to the midnight sun, or long day lengths. This is one reason why spinach, radish and beets can be hard crops to grow in Alaska. These plants bolt instead of producing a good crop of leaves or roots. This situation can also occur when plants are exposed to extreme environmental conditions such as temperature variation and drought.

Perennial plants live more than 2 years and are grouped into two categories: herbaceous perennials and woody perennials. *Herbaceous perennials* have soft, nonwoody stems that generally die back to the ground each winter. New stems grow from the plant's crown each spring. A delphinium is an example of an herbaceous plant. Trees and shrubs, on the other hand, have woody stems that withstand cold winter temperatures. They are referred to as *woody perennials*.

Internal plant parts

Cells are the basic structural and physiological units of plants. Most plant reactions (cell division, photosynthesis, respiration, etc.) occur at the cellular level. Plant *tissues* are organized groups of similar cells that work together to perform a specific function. An example would be the xylem, which functions to move the water through a plant or the phloem that moves food.

See Chapter 4,
Plant Propagation.

Plant cells are *totipotent*. In other words, plant cells retain all of the genetic information (encoded in DNA) necessary to develop into a complete plant. This characteristic is the reason vegetative (asexual) reproduction works. It is why it is so easy to share houseplants with friends. For example, the cells of a small leaf cutting from an African violet have the genetic information necessary to generate a root system, stems, leaves and ultimately flowers. This characteristic also allow growers to utilize tissue culture to propagate disease-free potatoes, orchids, etc.

Specialized groups of cells or tissue called *meristems/meristematic tissues* are a plant's growing points. Meristems are the site of rapid, almost continuous cell division. These cells either continue to divide or differentiate into tissues and organs. How they divide is controlled by a complex array of plant hormones and environmental conditions. Meristems can be manipulated to change plant growth patterns, flowering, branching or vegetative growth.

External plant parts

External plant structures such as leaves, stems, roots, flowers, fruits and seeds are known as plant organs. Each organ is an organized group of tissues that work together to perform a specific function. These structures can be divided into two groups: sexual reproductive and vegetative. *Sexual reproductive parts* produce seed; they include flower buds, flowers, fruit and seeds. *Vegetative parts* (Figure 1) include roots, stems, shoots, nodes, buds and leaves; they are not directly involved in sexual reproduction. Vegetative parts often are used in asexual forms of reproduction such as cuttings, budding or grafting.

Roots

Often roots are overlooked, probably because they are less visible than the rest of the plant. However, it's important to understand plant root systems because they have a pronounced effect on a plant's size and vigor, method of propagation, adaptation to soil types and response to cultural practices and irrigation.

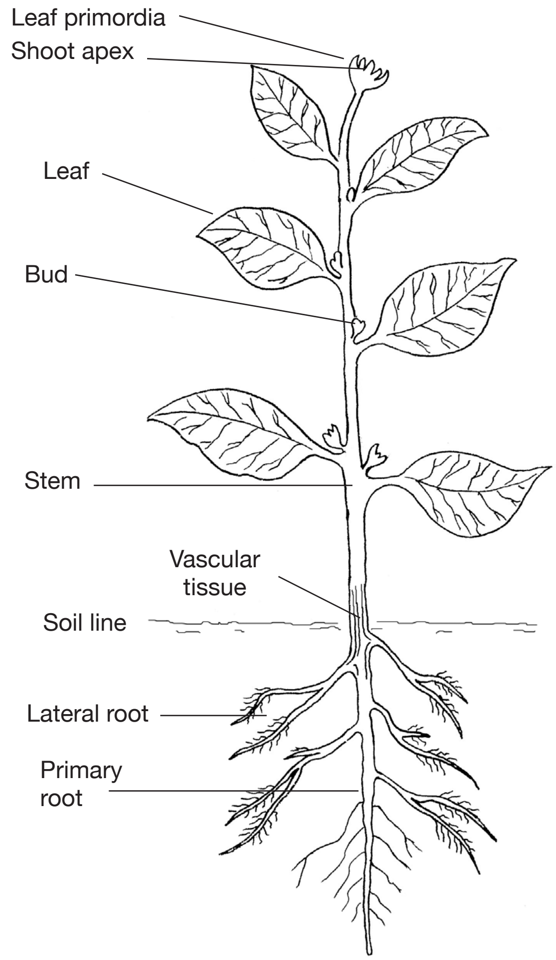


Figure 1.—Principal parts of a vascular plant.

Roots typically originate from the lower portion of a plant or cutting. They have a root cap, but lack nodes and never bear leaves or flowers directly. Their principal functions are to absorb nutrients and moisture, anchor the plant in the soil, support the stem and store food. In some plants, roots can be used for propagation.

Structure

Internally, there are three major parts of a root (Figure 2):

- The *meristematic zone* is at the tip and manufactures new cells; it is an area of cell division and growth.

- Behind the meristem is the *zone of elongation*. In this area, cells increase in size through food and water absorption. As they grow, they push the root through the soil.
- The *zone of maturation* is directly beneath the stem. Here, cells become specific tissues such as epidermis, cortex or vascular tissue.

A root's *epidermis* is its outermost layer of cells (Figure 3). These cells are responsible for absorbing water and minerals dissolved in water. *Cortex* cells are involved in moving water from the epidermis to the vascular tissue (xylem and phloem) and in storing food. Vascular tissue, located in the center of the root, conducts food and water.

Externally, there are two areas of importance: the root cap and the root hairs (Figure 2). The *root cap* is the root's outermost tip. It consists of cells that are sloughed off as the root grows through the soil. Its function is to protect the root meristem.

Root hairs are delicate, elongated epidermal cells that occur in a small zone just behind the root's growing tip. They generally resemble fine down to the naked eye. Their function is to increase the root's surface area and absorptive capacity. Root hairs usually live 1 or 2 days. When a plant is transplanted, they are easily torn off or may dry out in the sun.

Many roots have naturally occurring *symbiotic* (mutually beneficial) relationships with certain fungi. Fungi grow inside plant roots and in the surrounding soil helping to facilitate mineral uptake. The fungi hyphae (threadlike cells of the fungus) growing through the soil increase the area available for the absorption of water and nutrients. Plants provide carbohydrates (the products from photosynthesis) or food for the fungi. This beneficial association is called *mycorrhizae* (fungus + root).

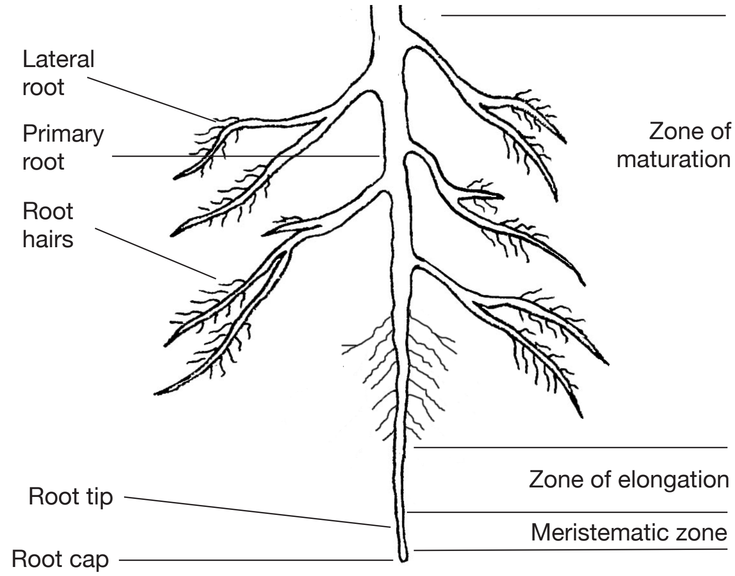


Figure 2.—Root structure.

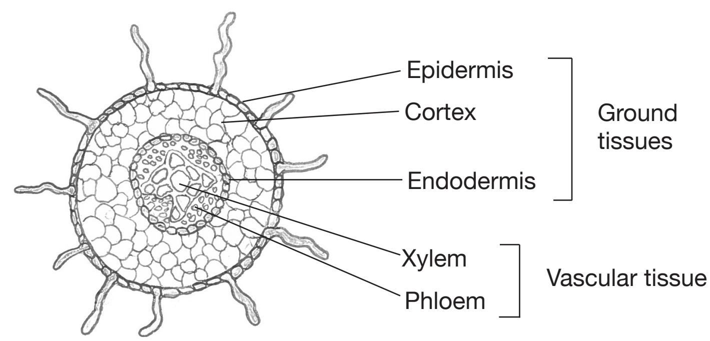


Figure 3.—Cross section of a root.

There are two types of mycorrhizal fungi, ectotrophic mycorrhizae and vesicular-arbuscular mycorrhizae. Ectotrophic typically form a thick sheath of fungal hyphae around the roots with some of the fungal mycelium growing between cortical cells. The ectotrophic fungi do not penetrate the cells. The vesicular-arbuscular mycorrhizae do not produce a fungal sheath around the roots but grow in clusters outside the root and penetrate individual cells of the cortex. Some plants require mycorrhizae to survive.

Legumes and a few plants such as alder produce *root nodules*, which contain nitro-

Figure 4.—Taproot of a carrot (a) and fibrous root of grass (b).

gen-fixing bacteria. These bacteria can fix atmospheric nitrogen into a form that can be used by plants. Garden seeds such as peas, beans and clover are inoculated with nitrogen fixing bacteria when planted. Because inoculums are living organisms they must be fresh and handled properly.

Types of roots

There are two major types of roots: primary and lateral roots.

A *primary* root originates at the lower end of a seedling's embryo (Figure 2). A primary root is called a taproot if it continues to elongate downward, has limited secondary branching and becomes the central feature of the root system (Figure 4a). Dandelions and carrots have taproots.

A *lateral*, or secondary, root is a side root that arises from another root. A *fibrous* root system is formed if the primary root ceases to elongate and produces numerous lateral roots (Figure 4b). These lateral roots branch repeatedly to form the network of feeding roots found on most plants. Some plants, such as grasses, naturally produce a fibrous root system. In other cases, severing a plant's taproot by undercutting it can encourage the plant to produce a fibrous root system. Nurseries use this technique with trees that naturally produce a taproot because trees with a compact fibrous root system transplant more successfully.

How roots grow

During early development, a seedling absorbs nutrients and moisture from the soil around the sprouting seed. A band of fertilizer several inches to each side and slightly below newly planted seeds helps early growth of most row crops.

As a plant becomes established, the quantity and distribution of its roots strongly influence its ability to absorb moisture and nutrients. For most plants, the majority of the absorbing (feeder) roots are located in the top 6–12 inches of soil. In Alaska plants growing on permafrost are close to the surface. The cold soils reduce deep root development.

See Chapter 3, *Soils and Fertilizers.*

The following factors are important in root growth:

- Roots in water-saturated soil do not grow well and may die due to lack of oxygen.
- Roots penetrate deeper in loose, well-drained soil than in heavy, poorly drained soil.
- Dense, compacted soil layers can restrict or terminate root growth.
- Container plants not only have a restricted area for root growth, but also are susceptible to cold damage because the limited amount of soil surrounding roots reduces insulation.
- In addition to growing downward, roots grow laterally and often extend well beyond a plant's drip line. Keep this extensive root system in mind when disturbing the soil around existing trees and shrubs.

Roots as food

Several vegetable crops are enlarged roots. Sweet potatoes are swollen tuberous roots; and carrots, beets, rutabaga, parsnips, turnips and radishes are elongated taproots.

Stems

Stems, support buds and leaves and serve as conduits for carrying water, minerals and food (*photosynthates*). Stems place the leaves in favorable positions for exposure to light. The vascular system inside the stem forms a continuous pathway from the root, through the stem, and finally to the leaves. It is through this system that water and food products move.

Structure

Vascular system

The vascular system consists of xylem, phloem and vascular cambium. It can be thought of as a plant's plumbing. *Xylem* tubes conduct water and dissolved minerals; *phloem* tubes carry food such as sugars. The *cambium* is a layer of meristematic tissue that separates the xylem and phloem and continuously produces new xylem and phloem cells. This new tissue is responsible for a stem's increase in girth.

The vascular cambium is important to gardeners in several ways. Xylem and phloem tissues on a grafted scion (top wood) and rootstock need to line up, if the graft is to take. Careless weed trimming can strip the bark off a tree, injuring the cambium and girdling the tree and causing it to die. This often occurs when string weed trimmers are used to remove grass from around the trunk of trees. Stem boring insects are attracted to cuts made by weed trimmers.

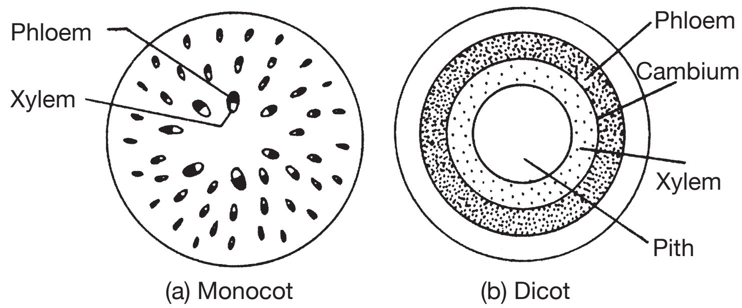


Figure 5.—Cross sections of stems: (a) Discontinuous vascular system of a monocot stem; (b) continuous vascular system of a woody dicot stem.

The vascular systems of monocots and dicots differ (Figure 5). Although both contain xylem and phloem, these structures are arranged differently in each. In a monocot, the xylem and phloem are paired in bundles dispersed throughout the stem. The vascular system in dicots is said to be continuous because it forms rings inside the stem. The phloem forms the outer ring and eventually becomes part of the bark in mature woody stems. The xylem forms the inner ring. Sapwood is newer xylem that is still conducting and heartwood is older xylem that is crushed in the center of the stem and is no longer conducting. Heartwood is filled with waste materials such as gums, resins, tannins and oils.

The difference in the vascular systems of monocots and dicots is of practical interest to gardeners because some herbicides affect only one group. For example, 2, 4-D kills only plants with a continuous vascular system (dicots). *Nonselective* herbicides, on the other hand (e.g., glyphosate), kill plants regardless of their type of vascular system.

Nodes

A node is an area on a stem where buds are located (Figure 6). It is a site of great

Stem terminology

Shoot—A young stem (1 year old or less) with leaves.
Twig—A young stem (1 year old or less) that is in the dormant winter stage (has no leaves).
Branch—A stem that is more than 1 year old, typically with lateral stems radiating from it.
Trunk—A woody plant's main stem.

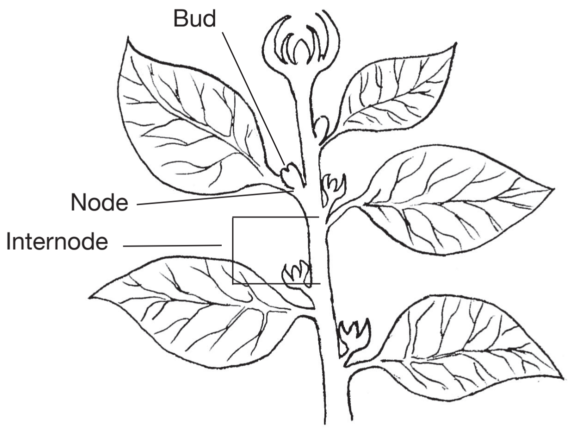


Figure 6.—Stem structure.

cellular activity and growth where small buds develop into leaves, stems or flowers. When pruning, it is important to locate a plant's nodes. Generally, you want to cut just above, but not too close to, a node. Pruning in this manner encourages the buds at that node to begin development and ultimately form new stems or leaves.

See Chapter 5, *Pruning*.

The area between nodes is called the *internode*. Its length depends on many factors, including genetics. Other factors also can influence internode length:

- Reduced soil fertility decreases internode length, while an application of high-nitrogen fertilizer can increase it.
- Lack of light increases internode length causing spindly stems. This situation is known as stretch, or etiolation, and often occurs in seedlings started indoors and in houseplants under low light conditions
- Internode length varies seasonally. Early-season growth has long internodes; late-season growth has shorter internodes.
- Plant energy divided among three or four side stems, or diverted into fruit growth and development, shortens internode length.
- Plant growth regulator substances and herbicides also can influence internode length.

Types of stems

Stems may be long with great distances between nodes (e.g., branches of trees, runners on strawberries) or compressed, with short distances between nodes (e.g., crowns of strawberry plants, fruit spurs, and African violets). Although stems commonly grow above ground, they sometimes grow below ground in the form of rhizomes, tubers, corms or bulbs. All stems must have buds or leaves.

Specialized aboveground stems

Some plants have specialized aboveground stems known as crowns, spurs or stolons (Figure 7). *Crowns* (on strawberries, dandelions and African violets) are compressed stems with leaves and flowers on short internodes. *Spurs* are short, stubby side stems that arise from a main stem. They are the fruit-bearing stems on pear, apple and cherry trees. If severe pruning is done too close to fruit-bearing spurs, they can revert to nonfruiting stems, thus eliminating the year's potential fruit crop.

Stolons are fleshy or semiwoody, elongated, horizontal stems that often lie along the soil surface. Strawberry runners are stolons that have small leaves at the nodes. Roots develop from these nodes, and a daughter plant is formed. This type of vegetative reproduction is an easy way to increase the size of a strawberry patch. Spider plants also produce stolons, which ultimately can become entirely new plants.

Specialized belowground stems

Potato tubers, iris rhizomes and tulip bulbs are underground stems that store food for the plant (Figure 8). It sometimes is difficult to distinguish between roots

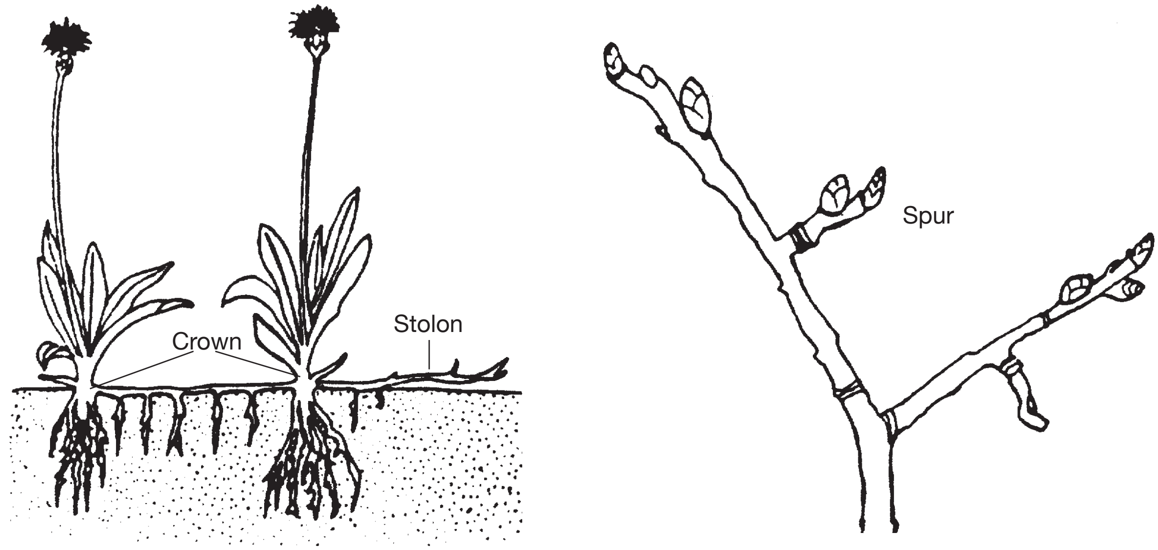


Figure 7.—Diversified aboveground stem development.

and stems, but one sure way is to look for nodes. Stems have nodes; roots do not.

In potato *tubers*, the "eyes" are the stem's nodes, and each eye contains a cluster of buds. When growing potatoes from seed pieces, it is important that each piece contain at least one eye and be at least 2 ounces or 2½ inches in diameter, so there will be enough energy for growth of new plant.

Rhizomes resemble stolons because they grow horizontally from plant to plant. Some rhizomes are compressed and fleshy (e.g., iris), while others are slender and have elongated internodes (e.g., bluegrass). Some grasses are insidious weeds principally because of the spreading capability of their rhizomes.

Tulips, lilies and onions produce *bulbs*, which are shortened, compressed underground stems surrounded by fleshy scales (leaves) that envelop a central bud at the tip of the stem. In late August you can cut a tulip or lily bulb in half and see all of the flower parts in miniature.

After a bulb-producing plant flowers, its phloem transports food reserves from the leaves to the bulb's scales. When the bulb begins growing in the spring, it utilizes the stored food. For this reason, it is important not to remove the leaves from lilies and other bulb producing plants until after they have turned yellow or had sufficient time to grow. In late summer and early fall, these plants store food for next year's flowering.

There are two types of bulbs: tunicate and nontunicate (Figure 8). *Tunicate* bulbs (e.g., tulips and onions) have a thin, papery covering, which actually is a modified leaf. It helps protect the bulb from damage during digging and from drying out once it is out of the soil. Nontunicate bulbs (e.g., lilies) do not have this papery covering. They are very susceptible to damage and drying out, and must be handled carefully.

Corms are another kind of belowground stem. Although both bulbs and corms are composed of stem tissue, they are not the same. Corms are shaped like bulbs, but do not contain fleshy scales. A corm is a solid, swollen stem with dry, scale-like leaves. Gladiolus and crocuses produce corms.

Some plants (e.g., tuberous begonias and cyclamen) produce a modified underground stem called a tuberous stem. These stems

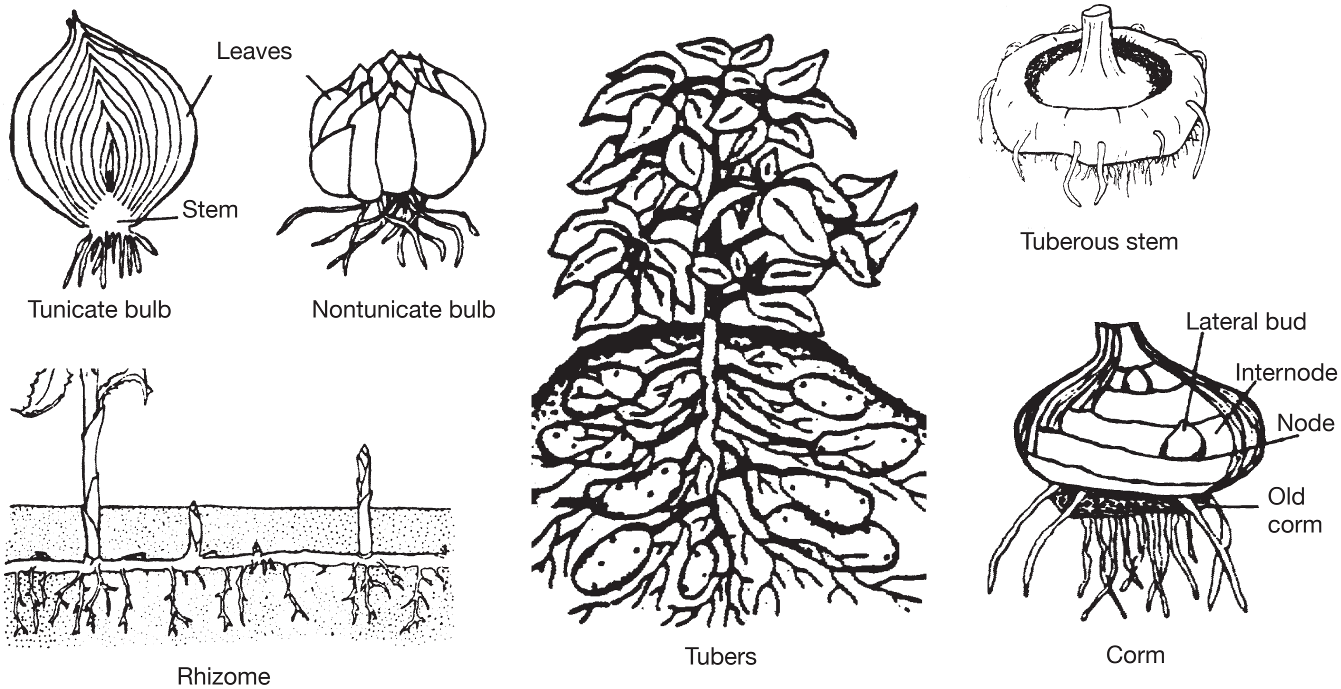


Figure 8.—Diversified below-ground stem development.

are short, flat and enlarged. Buds and shoots arise from the top (crown), and fibrous roots grow from the bottom.

Other plants (e.g., dahlias and sweet potatoes) produce underground storage organs called tuberous roots, which often are confused with bulbs and tubers. These have neither nodes nor internodes.

Stems and propagation

Stems often are used for vegetative plant propagation. Using sections of aboveground stems that contain nodes and internodes is an effective way to propagate many ornamental plants. Aboveground stem cuttings produce roots and, eventually, new plants.

See Chapter 4, ***Plant Propagation.***

Belowground stems also are good propagative tissues. You can divide rhizomes into pieces; remove small bulblets or cormels from their parent; and cut tubers into pieces containing eyes and nodes. All of these tissues will produce new plants.

Types of plants and their stems

Trees generally have one main trunk, usually more than 12 feet tall when mature. In contrast, shrubs have several main stems, less than 12 feet tall when mature.

Most fruit trees, ornamental trees and shrubs have woody stems. These stems contain relatively large amounts of hardened xylem tissue (heartwood) in the central core. The sapwood is the light colored living xylem near the outside just under the bark of a tree.

Herbaceous or succulent stems contain only a little xylem tissue and usually live for only one growing season. In perennial plants, new herbaceous stems develop from the crown (root-stem interface) each year.

Canes are stems with relatively large *pith* or central strength-giving tissues. They usually live only 1 or 2 years. Examples of plants with canes include roses, blackberries and raspberries. For fruit production, it

See Chapter 13, ***Berry Crops.***

is important to know which canes to prune, how to prune them, and when to prune them. For example, two-year old raspberry canes are pruned at the ground. One-year old canes are left to produce the following season.

A *vine* is a plant with long, trailing stems. Some vines grow along the ground, while others must be supported by another plant or structure. Twining vines circle a structure for support. Some circle clockwise (e.g., hops and honeysuckle), while others circle counterclockwise (e.g., pole beans). Climbing vines are supported either by aerial roots (e.g., English ivy and poison ivy), by slender tendrils that encircle a supporting object (e.g., cucumbers, gourds, grapes and passionflowers) or by tendrils with adhesive tips (e.g., Virginia and Japanese creeper).

Stems as food

The edible tuber of a potato and the Jerusalem artichoke are both fleshy underground stems. Asparagus and kohlrabi are enlarged, succulent stems. A ginger “root” is actually a rhizome or underground stem. Sugarcane and bamboo shoots are stems.

Buds

A bud is an undeveloped shoot from which leaves or flowers grow. The buds of temperate-zone trees and shrubs typically develop a protective outer layer of small, leathery scales. Annual plants and herbaceous perennials have naked buds with green succulent outer leaves.

Buds of many plants require exposure to a certain number of days below a critical temperature before resuming growth in the spring. This period, often referred to as the rest period, varies for different plants. Forsythia, for example, requires a relatively short rest period and grows at the first sign of warm weather. Many peach varieties, on the other hand, require 700 to 1,000 hours of temperatures below 45°F. During rest, dormant buds can withstand very low temperatures, but after the rest period is satisfied, they are more susceptible to damage by cold temperatures or frost. The rest period protects the plant from coming out of dormancy too soon and being damaged by early spring frost.

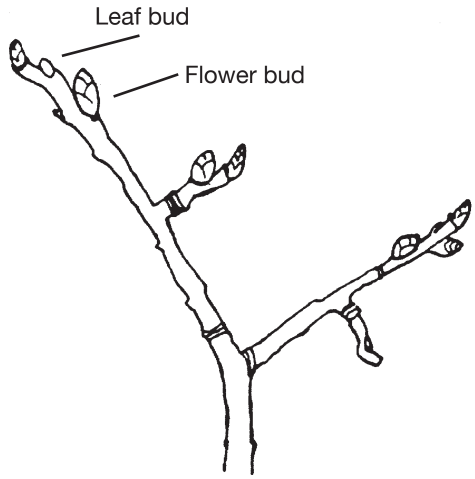


Figure 9.—Elm leaf and flower buds.

A leaf bud is composed of a short stem with embryonic leaves. Leaf buds often are less plump and more pointed than flower buds (Figure 9).

A flower bud is composed of a short stem with embryonic flower parts. In fruit crops, flower buds sometimes are called fruit buds. This terminology is inaccurate, however; although flowers have the potential to develop into fruits, they may not do so because of adverse weather conditions, lack of pollination, or other unfavorable circumstances.

Location

Buds are named for their location on the stem (Figure 10). *Terminal* buds are located at the

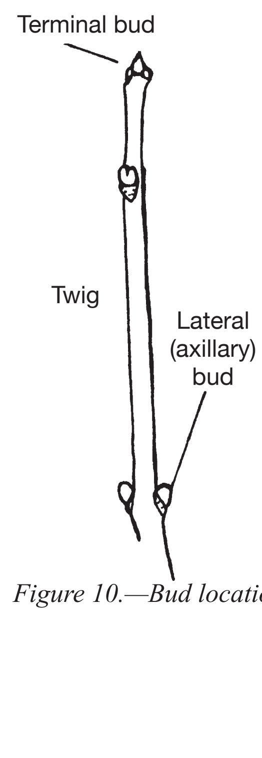


Figure 10.—Bud location.

apex (tip) of a stem. *Lateral* (axillary) buds are located on the sides of a stem and arise in the axil where a leaf meets a stem. In some instances, an axil contains more than one bud.

Adventitious buds arise at sites other than the terminal or axillary position. They may develop from roots, a stem internode, the edge of a leaf blade or callus tissue at the cut end of a stem or root. Adventitious buds allow stem, leaf and root cuttings to develop into entirely new plants.

Buds as food

Enlarged buds or parts of buds form the edible portion of some horticultural crops. Cabbage and head lettuce are examples of unusually large terminal buds. Succulent axillary buds are the edible part of Brussels sprouts. In the case of globe artichoke, the fleshy basal portion of the flower bud's bracts is eaten, along with its solid stem. Broccoli and cauliflower are important horticultural plants with edible flower buds. In this case, portions of the stem associated with the flower buds are eaten.

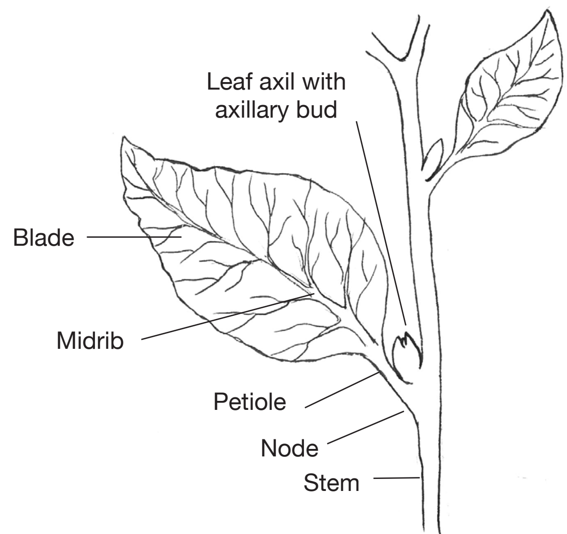


Figure 11.—Leaf parts.

Leaves

Function and structure

The principal function of leaves is to absorb sunlight needed to manufacture plant sugars through a process called *photosynthesis*. Leaf surfaces are flattened to present a large area for efficient light absorption. The blade is the expanded thin structure on either side of the midrib and usually is the largest, most conspicuous part of a leaf (Figure 11).

A leaf is held away from its stem by a stem-like appendage called a *petiole*, and the base of the petiole is attached to the stem at a node. Petioles vary in length or may be lacking entirely, in which case the leaf blade is described as *sessile* or stalkless. A celery stalk is a leaf petiole.

The node where a petiole meets a stem is called a *leaf axil*. The axil contains single buds or bud clusters, referred to as axillary

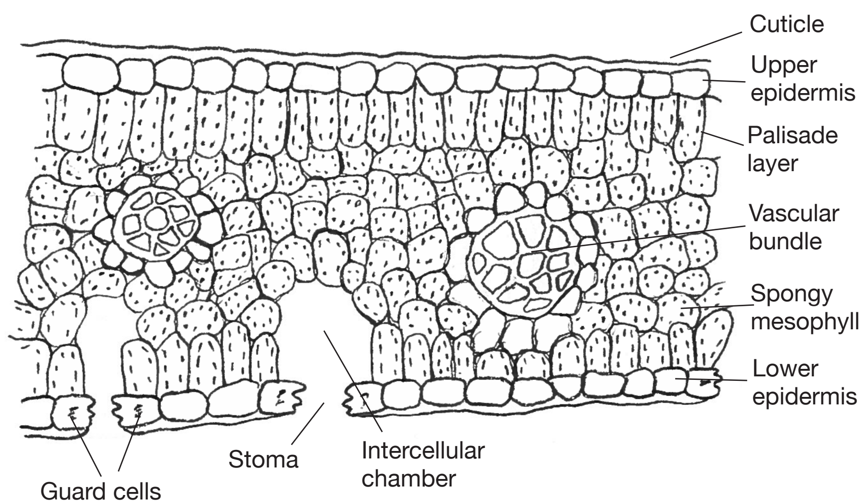


Figure 12.—Leaf cross section.

buds. They may be either active or dormant. Under the right conditions, they will develop into stems or leaves.

A leaf blade is composed of several layers (Figure 12). On the top and bottom is a layer of thick, tough cells called the *epidermis*. Its primary function is to protect the other layers of leaf tissue. The arrangement of epidermal cells determines the leaf's surface texture. Some leaves, such as those of African violets, have hairs (*pubescence*), which are extensions of epidermal cells that make the leaves feel like velvet.

The *cuticle* is part of the epidermis. It produces a waxy layer called *cutin*, which protects the leaf from dehydration and disease. The amount of cutin on a leaf increases with increasing light intensity. For this reason, when moving plants from shade into full sunlight, do so gradually over a period of a few weeks. This gradual exposure to sunlight is referred to as hardening off. It allows the cutin layer to build up and protect the leaves from rapid water loss or sunscald. Transplants produced indoors should be hardened off before planting outdoors.

The waxy cutin also repels water. For this reason, many pesticides contain a spray additive (sticker, spreader, etc.) to help the product adhere to, or penetrate, the cutin layer.

Special epidermal cells called *guard cells* open and close in response to environmental stimuli such as changes in weather and light. They regulate the passage of water, oxygen and carbon dioxide into and out of the leaf through tiny openings called *stomata*. In most species, the majority of the stomata are located on the undersides of leaves.

Conditions that would cause plants to lose a lot of water (high temperature, low humidity) stimulate guard cells to close. In mild weather, they remain open. Guard cells also close in the absence of light.

Located between the upper and lower epidermis is the *mesophyll*. It is divided into a dense upper layer (*palisade mesophyll*) and a lower layer that contains lots of air space (*spongy mesophyll*). Located within the mesophyll cells are chloroplasts, where photosynthesis takes place.

Types of leaves

There are many kinds of leaves. The most common and conspicuous leaves are referred to as foliage and are the primary location of photosynthesis. However, there are many other types of modified leaves:

- *Scale leaves* (cataphylls) are found on rhizomes and buds, which they enclose and protect.
- *Seed leaves* (cotyledons) are found on embryonic plants. They store food for the developing seedling.
- *Spines and tendrils*, such as those on barberry and pea plants, protect a plant or help support its stems.
- *Storage leaves,* such as those on bulbous plants and succulents, store food.
- *Bracts* often are brightly colored modified leaves. The showy structures on dogwoods and poinsettias are bracts, not petals.

Venation

The vascular bundles of xylem and phloem extend from the stem, through the petiole and into the leaf blade as veins. The term *venation* refers to how veins are distributed in the blade. There are two principal types of venation: parallel-veined and net-veined (Figure 13).

In *parallel-veined* leaves, numerous veins run parallel to each other and are connected laterally by minute, straight veinlets. Parallel-veined leaves occur most often on

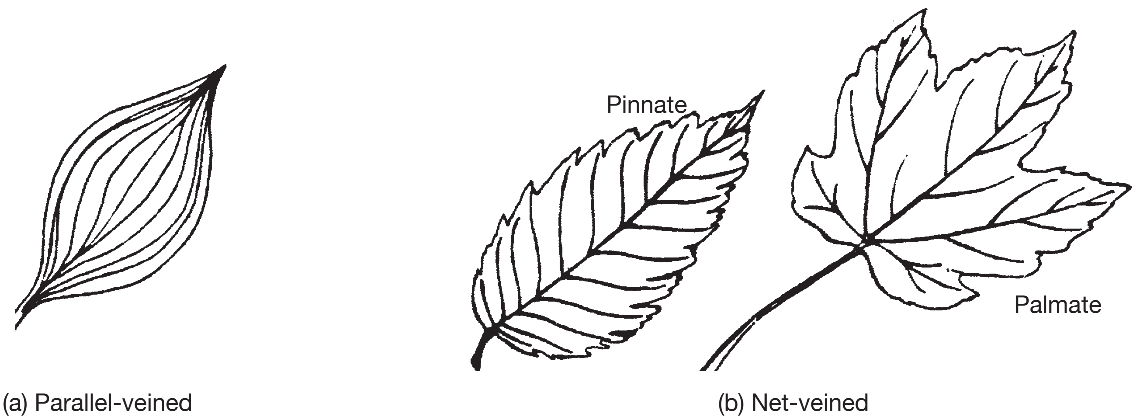


Figure 13.—Types of venation: (a) Parallel-veined; (b) net-veined.

monocotyledonous plants. The most common type of parallel veining is found in plants of the grass family, whose veins run from the leaf's base to its apex. Another type of parallel venation is found in plants such as banana, calla and pickerelweed. Their veins run laterally from the midrib.

In *net-veined* leaves (also called *reticulate-veined*), veins branch from the main rib or ribs and subdivide into finer veinlets. These veinlets then unite in a complicated network. This system of enmeshed veins makes the leaf more resistant to tearing than does a parallel vein structure. Net-veined leaves occur on dicotyledonous plants.

Net venation may be either pinnate or palmate. In *pinnate* venation, the veins extend laterally from the midrib to the edge (e.g., apples, cherries and peaches). In *palmate* venation, the principal veins extend outward, like the ribs of a fan, from the base of the leaf blade (e.g., grapes and maples).

Leaves as plant identifiers

Leaves are useful for plant identification. A leaf's shape, base, apex and margin can be important identifying characteristics (Figures 14–16).

Leaf type (Figure 17) also is important for identification. There are two types of leaves: simple and compound. In *simple* leaves, the leaf blade is a single, continuous unit. *Compound* leaves are composed of several separate leaflets arising from the same petiole. Some leaves are doubly compound. Leaf type can be confusing because a deeply lobed simple leaf may look like a compound leaf.

Leaf arrangement along a stem also is used in plant identification (Figure 18). There are four types of leaf arrangement:

- *Opposite* leaves are positioned across the stem from each other, with two leaves at each node.
- *Alternate* (spiral) leaves are arranged in alternate steps along the stem, with only one leaf at each node.
- *Whorled* leaves are arranged in circles along the stem.
- *Rosulate* leaves are arranged in a rosette around a stem with extremely short nodes.

Leaves as food

The leaf blade is the edible part of several horticultural crops, including chives, collards, endive, kale, leaf lettuce, mustard, parsley, spinach, Swiss chard and other greens. The edible part of leeks, onions, and Florence fennel is a cluster of fleshy leaf bases. The petiole is the edible product in celery and rhubarb.

Leaves and plant identification (blade and margin forms)

Common blade shapes (Figure 14)

Lanceolate—Longer than wide and tapering toward the apex and base.

Linear—Narrow, several times longer than wide and of approximately the same width throughout.

Cordate (heart-shaped)—Broadly ovate, tapering to an acute apex, with the base turning in and forming a notch where the petiole is attached.

Elliptical—About two or three times as long as wide, tapering to an acute or rounded apex and base.

Ovate—Egg-shaped, basal portion wide, tapering toward the apex.

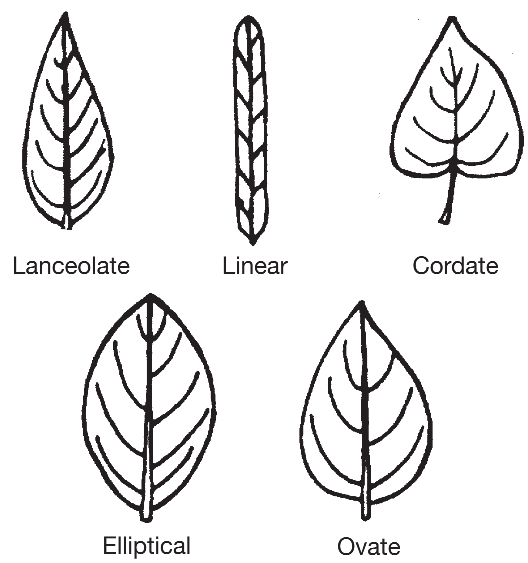


Figure 14.—Common leaf blade shapes.

Common margin forms (Figure 15)

Entire—Having a smooth edge with no teeth or notches.

Crenate—Having rounded teeth.

Dentate—Having teeth ending in an acute angle pointing outward.

Serrate—Having small, sharp teeth pointing toward the apex.

Incised—Having a margin cut into sharp, deep, irregular teeth or incisions.

Lobed—Having incisions that extend less than halfway to the midrib.

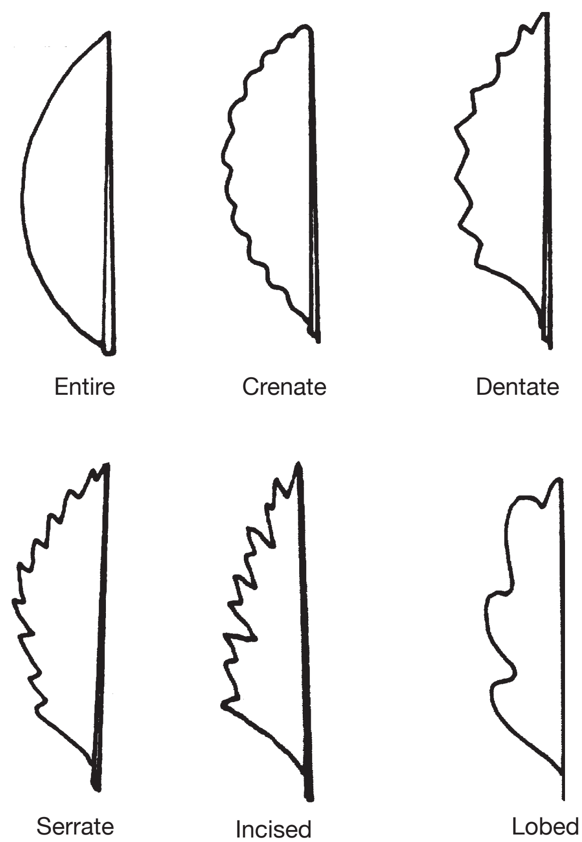


Figure 15.—Common leaf margin shapes.

Leaves and plant identification (apex and base shapes)

Common apex and base shapes (Figure 16)

Acute—Ending in an acute angle, with a sharp, but not acuminate, point.
Acuminate—Tapering to a long, narrow point.
Obtuse—Tapering to a rounded edge.
Cuneate—Wedge-shaped; triangular with the narrow end at the point of attachment.
Cordate (heart-shaped)—Turning in and forming a notch.

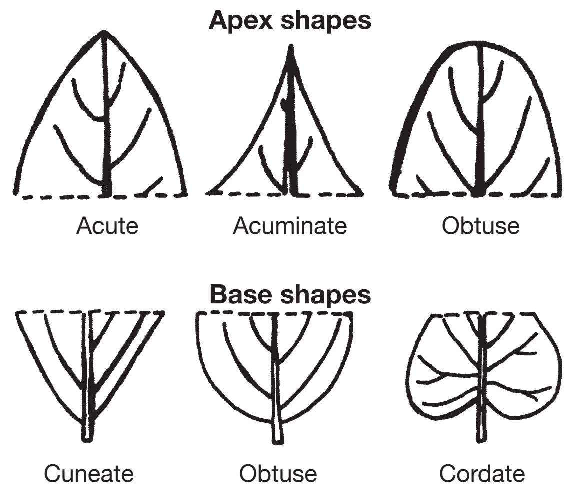


Figure 16.—Common leaf apex and base shapes.

Leaf types and arrangement (Figure 17-18)

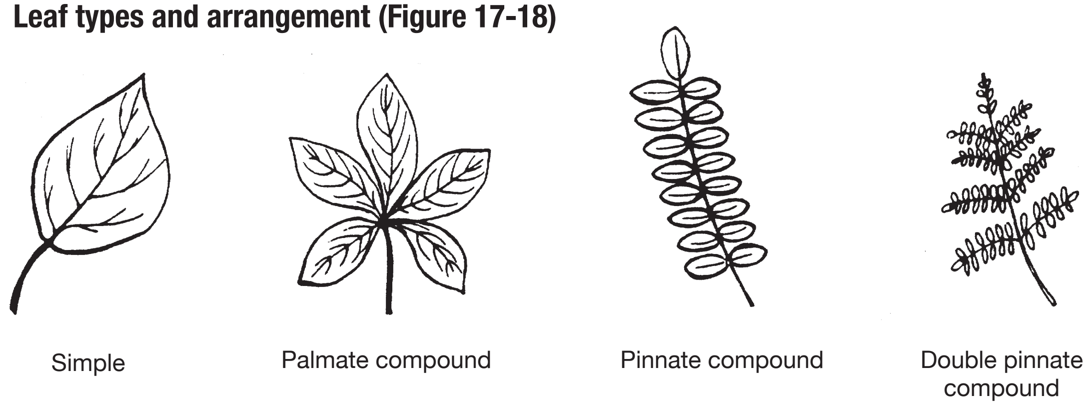


Figure 17.—Leaf types.

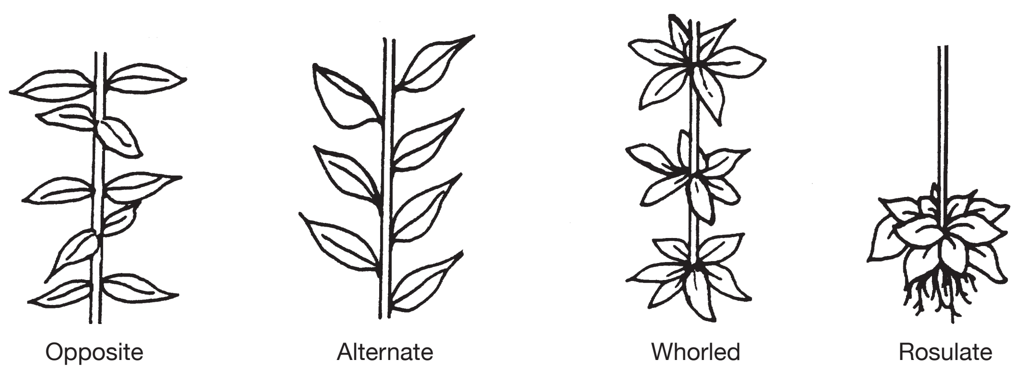


Figure 18.—Leaf arrangement.

Flowers

See Chapter 2, Plant Identification.

Flowers, which are the showiest part of a plant, have sexual reproduction as their sole function. Their beauty and fragrance have evolved not to please humans but to ensure continuance of the species. Fragrance and color attract pollinators (insects or birds) that play an important role in the reproductive process.

Flowers are important for plant classification. The system of plant nomenclature we use today was developed by Carl von Linné (Linnaeus) and is based on flowers and/or reproductive parts of plants. One reason his system is successful is because flowers are the plant part least influenced by environmental changes. Thus, knowledge of flowers and their parts is essential for anyone interested in plant identification.

Structure

Flowers contain a stamen (male flower part) and/or pistil (female flower part), plus accessory parts such as sepals, petals and nectar glands (Figure 19).

The *stamen* is the male reproductive organ. It consists of a pollen sac (*anther*) and a long supporting filament. This filament holds the anther in position, making the pollen available for dispersement by wind, insects, or birds.

The *pistil* is a plant's female part. It generally is shaped like a bowling pin and is located in the flower's center. It consists of a stigma, style and ovary. The *stigma* is located at the top and is connected by the *style* to the ovary. The *ovary* contains eggs, which reside in ovules. If an egg is fertilized, the ovule develops into a seed.

Sepals are small, green, leaf-like structures located at the base of a flower. They protect the flower bud. Collectively, the sepals are called a *calyx*.

Petals are the highly colored portions of a flower. Like nectar glands, petals may contain perfume. Collectively, the petals are called a *corolla*. The number of petals on a flower is used to help identify plant families and genera. Flowers of dicots typically have four or five sepals and/or petals, or multiples thereof. In monocots, these floral parts typically come in threes or multiples of three.

Types of flowers

If a flower has a stamen, pistil, petals and sepals, it is called a *complete* flower (Figure 19). Roses are an example. If one of these parts is missing, the flower is called *incomplete*.

The stamen and pistil are the essential parts of a flower and are involved in seed production. If a flower contains both functional stamens and pistils, it is called a *perfect* flower, even if it does not contain petals and sepals. If either stamens or pistils are lacking, the flower is called *imperfect* (Figure 20). *Pistillate* (female) flowers possess a functional pistil or pistils,

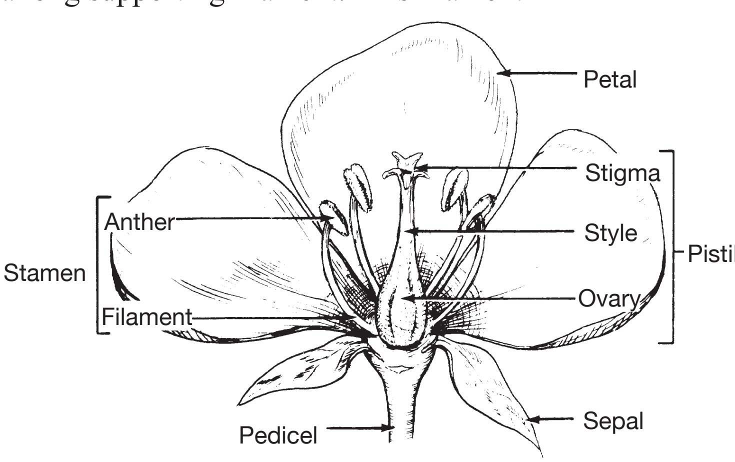


Figure 19.—Complete flower structure. (Reprinted by permission from Plant Science: Growth, Development, and Utilization of Cultivated Plants*, Prentice Hall, 1988.)*

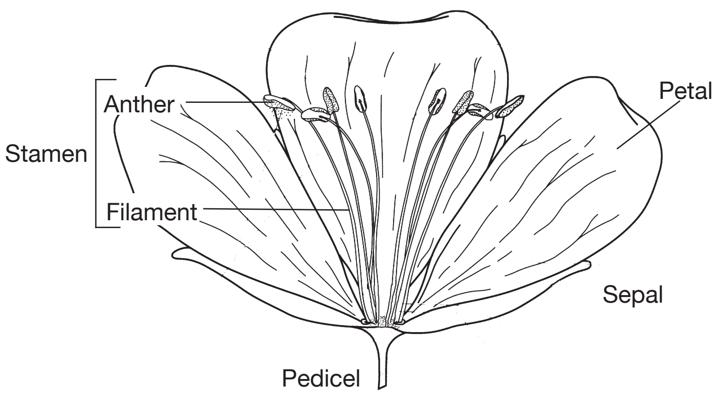


Figure 20.—Imperfect (staminate) flower structure.

but lack stamens. *Staminate* (male) flowers contain stamens, but no pistils.

Plants with imperfect flowers are further classified as monoecious or dioecious. *Monoecious* plants have separate male and female flowers on the same plant (e.g., corn and pecans). Monoecious is sometimes referred to as one house for both sexes. Some monoecious plants bear only male flowers at the beginning of the growing season, but later develop both sexes (e.g., cucumbers and squash).

Dioecious species have separate male and female plants. Examples include kiwi, ginkgos and cottonwood. In order to set fruit, male and female plants must be planted close enough together for pollination to occur. In some instances the fruit is desirable. In the case of ginkgos, the fruit is not desirable due to its putrid smell when ripe. Kiwis are complicated because they may have one plant with bisexual flowers and another plant with only male flowers. The plant world doesn't always have absolutes!

Types of inflorescences

Some plants bear only one flower per stem, which is called a *solitary* flower. Other plants produce an *inflorescence*, a cluster of flowers. Each flower in an inflorescence is called a floret.

Most inflorescences belong to one of two groups: racemes and cymes. In the *racemose* group, the florets start blooming from the bottom of the stem and progress toward the top. In a *cyme*, the top floret opens first and blooms progress downward along the stem. Detailed discussions of flower types are found in many botany textbooks. (See "For more information" at the end of this chapter.)

How seeds form

Pollination is the transfer of pollen from an anther to a stigma, either by wind or pollinators. Species pollinated by insects, animals or birds often have brightly colored or patterned flowers that contain fragrance or nectar. While searching for nectar, pollinators transfer pollen from flower to flower, either on the same plant or on different plants. Plants evolved this ingenious mechanism to ensure species survival.

In Alaska, cool-wet conditions can reduce the flight of pollinators. This can be the cause of a small blueberry crop, which depends on insect pollination. Zucchini flowers, which are normally pollinated by bees, may have to be hand pollinated in cool wet summers. Wind-pollinated flowers often lack showy floral parts and nectar because they don't need to attract pollinators.

A chemical in the stigma stimulates pollen to grow a long tube down the style to the ovules inside the ovary. The stigma recognizes pollen, which has a chemical specific to that type of plant. The wrong pollen will not germinate because it lacks the chemical signature.

When pollen reaches the ovules, it releases sperm and fertilization occurs. *Fertilization* is the union of a male sperm nucleus from a pollen grain with a female egg. If fertilization is successful, the ovule develops into a seed. Pollination does not guarantee that fertilization will occur. Moisture and temperature stresses can cause a lack of fertilization. High temperature in greenhouse settings can reduce fruit set in tomatoes and cucumbers.

Cross-fertilization combines genetic material from two similar parent plants from the same species. The resulting seed has a broader genetic base, which may enable the population to survive under a wider range of environmental conditions. Cross-pollinated plants usually are more successful than self-pollinated plants. Consequently, more plants reproduce by cross than by self-pollination.

Fruit

Structure

Fruit consists of fertilized, mature ovules (seeds) plus the ovary wall. Fruit may be fleshy, as in an apple, or dry and hard, as in an acorn. In some fruits, the seeds are enclosed within the ovary (e.g., apples, peaches, oranges, squash and cucumbers). In others, seeds are situated on the outside of fruit tissue (e.g., corn and strawberries).

The only part of the fruit that contains genes from both the male and female flowers is the seed. The rest of the fruit arises from the maternal plant and is genetically identical to it.

Types of fruit

Fruits are classified as simple, aggregate or multiple (Figure 21). *Simple* fruits develop from a single ovary. They include fleshy fruits such as cherries and peaches (drupe), pears and apples (pome) and tomatoes (berries). Although generally referred to as a vegetable, tomatoes technically are a fruit because they develop from a flower. Squash, cucumbers and eggplants also develop from a single ovary and are classified botanically as fruits.

Other types of simple fruit are dry. Their wall is either papery or leathery and hard, as opposed to the fleshy examples just mentioned. Examples are peanuts (legume), poppies (capsule), maples (samara) and walnuts (nut).

An *aggregate* fruit develops from a single flower with many ovaries. Examples are strawberries, raspberries and blackberries. The flower is a simple flower with one corolla, one calyx and one stem, but it has many pistils or ovaries. Each ovary is fertilized separately. If some ovules are not pollinated successfully, the fruit will be misshapen.

Multiple fruits are derived from a tight cluster of separate, independent flowers borne on a single structure. Each flower has its own calyx and corolla. Pineapples and figs are examples.

Fruit as food

Some foods that we call vegetables are actually fruit. A ripened, mature ovary that contains seeds is a fruit. Vegetable can also be a human dietary term for some fruit. So, botanically speaking, tomatoes, peppers, cucumbers, squash, green beans and eggplants are fruit. Other important fruits include apple, pear, peach, orange, lemon, lime, banana, pineapple, strawberry, vanilla, coconut and date.

Seeds

A seed contains all of the genetic information needed to develop into an entire plant. It is made up of three parts (Figure 22). The *embryo* is a miniature plant in an arrested state of development. It begins to grow when conditions are favorable. The *endosperm* or cotyledon is the seed's built-in food supply and is made up of proteins, carbohydrates or fats (orchids are an excep-

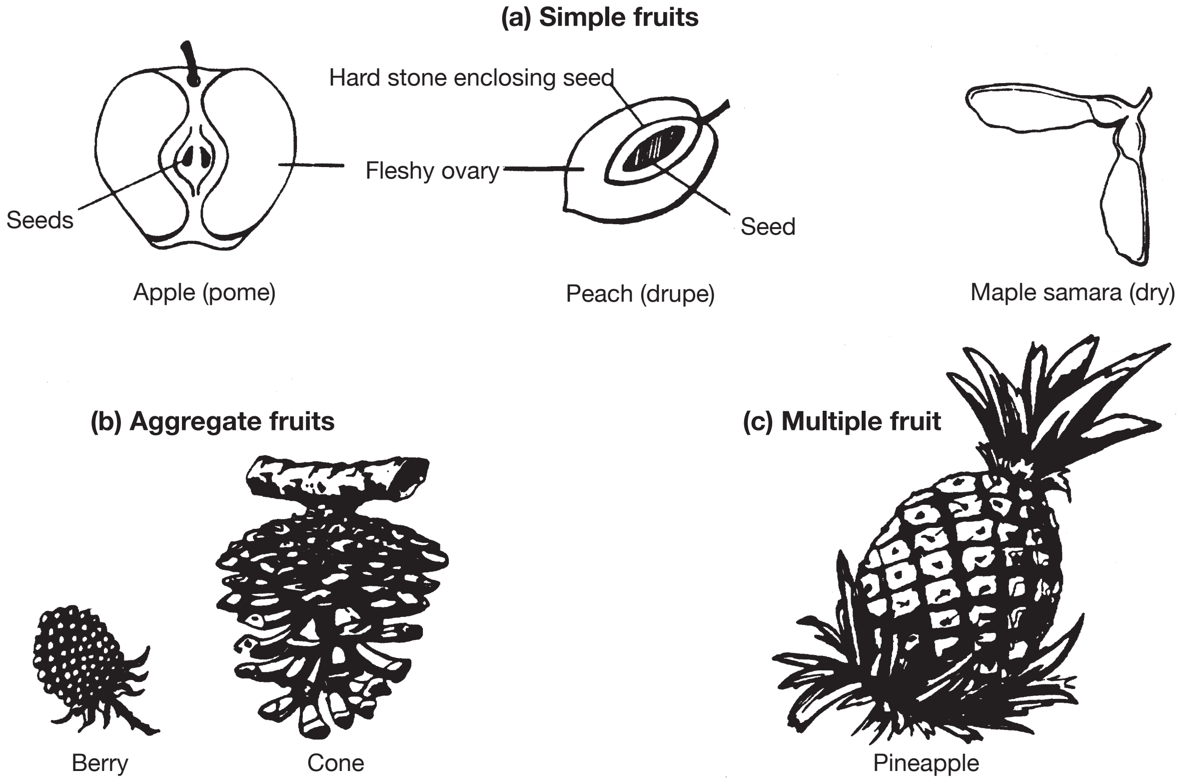


Figure 21.—Types of fruit: (a) Simple fruits (apple, peach, and maple); (b) aggregate fruits (berry and cone); (c) multiple fruit (pineapple).

tion). The third part is the *seed coat*, a hard outer covering that protects the seed from disease and insects. It also prevents water from entering the seed and initiating germination before the proper time.

Seed germination

Germination is a complex process whereby a seed embryo goes from a dormant state to an active, growing state (Figure 23). Before any visible signs of germination appear, the seed must absorb water through its seed coat. It also must have enough oxygen and a favorable temperature. Some species, such as celery, also require light. Others require darkness.

If these requirements are met, the *radicle* is the first part of the seedling to emerge from the seed. It develops into the primary root and grows downward in response to gravity. From this primary root, root hairs and lateral roots develop. Between the radicle and the first leaf-like structure is the *hypocotyl*, which grows upward in response to light.

The seed leaves, or *cotyledons*, encase the embryo. They usually are shaped differently than the leaves the mature plant will produce. Monocots produce one cotyledon, while dicots produce two.

Seeds are reproductive structures, important to survival, and have evolved many mechanisms to ensure their survival. One such mechanism is seed dormancy. Dormancy comes in two forms: seed coat dormancy and embryo dormancy.

In *seed coat dormancy*, a hard seed coat does not allow water to penetrate. Redbud, locust and many other ornamental trees and

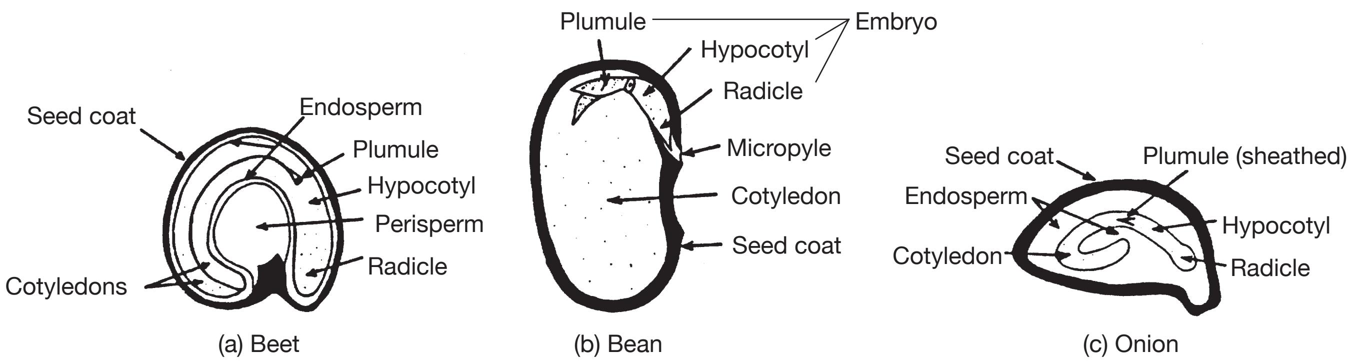


Figure 22.—Parts of a seed: (a) Beet; (b) bean; (c) onion.

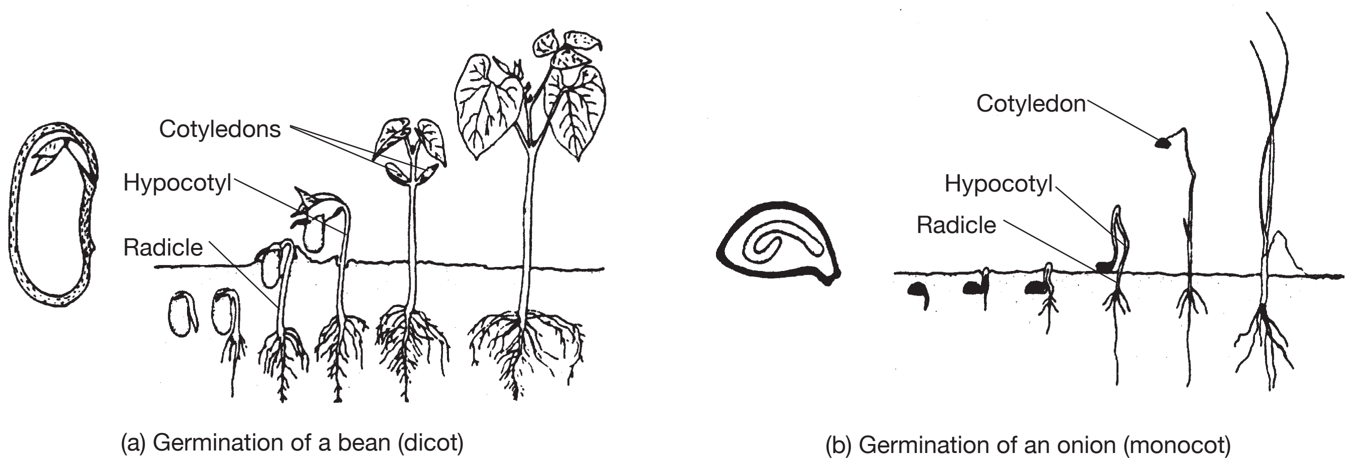


Figure 23.—Germination of a dicot (a) and a monocot (b).

shrubs exhibit this type of dormancy.

A process called *scarification* is used to break or soften the seed coat. In nature, scarification is accomplished by means such as the heat of a forest fire, digestion of the seed by a bird or mammal or partial breakdown of the seed coat by fungi or insects. It can be done mechanically by nicking the seed coat with a file, or chemically by softening the seed coat with sulfuric acid. In either instance, it is important to not damage the embryo.

Embryo dormancy is common in ornamental plants, including lupine and apple. These seeds must go through a chilling period before germinating. To break this type of dormancy, *stratification* is used. This process involves storing seeds in a moist medium (potting soil or paper towels) at temperatures between 32° and 50°F. The length of time required varies by species.

Even when environmental requirements for seed germination are met and dormancy is broken, other factors also affect germination:

- Age affects seed *viability* (ability to germinate). Older seed is less viable than young seed, and if it does germinate, the seedlings are less vigorous and grow more slowly.
- The seedbed must be properly prepared and made up of loose, fine-textured soil.
- Seeds must have a continual supply of moisture; however, if over-watered, they rot.
- Seeds must be planted at the proper depth and the right temperature.

The temperature required for germination varies by species. Generally, cool-season

See Chapter 4, *Plant Propagation.*

crops (e.g., spinach, radishes and lettuce) germinate best at 55° to 65°F, while warm-season crops (e.g., tomatoes, petunias and squash) germinate best at 65° to 75°F.

Many weed seeds are able to germinate quickly and under less than optimal conditions. This is one reason they make such formidable opponents in the garden.

Plant growth and development

Photosynthesis, respiration and transpiration are the three major physiological functions that drive plant growth and development (Figure 24). All three are essential to a plant's survival. How well a plant is able to regulate these functions affects its ability to compete and reproduce.

Photosynthesis

One of the major differences between plants and animals is plants' ability to manufacture their own food. This process is called *photosynthesis*, which literally means "to put together with light." To produce food, a plant requires energy from the sun, carbon dioxide from the air and water transported from the soil through the xylem. During photosynthesis, it splits carbon dioxide into carbon and oxygen, adds water and forms carbohydrates (starches and sugars). Carbohydrates are used by the cells or transported through the phloem to other parts of the plant. Oxygen is a by-product that exits the plant through the stomata.

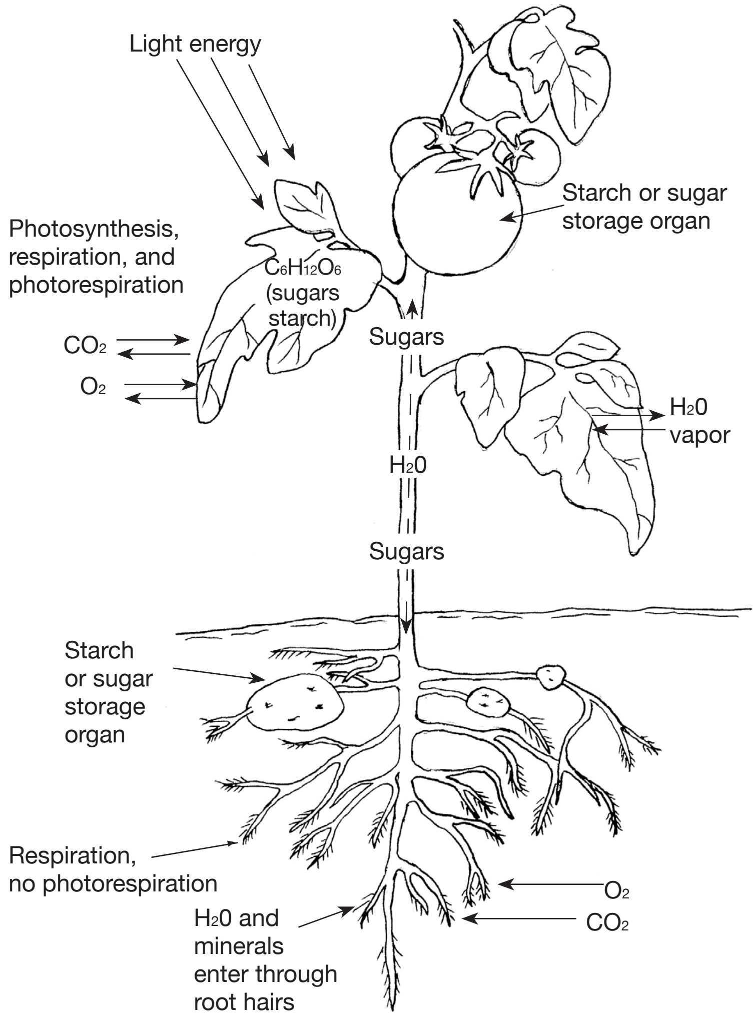


Figure 24.—Schematic representation of photosynthesis, respiration, leaf water exchange and translocation of sugar (photosynthate) in a plant.

The formula for photosynthesis can be written as follows:

Carbon dioxide + Water + Sunlight = Sugar + Oxygen

or

$$6CO_2 + 6H_20 = C_6H_{12}0_6 + 60_2$$

The produced carbohydrates will be used, stored or built into complex energy compounds such as oils and proteins. All of these food products are called *photosynthates*. The plant uses stored products when light is limited, or transports them to its roots or developing fruits.

Photosynthesis occurs only in the *mesophyll* layers of plant leaves and, in some instances, in mesophyll cells in the stem. Mesophyll cells are sandwiched between the leaf's upper and lower epidermis (Figure 12) and contain numerous *chloroplasts*, where photosynthesis takes place. Chloroplasts are incredibly small. One square millimeter, about the size of a period on a page, would contain 400,000 chloroplasts.

Chlorophyll, the pigment that makes leaves green, is found in the chloroplasts. It is responsible for trapping light energy from the sun. Chloroplasts are arranged perpendicular to incoming sun rays to absorb maximum sunlight.

Photosynthesis stops if any of the ingredients for photosynthesis — light, water and carbon dioxide — are lacking. If any factor is absent for a long period of time, a plant will die. Two of these factors are described below.

Light

Photosynthesis depends on the quantity, quality and duration of light. In general, as intensity increases, so does photosynthesis. However, for each plant species, there is a maximum level of light intensity above which photosynthesis does not increase. Many garden crops, such as tomatoes, respond best to maximum sunlight. Tomato production decreases drastically as light intensity drops, and only a few tomato varieties produce any fruit under minimal sunlight conditions. Plants do not use all the spectrum or wavelengths of light for photosynthesis. Photosynthesis occurs predominately in the orange-red region and in the blue-violet region of the spectrum. This corresponds with the wavelength of light that the chlorophylls absorb. As a general rule, plants do best when given 10 to 12 hours of suitable light. In the Arctic, photosynthesis can potentially occur for 18 to 20 hours a day.

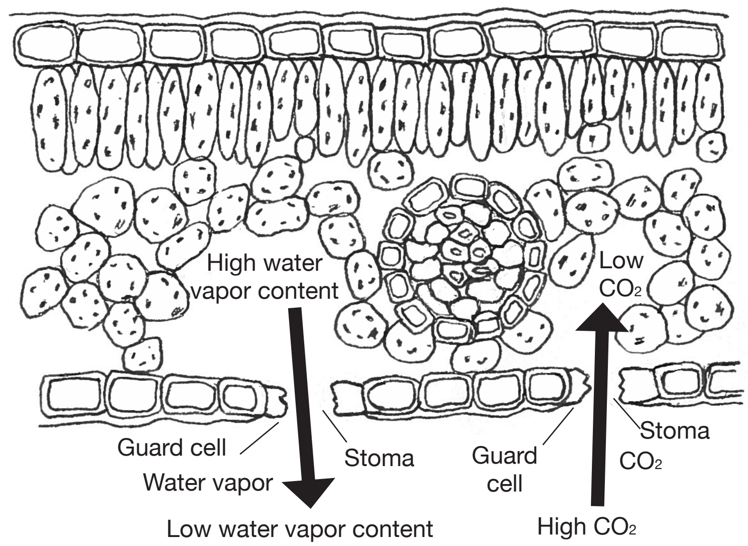


Figure 25.—Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave.

Carbon dioxide

Photosynthesis requires carbon dioxide (CO_2), which enters a plant through its stomata (Figure 25). Photosynthesis fluctuates throughout the day as stomata open and close. Typically, they open in the morning, close down at midday, reopen in late afternoon and shut down again in the evening.

Carbon dioxide is plentiful in the air, so it is not a limiting factor in plant growth. However, it is consumed rapidly during photosynthesis and is replenished very slowly in the atmosphere. Tightly sealed greenhouses with poor ventilation may lack adequate carbon dioxide for plant growth. Carbon dioxide generators are used to generate CO_2 in commercial greenhouses for high cash crops such as roses, carnations and tomatoes. In smaller home greenhouses, ventilation is the best method for insuring that adequate CO_2 is present.

Respiration

Carbohydrates made during photosynthesis are of value to a plant when converted to energy. This energy is used for cell growth and building new tissues. The chemical process by which sugars and starches are converted to energy is called *oxidation*. It is similar to the burning of wood or coal to produce heat. Controlled oxidation in a living cell is called *respiration* and is shown by this equation:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + \text{Energy}$$

This equation is essentially the opposite of photosynthesis. Photosynthesis is a building process, while respiration is a breaking-down process (Table 2). Unlike photosynthesis, respiration does not depend on light, so it occurs at night as well as during the day. Respiration occurs in all life forms and in all cells.

Transpiration

When a leaf's guard cells shrink, the stomata open and water vapor is lost. This process is called *transpiration*. Evaporating water causes a negative water pressure in the plant and more water is pulled up from the roots. Dissolved nutrients are pulled in with the water from the roots. The rate of transpiration is directly related to whether stomata are open or closed. Stomata account for only 1 percent of a leaf's surface but 90 percent of the water transpired.

Transpiration is a necessary process and uses about 90 percent of the water that enters a plant's roots. The other 10 percent is used in chemical reactions and in plant tissues. Water moving via the transpiration stream is responsible for several things:

- Transporting minerals from the soil throughout the plant
- Cooling the plant through evaporation
- Moving sugars and plant chemicals
- Maintaining cell firmness

The amount and rate of water loss depends on factors such as temperature, humidity and wind or air movement. Transpiration is greatest in hot, dry (low relative humidity), windy weather.

Table 2.—Photosynthesis and respiration.

Photosynthesis	Respiration
• Produces food.	• Uses food.
• Stores energy.	• Releases energy.
• Uses water.	• Produces water.
• Uses carbon dioxide.	• Produces carbon dioxide.
• Releases oxygen.	• Uses oxygen.
• Occurs in sunlight.	• Occurs in dark as well as in light.

A balancing act

In order for a plant to grow and develop properly, it must balance photosynthesis, respiration and transpiration. Left to their own devices, plants do a good job of managing this intricate balance. If a plant photosynthesizes at a high rate, but its respiration rate is not high enough to break down the photosynthates produced, photosynthesis will either slow down or stop. On the other hand, if respiration is much more rapid than photosynthesis, the plant won't have adequate photosynthates to produce energy for growth. Hence, growth either will slow down or stop altogether.

When stomata are open, transpiration occurs, sometimes at a very high rate. A corn plant may transpire 50 gallons of water per season, but a large tree may move 100 gallons per day! Plants have problems if they lose too much water, so stomata close during hot, dry periods when transpiration is highest. However, CO_2, needed for photosynthesis, also enters the plant through open stomata. Thus, if stomata stay closed a long time, not enough CO_2 will enter for photosynthesis. As a result, photosynthesis and respiration will slow down, reducing plant growth.

Many herb plants produce high-energy oils to help them survive in the dry landscapes where they evolved. Oils help plants survive extended periods of stomatal closure.

Environmental factors affecting growth

The environment affects plant growth and geographic distribution. If any environmental factor is less than ideal, it limits a plant's growth and/or distribution. For example, only plants adapted to limited amounts of water can live in deserts.

Either directly or indirectly, most plant problems are caused by environmental stress. In some cases, poor environmental conditions (e.g., too little water) damage a plant directly. In other cases, environmental stress weakens a plant and makes it more susceptible to disease or insect attack.

Environmental factors that affect plant growth include light, temperature, water, humidity and nutrition. It is important to understand how these factors affect plant growth and development. With a basic understanding of these factors, a plant can be manipulated to meet your needs for increased leaf, flower or fruit production. By recognizing the roles of these factors, you can better diagnose plant problems caused by environmental stress.

Light

Three principal characteristics of light affect plant growth: quantity, quality and duration (how much, what type and how long).

Quantity

Light quantity is the intensity, or concentration, of sunlight. It varies with the seasons. The maximum amount of light is present in summer, and the minimum in winter. Up to a point, the more sunlight a plant receives, the greater its capacity for producing food via photosynthesis.

Light quantity can be manipulated to achieve different plant growth patterns. Increase light by surrounding plants with reflective materials, a white background or supplemental lights. Decrease it by shading plants with cheesecloth or woven shade cloth.

See Chapter 19, ***Diagnosing Plant Problems.***

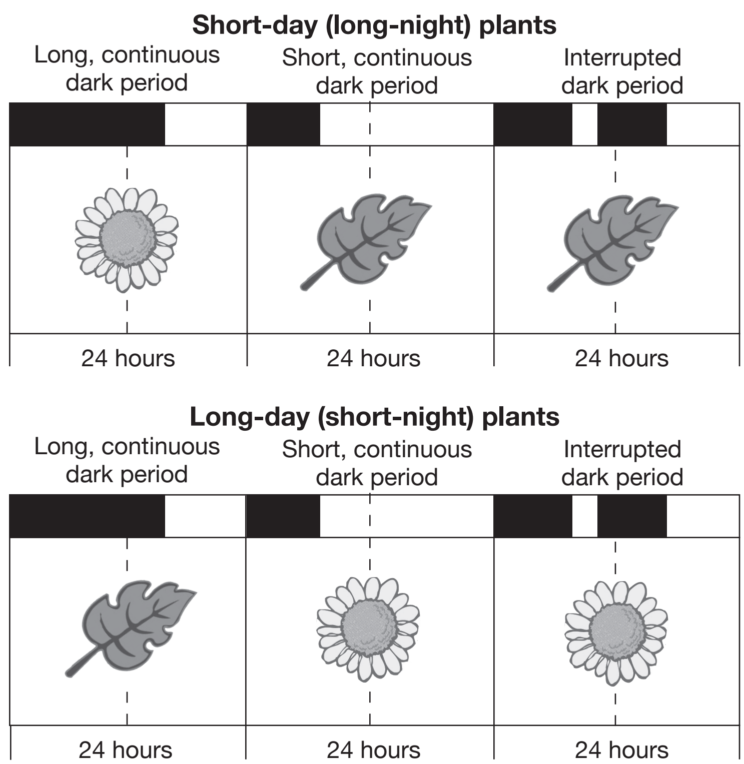


Figure 26.—Periodicity of plants. Short-day (long-night) plants require a long period of uninterrupted darkness to flower. Long-day (short-night) plants require a short period of uninterrupted darkness to flower.

Quality

Light quality refers to the color (wavelength) of light. Sunlight supplies the complete range of wavelengths and can be broken up by a prism into bands of red, orange, yellow, green, blue, indigo and violet.

Blue and red light is absorbed by plants and has the greatest effect on growth. Blue light is responsible for vegetative (leaf) growth. Red light, when combined with blue light, encourages flowering. Plants look green because they reflect, rather than absorb, green light. This means that plants do not use green light for growth.

Knowing which light source to use is important for manipulating plant growth. For example, fluorescent (cool white) light is high in the blue wavelength. It encourages leafy growth and is excellent for starting seedlings. Incandescent light is high in the red or orange range, but generally produces too much heat to be a valuable light source for plants. Fluorescent grow lights attempt to imitate sunlight with a mixture of red and blue wavelengths, but they are costly and generally no better than regular fluorescent lights.

Duration

Duration, or *photoperiod*, refers to the amount of time a plant is exposed to light. Photoperiod controls flowering in many plants (Figure 26). Scientists initially thought the length of light period triggered flowering and other responses within plants. Thus, they describe plants as short-day or long-day, depending on what conditions they flower under. We now know that it is not the length of the light period, but rather the length of uninterrupted darkness, that is critical to floral development.

Plants are classified into three categories: short-day (long-night), long-day (short-night) or day-neutral, depending on their response to the duration of light or darkness. *Short-day* plants form flowers only when day length is less than about 12 hours. Many spring and fall-flowering plants, such as chrysanthemums, poinsettias and Christmas cactus, are in this category.

In contrast, *long-day* plants form flowers only when day length exceeds 12 hours. Most summer-flowering plants (e.g., rudbeckia, California poppies and asters), as well as many vegetables (beets, radishes, lettuce, spinach and potatoes), are in this category. Alaska summers are full of long-day conditions.

Day-neutral plants form flowers regardless of day length. Examples are tomatoes, corn, cucumbers and some strawberry cultivars. Some plants do not fit into any category, but may respond to combinations of day lengths. Petunias, for example, flower regardless of day length, they but flower earlier and more profusely with long days.

You can easily manipulate photoperiod to stimulate flowering. For example, chrysanthemums normally flower in the short days of spring or fall, but bloom in midsummer when covered with a cloth that completely blocks out light for 12 hours each day. After several weeks of this treatment, the artificial dark period is no longer needed, and the plants will bloom as if it were spring or fall. This method also is used to make poinsettias flower in time for Christmas.

To bring a long-day plant into flower when day length is less than 12 hours, expose the plant to supplemental light. After a few weeks, flower buds will form.

Temperature

Temperature is a fundamental factor that affects the rate of most biological and chemical reactions. It influences most plant processes, including photosynthesis, transpiration, respiration, germination and flowering. As temperature increases (up to a point), photosynthesis, transpiration and respiration increase. When combined with day length, temperature also affects the change from vegetative (leafy) to reproductive (flowering) growth. Depending on the situation and the specific plant, the effect of temperature can either speed up or slow down this transition. High temperatures can damage fruit production by killing the pollen that is developing in pollinated flowers.

Sometimes horticulturists use temperature in combination with day length to manipulate flowering. For example, a Christmas cactus forms flowers as a result of short days and low temperatures (Figure 26). To encourage a Christmas cactus to bloom, place it in a room with more than 12 hours of darkness each day and a temperature of 50° to 55°F until flower buds form.

If temperatures are high and days are long, cool-season crops such as spinach will flower (bolt). However, if temperatures are too cool, fruit will not set on warm-season crops such as tomatoes.

Low temperatures reduce energy use and increase sugar storage. Thus, leaving crops such as ripe winter squash on the vine during cool, fall nights increases their sweetness. This is one reason vegetables in Alaska are so sweet. Potatoes in cool storage also become sweet over time and need to be brought up to room temperature in order for the sugars to be converted back to starch.

Adverse temperatures can cause stunted growth and poor-quality vegetables. For example, high temperatures cause bitter lettuce and cucumber.

Photosynthesis and respiration

Thermoperiod refers to daily temperature change. Plants grow best when daytime temperature is about 10° to 15° higher than nighttime temperature. Under these conditions, plants photosynthesize (build up) and respire (break down) during optimum daytime temperatures and then curtail respiration at night. However, not all plants grow best under the same nighttime and daytime temperatures. For example, snapdragons grow best at nighttime temperatures of 55°F, poinsettias at 62°F.

Photosynthesis occurs at its highest rate between 65° and 85°F and decreases at higher or lower temperatures. Temperatures higher than needed increase respiration, sometimes above the rate of photosynthesis. Thus, photosynthates are used faster than they are produced. For growth to occur, photosynthesis must be greater than respiration.

Daytime temperatures that are too low often produce poor growth by slowing down photosynthesis. The result is reduced yield (e.g., fruit or grain production).

Breaking dormancy

Some plants that grow in cold regions need a certain number of days of low temperature (dormancy). Knowing the period of low temperature required by a plant is essential in getting it to grow to its potential.

Peaches are a prime example: most varieties require 700 to 1,000 hours between 32° and 45°F before breaking their rest period and beginning growth. Lilies need 6 weeks of temperatures at or slightly below 33°F before blooming.

Daffodils can be forced to flower by storing the bulbs at 35° to 40°F in October. The cold temperature allows the bulbs to mature. When transferred to a greenhouse in midwinter, they begin to grow, and flowers are ready to cut in 3 to 4 weeks.

Hardiness

Plants are classified as hardy or nonhardy depending on their ability to withstand cold temperatures. *Hardy* plants are those that are adapted to the cold temperatures of their growing environment.

Woody plants in the temperate zone have very sophisticated means for sensing the progression from fall to winter. Decreasing day length and temperatures trigger hormonal changes that cause leaves to stop photosynthesizing and to ship nutrients to twigs, buds, stems and roots. An *abscission* layer forms where each petiole joins a stem, and the leaves eventually fall off. Changes within the trunk and stem tissues over a relatively short period of time "freeze-proof" the plant.

Fall days are longer in Alaska than in the lower 48 states. Because of this, plants may not get the short day triggers necessary to harden off for winter. Consequently, plants that would normally withstand cold temperature are not winter hardy in Alaska.

Winter injury to hardy plants may occur when temperatures drop too quickly in the fall before a plant has progressed to full dormancy. In other cases, a plant may break dormancy in mid- or late winter if the weather is unseasonably warm. If a sudden, severe cold snap follows the warm spell, otherwise hardy plants can be seriously damaged.

It is worth noting that the tops of hardy plants are much more cold tolerant than the roots. Plants that normally are hardy to 10°F may be killed if they are in containers and the roots are exposed to 20°F.

Winter injury also may occur because of *desiccation* (drying out) of plant tissues. People often forget that plants need water even during winter. In the spring, when the soil is frozen, water movement into a plant is severely restricted. These conditions are common in Alaska. On a windy winter day, broadleaf evergreens can become water-deficient in a few minutes, and the leaves or needles then turn brown. To minimize the risk of this type of injury, it is important that plants, especially trees, go into the winter well watered.

Water and humidity

Most growing plants contain about 90 percent water. Water is taken up into the plant by roots and moved upward through the xylem. Water plays many roles in plants. It is:

- a primary component in photosynthesis and respiration.
- responsible for turgor pressure in cells (Like air in an inflated balloon, water is responsible for the fullness and firmness of plant tissue. Turgor is needed to maintain cell shape and ensure cell growth.).
- a solvent for moving minerals and carbohydrates through the plant.
- responsible for cooling leaves as it evaporates from leaf tissue during transpiration.
- a regulator of stomatal opening and closing, thus controlling transpiration and photosynthesis.
- the source of pressure to move roots through the soil.
- the medium in which most biochemical reactions takes place.

Relative humidity is the ratio of water vapor in the air to the amount of water the air could hold at the current temperature and pressure. Warm air can hold more water vapor than cold air. Relative humidity (RH) is expressed by the following equation:

$$RH = \text{Water in air} \div \text{Water air could hold}$$
$$\text{(at constant temperature and pressure)}$$

Relative humidity is given as a percent. For example, if a pound of air at 75°F could hold 4 grams of water vapor and there are only 3 grams of water in the air, then the (RH) is:

$$3 \div 4 = 0.75 = 75\%$$

Water vapor moves from an area of high relative humidity to one of low relative humidity. The greater the difference in humidity, the faster water moves. This factor is important because the rate of water movement directly affects a plant's transpiration rate.

The relative humidity in the air spaces between leaf cells approaches 100 percent. When a stoma opens, water vapor inside the leaf rushes out into the surrounding air (Figure 25), and a bubble of high humidity forms around the stoma. By saturating this small area of air, the bubble reduces the difference in relative humidity between the air spaces within the leaf and the air adjacent to the leaf. As a result, transpiration slows down. How does this affect nutrient uptake?

If wind blows the humidity bubble away, however, transpiration increases. Thus, transpiration usually is at its peak on hot, dry, windy days. On the other hand, transpiration generally is quite slow when temperatures are cool, humidity is high and there is no wind.

Hot, dry conditions generally occur during the summer, which partially explains why plants wilt quickly in the summer. If a constant supply of water is not available to be absorbed by the roots and moved to the leaves, turgor pressure is lost and leaves go limp.

Plant nutrition

Plant nutrition often is confused with fertilization. Plant nutrition refers to a plant's need for and use of basic chemical elements. *Fertilization* is the term used when these materials are added to the environment around a plant. A lot must happen before a plant can use a chemical element in a fertilizer.

Plants need 17 elements for normal growth. Three of them — carbon, hydrogen and oxygen — are found in air and water. The rest are found in the soil.

See Chapter 3, ***Soils and Fertilizers.***
See Chapter 8, ***Vegetable Gardening.***

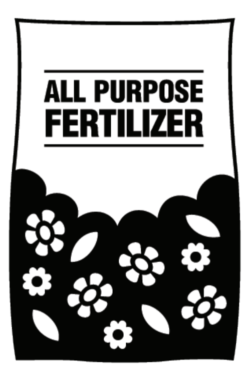
Three soil elements are called primary nutrients because they are used in relatively large amounts by plants. They are nitrogen, phosphorus and potassium. Calcium, magnesium and sulfur are called secondary nutrients because they are used in moderate amounts. Often, primary and secondary nutrients are collectively called macronutrients (Table 3).

Seven other soil elements are used in much smaller amounts and are called micronutrients or trace elements (Table 4). They are iron, boron, zinc, copper, manganese, molybdenum and chlorine.

Most of the nutrients a plant needs are dissolved in water and then absorbed by its roots. In fact, 98 percent are absorbed from the soil-water solution, and only about 2 percent are actually extracted from soil particles.

Fertilizers

Fertilizers are materials containing plant nutrients that are added to the environment around a plant. Generally, fertilizers are added to the water or soil, but some can be sprayed on leaves. This method is called *foliar* fertilization. It should be done carefully with a dilute solution, because a high fertilizer concentration can injure leaf cells. The nutrient, however, does need to pass through the thin layer of wax (cutin) on the leaf surface.



Fertilizers are not plant food! Plants produce their own food from water, carbon dioxide and solar energy through photosyn-

Table 3.—Plant macronutrients.

Element	**Absorbed as**	**Leachability in soil/ Mobility in plants**	**Signs of excess**	**Signs of deficiency**	**Notes**
Nitrogen (N)	NO_3^- (nitrate), NH_4^+ (ammonium)	Leachable, especially NO_3^-. Mobile in plants.	Succulent growth; dark green color; weak, spindly growth; few fruits. May cause brittle growth, especially under high temperatures.	Reduced growth, yellowing (chlorosis). Reds and purples may intensify in some plants. Reduced lateral bud breaks. Symptoms appear first on older growth.	In general, the best NH_4^+:NO_3^- ratio is 1:1. Under low-light conditions , high NH_4^+ can cause leaf curl. Uptake is inhibited by high P levels. The N:K ratio is extremely important. Indoors, the best N:K ratio is 1:1 unless light is extremely high. In soils with a high C:N ratio, more N should be supplied.
Phosphorus (P)	$H_2PO_4^-$, HPO_4^- (phosphate)	Normally not leachable, but may leach from soil high in bark or peat. Not readily mobile in plants.	Shows up as micronutrient deficiency of Zn or Fe.	Reduced growth. Color may intensify. Browning or purpling of foliage in some plants. Thin stems, reduced lateral bud breaks, loss of lower leaves, reduced flowering.	Rapidly bound (fixed) on soil particles. Under acid conditions, fixed with Fe, Mg and Al (aluminum). Under alkaline conditions, fixed with Ca. Important for young plant and seedling growth. High P interferes with micronutrient absorption and N absorption. Used in relatively small amounts when compared to N and K.
Potassium (K)	K^+	Can leach in sandy soils. Mobile in plants.	Causes N deficiency in plant and may affect the uptake of other positive ions.	Reduced growth, shortened internodes. Marginal burn or scorch (brown leaf edges), necrotic (dead) spots in leaves. Reduction of lateral bud breaks, tendency to wilt readily.	N:K balance is important. High N:low K favors vegetative growth; low N:high K promotes reproductive growth (flowers, fruit).
Magnesium (Mg)	Mg^{++}	Leachable. Mobile in plants.	Interferes with Ca uptake.	Reduction in growth. Marginal chlorosis, interveinal chlorosis (yellow between the veins) in some species (may occur on middle or lower leaves). Reduction in seed production, cupped leaves.	Mg commonly is deficient in foliage plants because it is leached and not replaced. Epsom salts at a rate of 1 teaspoon per gallon may be used two times per year. Mg also can be absorbed by leaves if sprayed in a weak solution. Dolomitic limestone can be applied in outdoor situations to correct a deficiency.

Table 3.—Plant macronutrients (continued).

Element	Absorbed as	Leachability in soil/ Mobility in plants	Signs of excess	Signs of deficiency	Notes
Calcium (Ca)	Ca^{++}	Normally not leachable. Moderately limited mobility in plants. Interferes with Mg absorption.	High Ca usually causes high pH, which then precipitates many micronutrients so that they become unavailable to plants.	Inhibition of bud growth, death of root tips. Cupping of maturing leaves, weak growth. Blossom-end rot of many fruits, pits on root vegetables.	Ca is important to pH control and rarely is deficient if the correct pH is maintained. Water stress (too much or too little) can affect Ca relations within plants, causing deficiency in the location where Ca was needed at the time of stress.
Sulfur (S)	SO_4^- (sulfate)	Leachable. Not mobile in plants.	Sulfur excess usually is in the form of air pollution.	General yellowing of affected leaves or the entire plant.	S often is a carrier or impurity in fertilizers and rarely is deficient. It also may be absorbed from the air and is a by-product of combustion.

Table 4.—Plant micronutrients.

Element	Absorbed as	Signs of excess	Signs of deficiency	Notes
Iron (Fe)	Fe^{++}, Fe^{+++}	Rare except on flooded soils. Interveinal chlorosis, primarily on young tissue, which eventually may turn white.	Soil high in Ca, Mn, P or heavy metals (Cu, Zn); high pH; poorly drained soil; oxygen-deficient soil; nematode attack on roots.	Add Fe in the chelate form. The type of chelate needed depends on soil pH.
Boron (B)	BO_3^- (borate)	Blackening or death of tissue between veins.	Failure to set seed, internal breakdown, death of apical buds.	
Zinc (Zn)	Zn^{++}	Shows up as Fe deficiency. Also interferes with Mg absorption.	“Little leaf” (reduction in leaf size), short internodes, distorted or puckered leaf margins, interveinal chlorosis.	
Copper (Cu)	Cu^{++}, Cu^{+}	Can occur at low pH. Shows up as Fe deficiency.	New growth small, mis-shapen, wilted.	May be found in some peat soils.
Manganese (Mn)	Mn^{++}	Reduction in growth, brown spotting on leaves. Shows up as Fe deficiency.	Interveinal chlorosis of leaves followed by brown spots, producing a checkered effect.	Found under acid conditions.
Molybdenum (Mo)	MoO_4^- (molybdate)		Interveinal chlorosis on older or midstem leaves, twisted leaves (whiptail).	
Chlorine (Cl)	Cl^-	Salt injury, leaf burn. May increase succulence.	Leaves wilt, then become bronze, then chlorotic, then die; club roots.	

thesis. This food (sugars and carbohydrates) is combined with plant nutrients to produce proteins, enzymes, vitamins and other elements essential to growth.

Nutrient absorption

Anything that reduces or stops sugar production in leaves can lower nutrient absorption. If a plant is under stress because of low light or extreme temperatures, nutrient deficiency may develop.

A plant's developmental stage or rate of growth also may affect the amount of nutrients absorbed. Many plants have a rest (dormant) period during part of the year. During this time, few nutrients are absorbed. Plants also may absorb different nutrients as flower buds begin to develop than they do during periods of rapid vegetative growth.

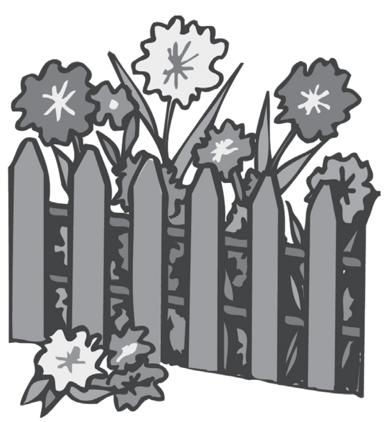
Plants in communities

The preceding discussion focused on the structure and physiology of individual plants. Interactions among plants also are important for gardeners. The study of these interactions is called plant or landscape *ecology*.

In ornamental gardens, we generally aim to develop a stable community of plants that complement each other in form, color, leaf characteristics and bloom. We must pay attention to the differing requirements of plants within this community.

See Chapter 15, ***Sustainable Landscape Design.***
See Chapter 14, ***Lawns.***
See Chapter 20, ***Weed Management.***

A garden's framework often is defined by large shrubs or trees, which cast differing amounts of summer shade and winter structures over the course of the year. When choosing plants to grow under or near large framework specimens, be sure their needs match the available light and moisture.



As trees and shrubs grow and mature, you may need to manipulate them, either by removing those that have outgrown their space or by selective pruning and thinning. Often, understory plants that did well when the landscape was young must be replaced with plants that are more shade-tolerant. This process is a kind of plant succession, dictated by the changing light and moisture environment and carried out by the owner.

A lawn also is a changing landscape. It starts out as a mix of several adapted grass species on bare ground. Weeds sprout from seed reserves in the soil. Additional seeds and plants move in and grow if conditions are right. Broadleaf weeds also may find niches. Moss begins to take over where the lawn is thin, a common problem in semi-shaded areas. These changes are another example of plant succession.

To manage invasive plants, keep your lawn grasses competitive by using proper nutrition and cultural practices (mowing, thatch, aerating etc.) and by periodically overseeding. In spite of your best efforts, however, plant succession may occur.

Gardeners who plant wildflower mixtures often discover that there is much more variety in flowers the first year than in succeeding years. Some species do very well, and others simply cannot compete. Again, plant succession occurs.

The most short-term assemblage of plants in a garden occurs in annual vegetable and flower beds. Here there is no attempt to create a community that will last more than one season.

Since many of the most competitive weeds thrive in recently disturbed soil, it is a challenge to give desired annual crop plants an advantage. The plant that captures light first will grow and suppress plants beneath it. Early weed competition can have a devastating impact on crop growth. Consistent weeding, mulching, and the use of transplants improve the odds for annual vegetable and flower crops.

Another type of relationship between plants is called *allelopathy*. In this phenomenon, some plants produce compounds in their leaves, roots or both that inhibit the growth of other plants. Black walnut is the most notorious example. Its roots can suppress many common vegetable plants, and its leaves, if mulched on a vegetable garden over the winter, can affect many annual crops like an herbicide the following spring. Some of the worst weeds show allelopathic traits and prevent desired ornamental or vegetable species from growing.

Finally, there are relationships between plants that involve pollinators, animals, birds, pests, predators and even nutrient transport between species through symbiotic fungi called mycorrhizae. These relationships are quite complex, and many are not well understood. They are the subject of active research and offer much to think about for thoughtful gardeners.

Plant hormones and growth regulators

Plant hormones and growth regulators are chemicals that affect flowering; aging; root growth; distortion and killing of leaves, stems and other plant parts; prevention or promotion of stem elongation; color enhancement of fruit; prevention of leafing and/or leaf fall; and many other conditions (Table 5). Very small concentrations of these substances produce major growth changes.

Plants produce hormones naturally, while humans apply plant growth regulators to plants. Plant growth regulators may be synthetic compounds (e.g., IBA and Cycocel) that mimic naturally occurring plant hormones, or they may be natural hormones that were extracted from plant tissue (e.g., IAA).

Table 5.—Common growth-affecting materials.

Compound	Effect/Use
Hormones	
Gibberellic acid (GA)	Stimulates cell division and elongation, breaks dormancy, speeds germination
Ethylene gas (CH_2)	Ripening agent; stimulates leaf and fruit abscission
Indoleacetic acid (IAA)	Stimulates apical dominance, rooting and leaf abscission
Plant growth regulators	
Indolebutyric acid (IBA)	Stimulates root growth
Naphthalene acetic acid (NAA)	Stimulates root growth, slows respiration (used as a dip on holly)
Growth retardants (Alar, B-9, Cycocel, Arest)	Prevent stem elongation in selected crops (e.g., chrysanthemums, poinsettias and lilies)
Herbicides (2,4-D, etc.)	Distort plant growth; selective and nonselective materials used for killing unwanted plants

Applied concentrations of these substances usually are measured in parts per million (ppm) and in some cases parts per billion (ppb). These growth-regulating substances most often are applied as a spray to foliage or as a liquid drench to soil around a plant's base. Generally, their effects are short lived, and they may need to be reapplied in order to achieve the desired effect.

There are five groups of plant growth-regulating compounds: auxin, gibberellin (GA), cytokinin, ethylene and abscisic acid (ABA). For the most part, each group contains both naturally occurring hormones and synthetic substances.

Auxin causes several responses in plants:

- Bending toward a light source (*phototropism*)
- Downward root growth in response to gravity (*geotropism*)
- Promotion of apical dominance
- Flower formation
- Fruit set and growth
- Formation of adventitious roots

Auxin is the active ingredient in most rooting compounds in which cuttings are dipped during vegetative propagation.

Gibberellins stimulate cell division and elongation, break seed dormancy and speed germination. The seeds of some species are difficult to germinate; you can soak them in a GA solution to get them started.

Unlike other hormones, *cytokinins* are found in both plants and animals. They stimulate cell division and often are included in the sterile media used for growing plants from tissue culture. If a medium's mix of growth-regulating compounds is high in cytokinins and low in auxin, the tissue culture explant (small plant part) will produce numerous shoots. On the other hand, if the mix has a high ratio of auxin to cytokinin, the explant will produce more roots. Cytokinins also are used to delay plant aging and death (*senescence*).

Ethylene is unique in that it is found only in the gaseous form. It induces ripening, causes leaves to droop (*epinasty*) and drop (abscission) and promotes senescence. Plants often increase ethylene production in response to stress, and ethylene often is found in high concentrations within cells at the end of a plant's life. The increased ethylene in leaf tissue in the fall is part of the reason leaves fall off of trees. Ethylene also is used to ripen fruit (e.g., green bananas).

Abscisic acid (ABA) is a general plant-growth inhibitor. It induces dormancy; prevents seeds from germinating; causes abscission of leaves, fruits and flowers; and causes stomata to close. High concentrations of ABA in guard cells during periods of drought stress probably play a role in stomatal closure.

For more information

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