Botany and Basic Plant Science

Adapted from the Texas Master Gardener Manual
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Plant science or botany is the study of plants. Horticulture, on the other hand, along with agronomy and other applied sciences, is the application of that knowledge to accomplish an economic or aesthetic purpose. Botany consists of several subsciences:

- **taxonomy**, naming and classifying plants
- **morphology**, descriptions and structures, includes anatomy
- **physiology**, the inner workings of plants
- **genetics,** plant breeding
- **ecology**, biological relationships in the environment
- **autecology**, individual organisms and their interaction with the physical environment
- **synecology**, interactions with other biological systems

These subdisciplines are not mutually exclusive and often overlap and cannot be studied alone. In this discussion, morphology (plant structures) will be discussed in conjunction with physiology (functions). So as we discuss leaves, we also will consider their function. Other subdisciplines will be discussed as appropriate.

To gain a working knowledge of horticulture, it is necessary to understand the structure and function of plants (morphology and physiology), their processes, and factors that ultimately can affect plant growth. To begin to understand plants, it is necessary to understand how plants are categorized (taxonomy).

Plant Categories

In the plant kingdom, plants can be loosely characterized into either angiosperms or gymnosperms. Angiosperms are all flowering plants, and gymnosperms are cone-bearing plants (though the cones may not look like cones as with junipers and ginko). Angiosperms are further divided into monocotyledons (monocots) and dicotyledons (dicots). Although monocots and dicots are similar in many ways, there are differences in seed leaf number, flower part numbers, leaf vein patterns, and root structures. Also there are physiological differences, such as the plant's response to weed killers.

All plants are classified further by the number of growing seasons required to complete a life cycle. Annuals pass through their entire life cycle, from seed germination to seed production, in one growing season, and then die.

Biennials are plants that start from seeds. They produce vegetative structures and food storage organs in the first season. During the first winter, a hardy evergreen rosette of basal leaves persists. During the second season, flowers, fruit and seed develop to complete the life cycle. The plant then dies. Carrots, beets, cabbage, celery and onions are biennial plants that produce seed by flowers that develop in the second growth year. Hollyhock (*Althaea rosea*), Canterbury bells (*Campanula medium*), and Sweet William (*Dianthus barbatus*) are biennials commonly grown for their attractive flowers.

Plants that typically develop as biennials may, in some cases, complete the growth cycle from seed germination to seed production in only one growing season. This occurs when drought, variations in temperature, or other climatic conditions cause the plant to pass through the physiological equivalent of two growing seasons in only a single growing season.

Perennial plants may live for many years and typically produce flowers and seeds each year, after reaching maturity. Perennials are classified as herbaceous, if the top dies back to the ground each winter and new stems grow from the roots each spring. They are classified as woody, if the top persists, as in shrubs or trees.

The characteristics used to classify plants also are used to identify and name them. As we discuss plants in our gardens, we tend to use one of two different naming systems. The "common name" is the name commonly used by most people. For this very reason, it is very imprecise. For more precision, scientists and more experienced gardeners use the "scientific name." This name consists of a generic noun and specific epithet. That is, it consists of at least two words. Other elements of a scientific name also may be used, including variety name, cultivar name, form name, and such. Use of common names is rather free-form, there are no rules governing their use. However, scientific names are governed by specific rules of nomenclature, which prevent the problems inherent with common names. With common names, one plant may have more than one common name, or one common name may refer to more than one type of plant. This leads to considerable confusion. The following characteristics are useful in identifying and understanding proper plant culture.

Binomial nomenclature is the scientific system of giving a double name to each plant or animal. The first (genus) name is followed by a descriptive (species) name. Modern plant classification, or taxonomy, is based on the system of binomial nomenclature developed by a Swedish physician, Carl von Linné (Linnaeus). Prior to Linnaeus, people based classification on leaf shape, plant size, flower color, etc. However, none of these systems proved workable. Linnaeus's revolutionary approach based classification on the flowers or reproductive parts of a plant and gave plants a genus and species name. This has proven to be the best system since flowers are the plant part least influenced by environmental changes. For this reason, knowledge of the flower and its parts is essential for those interested in identifying plants (fig. 1).

Asexual Plant Parts and Functions

Plant parts can be divided into two groups: vegetative (asexual) parts, and sexual reproductive parts (fig.2). The vegetative parts, which include roots, stems, shoot buds, and leaves, are not involved directly in plant reproduction. However, they are used often in asexual or vegetative forms of reproduction, such as cuttings. Sexual reproductive parts are those involved in seed production. These include flowers, fruit, flower buds, and seeds.

Meristems

Plant meristems are dividing cells responsible for plant growth.

Apical meristems are found in the buds of each shoot's tip and in all lateral buds. They also are found in the root tips. These meristems are responsible for the cell division that leads to growth in the length of these organs. Primary apical meristems originate within the seed. Each subsequent apical meristem that forms is derived directly from the original meristem in the seed. Secondary apical meristems are not derived directly from the meristem in a seed and are produced "adventitiously" at the site of a wound, such as that caused by pruning. They also may be produced

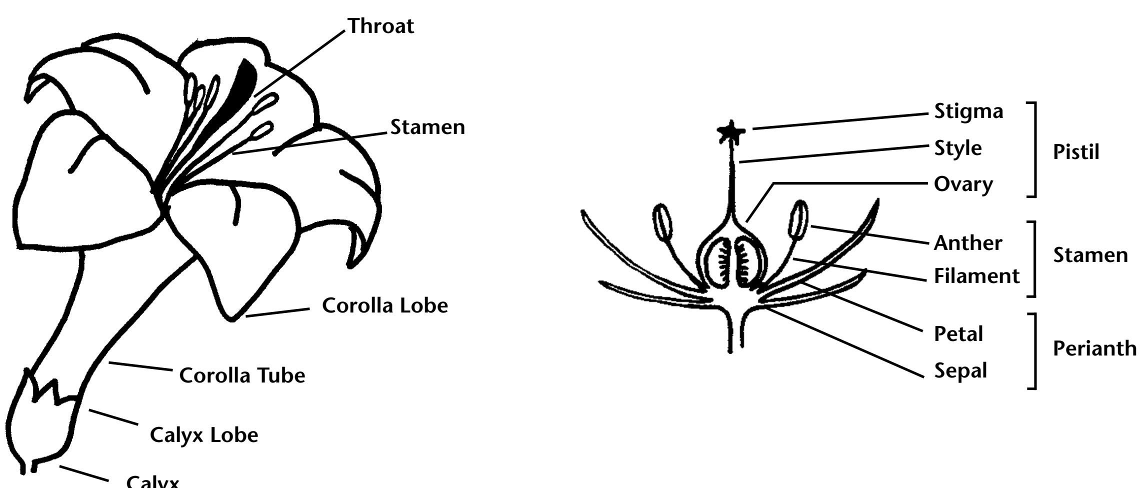


Figure 1. Parts of the flower.

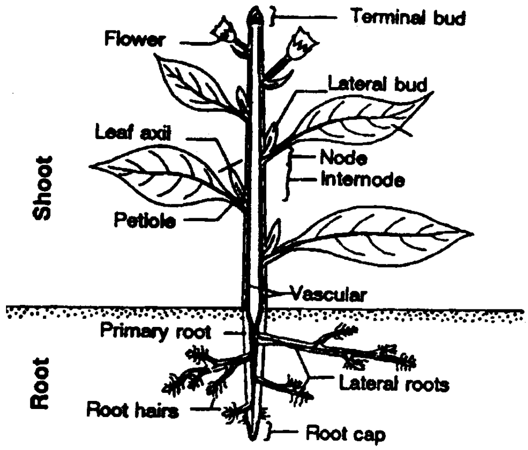
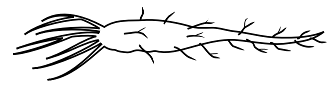
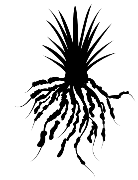


Figure 2. Principal parts of a vascular plant.



Taproot of carrot



Fibrous rot of grass

Figure 3. Types of roots.

naturally without a wound. In either case, they formed from cells that had previously lost the ability to be meristematic.

Cambium is the meristem responsible for lateral growth, or growth in girth, of dicot perennial plants such as trees. These dividing cells produce cells to the outside of a stem that become phloem cells and to the inside of the plant that become xylem cells.

Cork cambium is a layer of dividing cells just below the bark that produces cells which, form the bark of a tree or shrub.

Monocots, such as grasses, do not have a cambium, but they possess a type of meristematic region called intercalary meristem. Intercalary meristems are found at the base of the leaves. They are the growth source and allow continued growth of grass leaves following mowing.

Roots

A thorough knowledge of the plant root system is essential if their growth, flowering, and fruiting responses are to be understood (fig. 3). Roots' structure and growth habits have a pronounced effect on the plant's size and vigor, propagation methods, adaptation to certain soil types, and responses to cultural practices and irrigation. In addition, the roots of certain vegetable crops are important as food.

Roots typically originate from the lower portion of a plant or cutting. They possess a root cap, have no nodes, and never directly bear leaves or flowers. The principal functions of roots are to absorb nutrients and moisture, anchor the plant in the soil, furnish physical support for the stem, and serve as food storage organs. In some plants, roots may be used as a means of propagation.

Types of Roots

A primary root originates at the lower end of a seedling plant's embryo. A taproot is formed when the primary root continues to grow down into the soil and becomes the root system's central and important feature with a somewhat limited amount of secondary branching. Some trees, especially nut trees like pecan, have a long taproot with very few lateral or fibrous roots. This causes them to be difficult to transplant and requires that they be planted only in deep, well-drained soil.

A lateral or secondary root is a side or branch root that arises from another root. A fibrous root is one that remains small in diameter due to very little cambial activity. One factor that causes shrubs and dwarf trees to remain smaller than standard or large trees is the inactivity of the cambium tissue in the roots.

A fibrous root system is one in which the primary root ceases to elongate. Numerous lateral roots, which repeatedly branch and form the plant's feeding root system, develop.

If plants that normally develop a taproot are undercut so that the taproot is severed early in the plant's life, the root will lose its taproot characteristic and develop a fibrous root system. This is done commercially in nurseries so that trees that naturally have taproots will develop a compact, fibrous root system. This helps to ensure better transplanting success in the field.

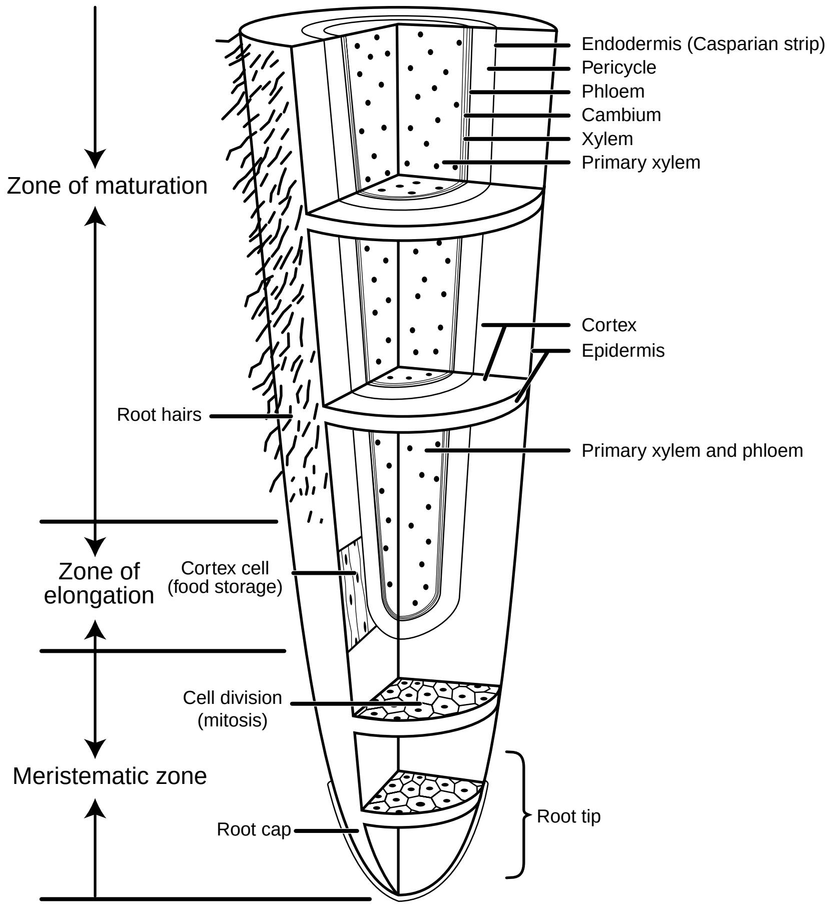


Figure 4. Root structure.

The quantity and distribution of plant roots are two very important factors, because they have a major influence on moisture and nutrient absorption. The depth and spread of roots are dependent on the plant's inherent growth characteristics, the soil moisture, and the soil's texture and structure. Roots penetrate much deeper in a loose, well-drained soil than in a heavy, poorly drained soil. A dense, compact soil layer will restrict or terminate root growth. Likewise, dry subsoils will not enhance root spread.

During early development, a seedling plant absorbs nutrients and moisture from the soil within a few inches of the seed from which the plant grew. Therefore, the early growth of most horticultural crops, which are seeded in rows, benefits from band application of fertilizer several inches on either side and slightly below the location of the seeds.

As plants become well-established, the root system develops laterally and usually extends somewhat beyond the spread of the branches. For most cultivated crops, roots meet and overlap between the rows. The greatest concentration of fibrous roots occurs in the top foot of soil, but significant numbers of laterals may grow downward from these roots to provide an effective absorption system several feet deep.

Parts of a Root

There are three major internal parts of a root (fig. 4). The apical meristem, which is at the tip and manufactures new cells, is an area of cell division and growth. Behind it is the elongation zone. In this area, cells increase in size through food and water absorption. These cells, by increasing in size, push the root through the soil. The third part is the maturation zone, where cells undergo changes to become specific tissues, such as epidermis, cortex, or vascular tissue. The epidermis is the outermost cell layer surrounding the root. These cells are responsible for the absorbing water and minerals dissolved in water. Cortex cells are involved in the moving water from the epidermis and the food storage. Vascular tissue is located in the root's center and conducts food and water.

Externally, there are two areas of importance: root hairs and the root cap. Root hairs are found along the main root and perform much of the actual water nutrient absorption. The root cap is the root's outermost tip and consists of cells that are sloughed off as the root grows through the soil. The meristem (the area of cell division) is behind the root cap and is protected by it.

Roots as Food Crops

The enlarged root is the edible portion of several vegetable crops. The sweet potato is a swollen root, called a tuberous root, that serves as a food storage area for the plant. Carrot, parsnip, salsify, and radish are enlarged taproots.

Stems

Stems are structures that support buds and leaves and serve as conduits for carrying water, minerals, and sugars. The three major internal parts of a stem are the xylem, phloem, and cambium. The xylem and phloem are the major components of a plant's vascular system, which transports food, water, and minerals and offers support for the plant. Xylem tubes are the water and mineral conducting channels, while phloem tubes are the food conducting channels.

While monocots and dicots both contain xylem and phloem tubes, their vascular systems are arranged differently (fig. 5). In the monocot's stem, the xylem and phloem are paired into bundles, which are dispersed throughout the stem. The vascular system in a dicot is said to be continuous, because it forms rings inside the stem. The phloem ring is near the bark or the stem's external cover and is a bark component in mature stems. The xylem forms the inner ring and is the sapwood and heartwood in woody plants. The difference in the vascular system of the two groups is important to the horticulturist, because certain herbicides are specific to either monocots or dicots.

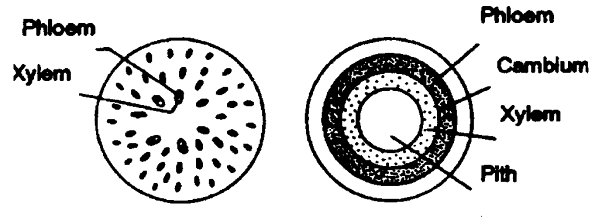


Figure 5. Cross section of stems. Left: discontinuous vascular system of a monocotyledonous stem. Right: continuous vascular system of a dicotyledonous stem.

An example is 2,4,-D, which only kills plants with a continuous vascular system, or dicots.

The cambium is a meristem that is a site of cell division and active growth. It is located between the xylem and phloem inside the stem's bark and is the tissue responsible for a stem's increase in girth as it produces both the xylem and phloem tissues.

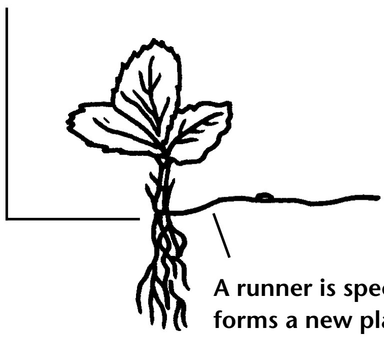
Stems may be long with great distances between leaves and buds (branches of trees, runners on strawberries) or compressed with short distances between buds and leaves (fruit spurs, crowns of strawberry plants, dandelions). Stems may be above the ground or below the ground (potatoes, tulip bulbs) (fig. 6). All stems must have buds or leaves present to be classified as stem tissue.

An area of the stem where leaves are located is called a node. Nodes are areas of great cellular activity and growth and are the point at which buds develop into leaves or flowers. The area between nodes is called an internode (fig. 7).

The length of an internode depends on many factors. Decreasing fertility will decrease internode length. Growth produced early in the season has the greatest internode length; internode length decreases as the growing season nears its end. Too little light will cause stretch, or etiolation, resulting in a long, spindly stem. Vigorously growing plants tend to have greater internode length than less vigorous plants. Internode length will vary in relation to competition with surrounding stems or developing fruit. If the energy for a stem is divided between three or four stems or if the energy is diverted into fruit growth, internode length will be shortened.

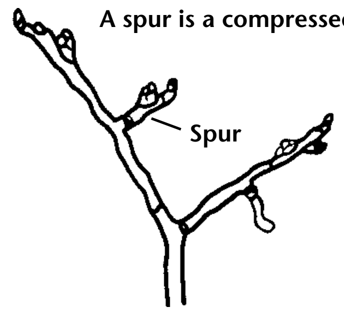
Aboveground Modifications

A crown is a region of compressed stem tissue from which new shoots are produced—generally found near the soil surface.

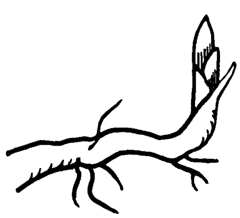


A runner is specialized stem, which forms a new plant at one or more of its nodes. A branch is a stem, which is more than 1 year old.

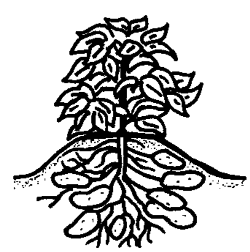
A spur is a compressed fruiting branch.



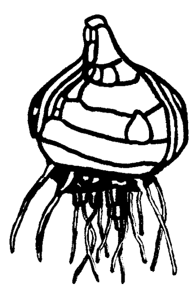
Belowground Modifications



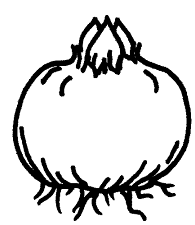
A rhizome is a specialized stem that grows horizontally at or just below the soil surface and acts as a storage organ and means of propagation in some plants.



A tuber is an enlarged portion of an underground stem.



A bulb is composed of a short stem with reduced scaly leaves.



A corm is a compressed stem plate and closely spaced buds and fleshy leaves.

Figure 6. Diversified stem development.

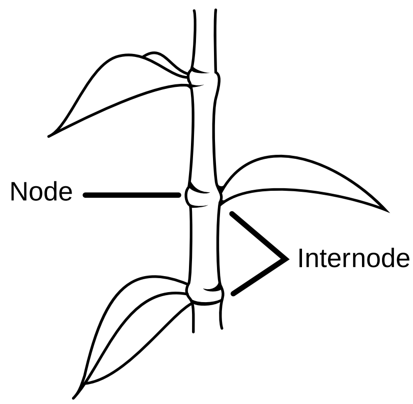


Figure 7. Parts of a stem.

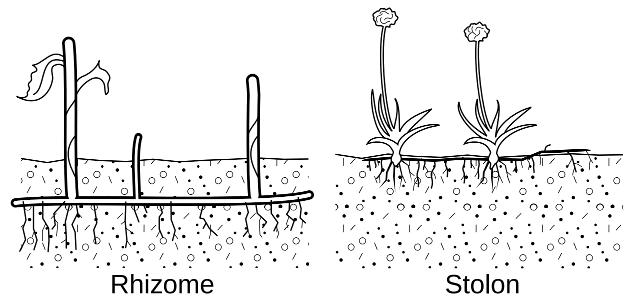


Figure 8. Modified stems.

Although typical stems are aboveground trunks and branches, there are modified stems that can be found aboveground and belowground (fig. 8). Aboveground modified stems include crowns, spurs, stolons, or runners, while belowground stems include bulbs, corms, rhizomes, and tubers.

Crowns (strawberries, dandelions, and African violets) are compressed stems with leaves and flowers on short internodes. Spurs are short, stubby, side-stems that arise from the main stem; they are common on such fruit trees as pears, apples, and cherries through which they may bear fruit. If severe pruning is done close to fruit-bearing spurs, the spurs can revert to a nonfruiting long stem.

A stolon is a horizontal stem that is fleshy or semiwoody and lies along the top of the ground. Strawberry runners are an example. Remember, all stems have nodes and buds or leaves. The leaves on strawberry runners are small, but they are located at the nodes and are easy to see. The nodes on the runner are the points where roots begin to form. The spider plant has stolons that can produce an entirely new plant.

Rhizomes are similar to stolons, but they grow underground rather than aboveground. Some rhizomes are compressed and fleshy, such as iris; others are slender with elongated internodes, such as Bermudagrass. Johnson grass is an insidious weed, principally because of the rhizomes' spreading capability.

Belowground stem variations, such as the potato tuber and the iris rhizome, are underground stems that store food for the plant (fig. 9). The tuber, like any other stem, has nodes that produce buds. The eyes of a potato actually are the nodes on the stem, each containing a bud cluster.

Tulips, lilies, daffodils, and onions are plants that produce bulbs — shortened, compressed underground stems surrounded by fleshy scales (leaves) that envelop a central bud located at the stem's tip. In bulbs, the stem is reduce to a very small "basal plate" from which roots grow. Cutting through the center of a tulip or daffodil bulb in November will reveal all the flower parts in miniature already present within the bulb.

Many bulbs require a period of low temperature exposure, before they begin to send up the new plant. Both the length of this exposure and the temperature are of critical importance to commercial growers who force bulbs for holidays. Easter lilies are especially difficult to time, since the date of Easter may vary by as much as six weeks.

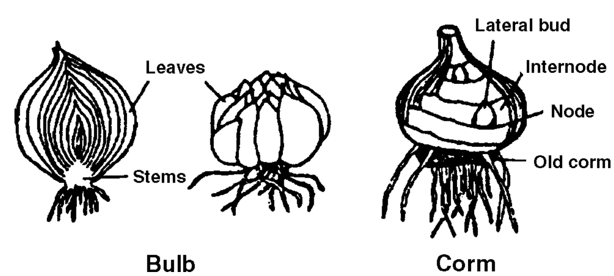
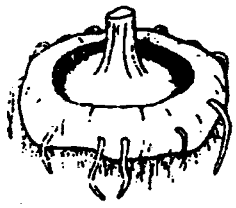


Figure 9. Belowground stems.



Tuberous begonia

Sweet potato

Figure 10. Tuberous roots (underground storage organs).

Corms have shapes similar to bulbs, but they do not contain fleshy scales. A corm is a solid, swollen stem whose scales have been reduced to dry, scalelike leaves.

Some plants produce a modified stem called a tuberous stem; examples include tuberous begonia and cyclamen. The stem is shortened, flattened, enlarged, and underground. Buds and shoots arise from the top or crown, and fibrous roots are found on the bottom of the tuberous stem.

In addition, some plants, such as the dahlia and the sweet potato, produce an underground storage organ called a tuberous root, which is often confused with bulbs and tubers (fig. 10). However, these are roots, not stems, and have neither nodes nor internodes.

Stems are one of the most commonly used parts for plant propagation purposes. Aboveground stems can be divided into sections that contain internodes and nodes. They are referred to as cuttings and will produce roots and new plants. Belowground stems also are good propagative tissues. Rhizomes can be divided into pieces, while bulbs form small bulblets at the base of the parent bulb. Cormels are miniature corms that form under the parent corm, and tubers can be cut into pieces containing eyes and nodes. All of these will produce new plants. It may sometimes be difficult to distinguish between roots and stems, but one certain sign is the presence of nodes. Stems have nodes; roots do not.

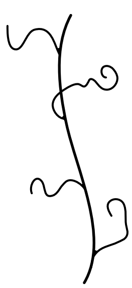
Types of Stems

A shoot is a young stem with leaves present. A twig is a stem that is one year old or less and has no leaves; it is still in the winter dormant stage. A branch is a stem that is more than one year old and typically has lateral stems. A trunk is a woody plant's main stem. Most trees have a single trunk.

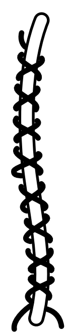
Trees are perennial woody plants with one (or sometimes several) main trunks, which at maturity are usually more than 12 feet tall.

Shrubs are perennial woody plants that may have one or several main stems, which at maturity are usually less than 12 feet tall.

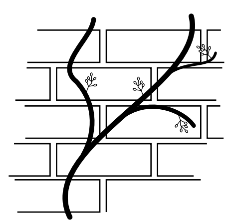
A vine is a plant that develops long trailing stems, which either grow along the ground or must be supported by another plant or structure (fig. 11).



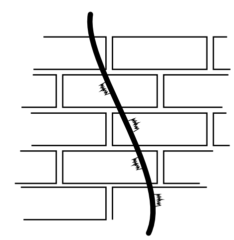
Some vines have tendrils that wrap around any type of support.



The twining vines climb by winding their stems around any available support.



Some clinging vines climb by means of tendrils with disklike adhesive tips that attach to any surface.



Other clinging vines attach themselves to surfaces with small serial rootlets along the stem.

Figure 11. Types of vines.

Some twining vines circle the support clockwise (hops or honeysuckle), while others circle counterclockwise (pole beans or Dutchman's pipe vine). Climbing vines are supported by aerial roots, as in English ivy or poison ivy; by slender tendrils that encircle the supporting object, as in cucumber, gourds, grapes, and passionflowers; or by tendrils with adhesive tips, as in Virginia and Japanese creeper.

Stem Texture and Growth

Woody stems contain relatively large amounts of hardened xylem tissue in the central core and are typical of most fruit trees, ornamental trees, and shrubs.

A cane is a stem that has a relatively large pith (the stem's central strengthening tissue) and usually lives only one, two, or a few years. Examples of plants with canes include rose, grape, blackberry, and raspberry.

Herbaceous or succulent stems contain only small amounts of xylem tissue and usually live only one growing season. If the plant is perennial, it will develop new shoots from the root or crown where root and stem meet.

Stems as Food

The edible portion of several cultivated plants, such as asparagus and kohlrabi, is an enlarged succulent stem. The edible parts of broccoli are composed of stem tissue, flower buds, and a few small leaves. The edible part of the white or Irish potato is a fleshy underground stem called a tuber. Although the name suggests otherwise, the edible part of the cauliflower is proliferated stem tissue. The flower of this biennial develops from buds in the compact branched stem tissue.

Buds

A bud is an undeveloped shoot from which embryonic leaves or flower parts arise (fig. 12). Tree and shrub buds of the temperate zone typically develop a protective outer layer of small, leathery bud scales. Annual plants and herbaceous perennials have naked buds in which the outer leaves are green and somewhat succulent.

Buds of many plants require exposure to a certain number of days below a critical temperature (rest),

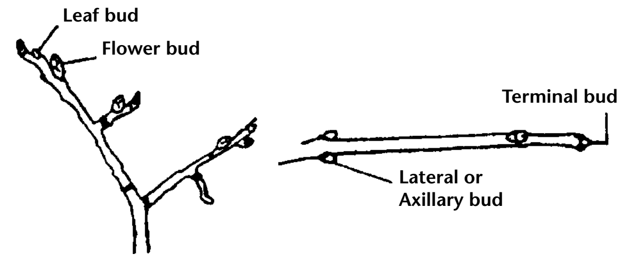


Figure 12. Types of buds.

before they will resume growth in spring. This period varies for different plants. The flower buds of forsythia require a relatively short rest period and will grow at the first sign of warm weather. Many peach varieties require 700 to 1,000 hours of temperatures below 46° F (7° C) before they will resume growth. During rest, dormant buds can withstand very low temperatures, but after the rest period has passed, buds become more susceptible to weather conditions and can be easily damaged by cold temperatures or frost.

A **leaf bud** is composed of a short stem with embryonic leaves. Bud primordia are found in the axils and at the apex. Such buds develop into leafy shoots. Leaf buds often are less plump and more pointed than flower buds. These contain the apical meristem necessary for the stem's continued elongation growth.

A **flower bud** is composed of a short stem with embryonic flower parts. In some cases, the flower buds of plants that produce fruit crops of economic importance are called fruit buds. This terminology is objectionable. Although flowers have the potential for developing into fruits, this development may never occur because of adverse weather conditions, lack of pollination, or other unfavorable circumstances. In the flower bud, the apical meristem has differentiated to form the flowers and usually will not result in continued elongation growth.

Location of Buds

Buds are named for the location they inhabit on the stem surface. Terminal buds are located at the stem's apex. Lateral buds are borne on the stem's sides. Most lateral buds arise in the leaf axis and are called axillary buds. In some instances, more than one bud is formed. Adventitious buds arise at sites other than the terminal or axillary position. Adventitious buds may develop from the stem's internode, at the edge of a leaf blade, from callus tissue at the cut end of a stem or root, or laterally from the roots of plants.

Buds as Food

Enlarged buds or bud parts form the edible portion of some horticultural crops. Cabbage and head lettuce are examples of unusually large terminal buds. Succulent axillary buds of Brussels sprouts become the edible part of this plant. In the case of globe artichoke, the fleshy basal portion of the flower bud's bracts are eaten along with the bud's solid stem portion. Broccoli is the most common horticultural plant in which edible flower buds are consumed. In this case, portions of the stem, as well as small leaves associated with the flower buds, are eaten.

Leaves

Parts of Leaves

The principal function of leaves is to absorb sunlight for manufacturing plant sugars in a process called photosynthesis. Leaves develop into a flattened surface to present a large area to efficiently absorb light energy. The leaf is supported away from the stem by a stemlike appendage called a petiole, the base of which is attached to the stem at the node. The smaller angle formed between the petiole and the stem is called the leaf axil. An active or dormant bud or cluster of buds usually is located in the axil.

The leaf blade is composed of several layers (fig. 13). On the top and bottom is a layer of tough, thickened cells called the epidermis. The primary function of the epidermis is to protect leaf tissue. The way in which cells in the epidermis are arranged determines the leaf surface texture. Some leaves have hairs, which are an extension of certain epidermal cells. The African violet, for instance, has so many of these hairs that the leaf feels like velvet.

Part of the epidermis is the cuticle, which produces a waxy layer called cutin that protects the leaf from dehydration and prevents some disease-causing organisms from penetrating. The amount of cutin produced is a direct response to sunlight, increasing with greater light intensity. For this reason, plants grown in the shade should be moved into full sunlight gradually, over a period of a few weeks, to allow the cutin layer to build and to protect the leaves from the shock of rapid water loss or sunscald. The waxy cutin also repels water and can shed pesticides if wetting agents or soaps are not used. This is the reason many pesticide manufacturers include some sort of spray additive to adhere to or to penetrate the cutin layer.

Some epidermal cells on the underside of leaves are capable of opening and closing. These cells, known as guard cells, guard the leaf's interior and regulate water, oxygen, and carbon dioxide passage through the leaf. They also protect the openings in the leaf surface called stomata. Weather and light determine whether guard cells are open or closed. Conditions that would cause large water losses from plants, such as high temperature and low humidity, cause guard cells to close. Mild weather conditions leave guard cells open. Guard cells also will close in the absence of light.

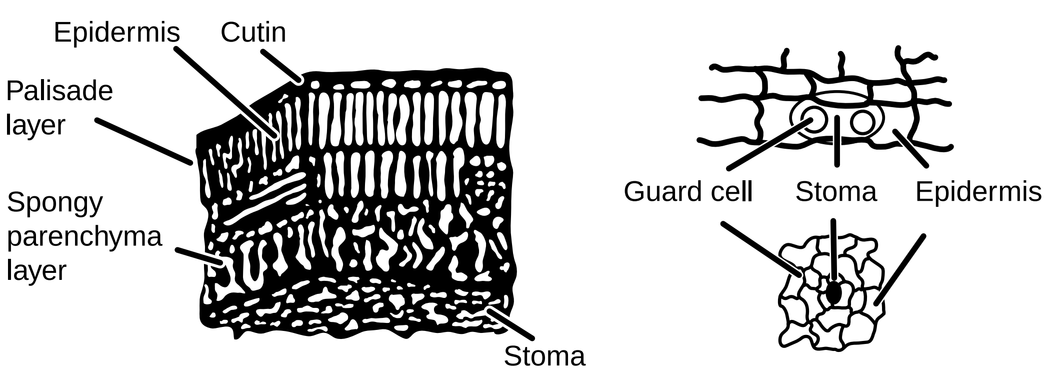


Figure 13. Leaf cross section.

The leaf's middle layer, the mesophyll, is located between the upper and lower epidermis. This is the layer in which photosynthesis occurs. The mesophyll is divided into a dense, upper layer called the palisade and a lower cell layer that contains air space or the spongy parenchyma layer. The cells in these two layers contain chloroplasts, which are the actual site of the photosynthetic process.

Types of Leaves

A number of distinct leaf types are found on plants. Leaves commonly referred to as foliage are the most common and conspicuous. They serve as manufacturing centers for photosynthesis. Scale leaves or cataphylls are found on rhizomes and also are the small, leathery protective leaves that enclose and protect the bud. Seed leaves or cotyledons are modified leaves that are found on the embryonic plant and commonly serve as storage organs. Spines and tendrils, as found on barberry and pea plants, are specialized, modified leaves that protect the plant or assist in supporting the stems. Storage leaves, as found in bulbous plants and succulents, serve as food storage organs. Other specialized leaves include bracts, which are often brightly colored. The showy structures on dogwood and poinsettias are bracts, not petals.

Parts of a Leaf

The blade is the expanded, thin structure on either side of the midrib (fig. 14). The blade usually is the largest and most conspicuous leaf part. The petiole is the stalk that supports the leaf blade. It may vary in length. Or in some cases, it may be entirely absent, whereby the leaf blade is described as sessile or stalkless.

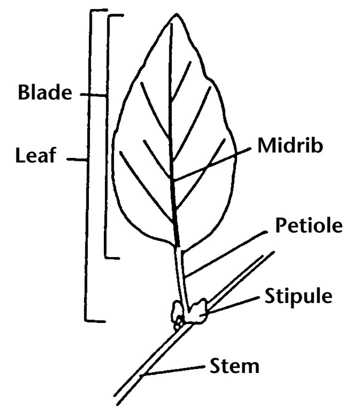


Figure 14. Parts of a leaf.

Venation of Leaves

The vascular bundles from the stem extend through the petiole and spread out in the blade. The term venation refers to the patterns in which the veins are distributed in the blade (fig. 15). Two principal types of venation are parallel-veined and net-veined.

Parallel-veined leaves have numerous veins that essentially run parallel to each other and are connected laterally by minute, straight veinlets. Possibly the most common type of parallel veining is found in plants of the grass family, where the veins run from the leaf's base to apex. Another type of parallel venation is found in plants, such as banana, calla, and pickerel weed. The parallel veins run laterally

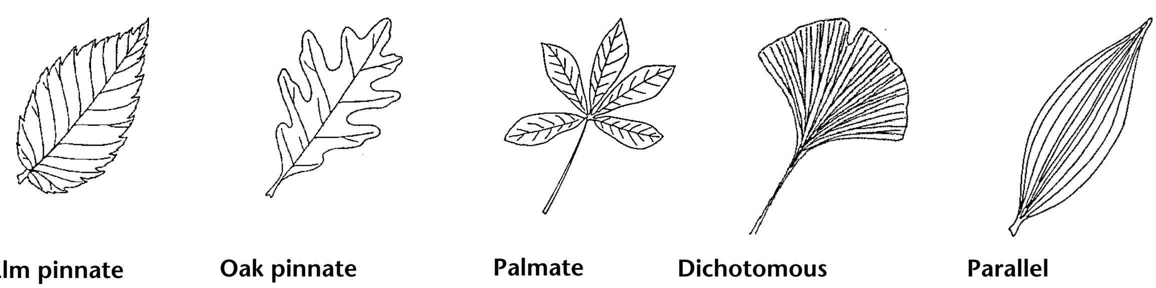


Figure 15. Types of venation.

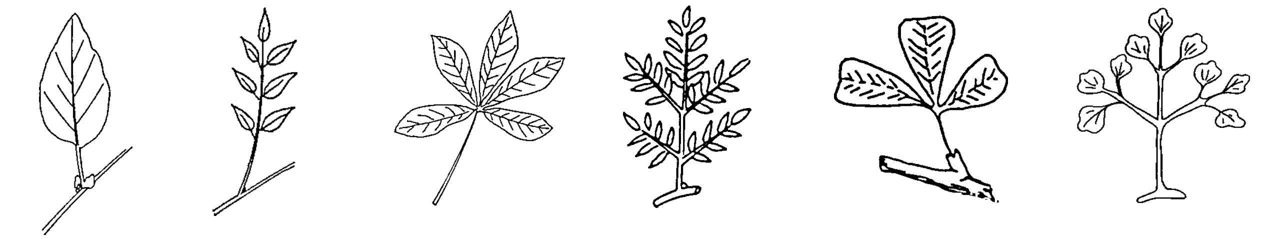


Figure 16. Leaf shapes.

Figure 17. Leaf arrangement.

from the midrib. Parallel-veined leaves occur on plants that are part of the monocotyledon group.

Net-veined leaves, also called reticulate-veined, have veins that branch from the main rib or ribs and then subdivide into finer veinlets that unite in a complicated network. This system of enmeshed veins gives the leaf more resistance to tearing than most parallel-veined leaves. Net venation may be either pinnate or palmate. In pinnate venation, the veins extend laterally from the midrib to the edge, such as in apple, cherry, and peach leaves. Palmate venation occurs in grape and maple leaves, because the principal veins extend outward from the petiole near the leaf blade's base like the ribs of a fan. Net-veined leaves occur on plants that are part of the dicotyledon group.

Leaves as a Means of Identifying Plants

Leaves are useful in identifying species and varieties of horticultural plants. The leaf blade shape and the type of margin are of major importance in identification.

Leaf Shape

Plant leaves have characteristic shapes that may be used to identify species and varieties (fig. 16). Simple leaves are those in which the leaf blade is a single, continuous unit. A compound leaf is composed of several separate leaflets arising from the same petiole. A deeply lobed leaf may appear similar to a compound leaf. But if the leaflets are connected by narrow bands of blade tissue, it may be classified as a simple leaf. If the leaflets have separate stalks and particularly if these stalks are jointed at the point of union with the main leafstalk, the leaf is considered compound. Some leaves are doubly compound with leaflet divisions.

Leaf Arrangement Along a Stem

The various ways leaves are arranged along a stem also are helpful identifiers (fig. 17). Rosulate arrangement is one in which the basal leaves form a rosette around the stem with extremely short nodes. Opposite and

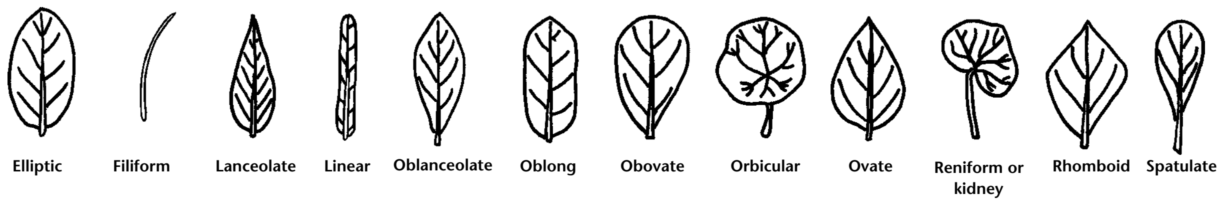


Figure 18. Leaf blade shapes.

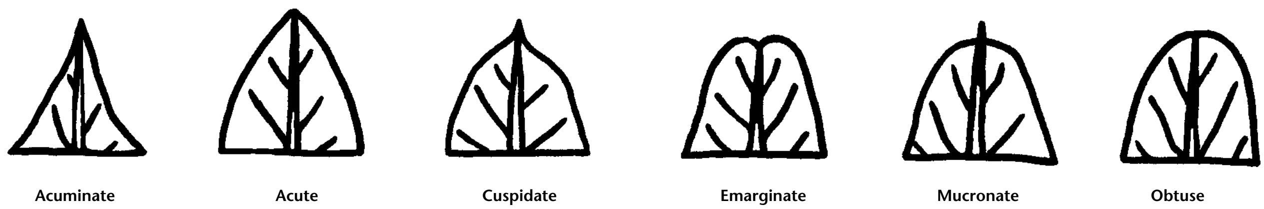


Figure 19. Leaf apices.

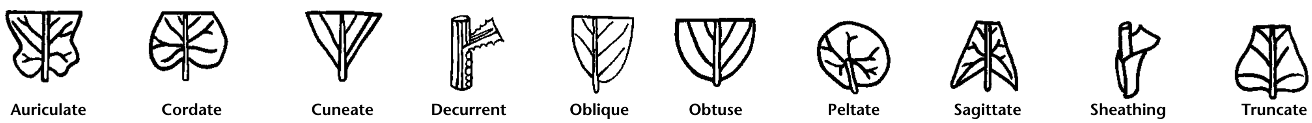


Figure 20. Leaf bases.

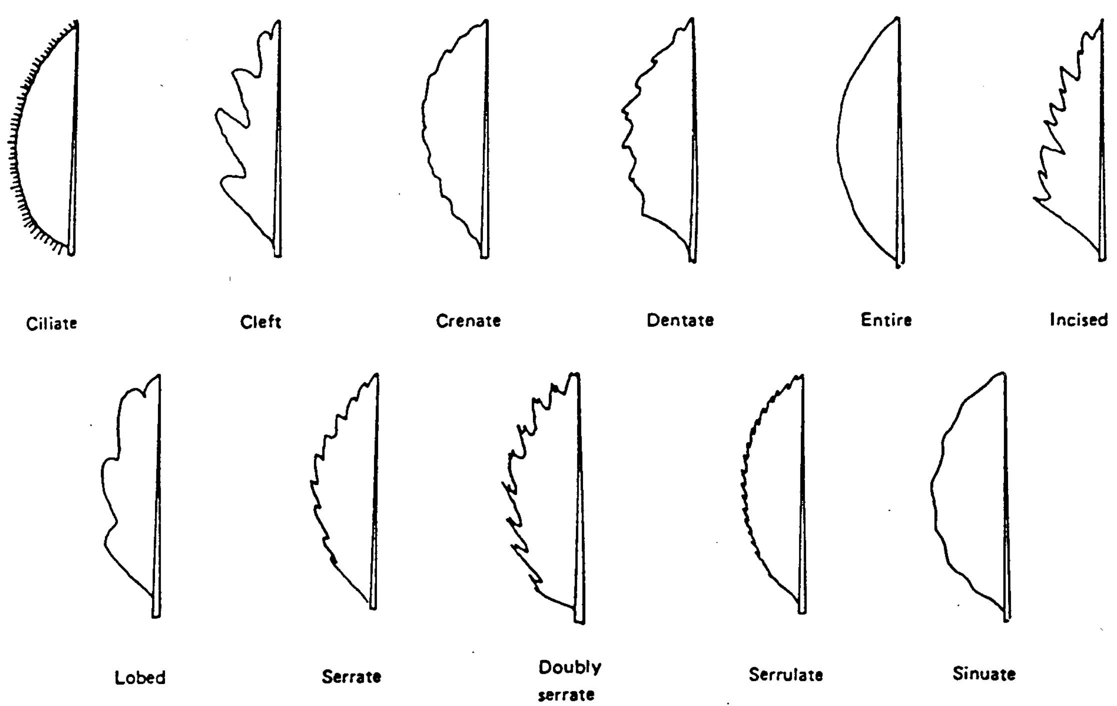


Figure 21. Leaf margins.

whorled leaves are positioned across the stem from each other with two or more leaves at each node. Alternate or spiral leaves are arranged in alternate steps along the stem with only one leaf at each node.

Shape of the Leaf Blade

Some common shapes found in leaves and leaflets are shown (fig. 18).

Shape of the Leaf Apex and Base

Some common shapes found in leaves are shown (figs. 19 and 20).

Leaf Margins

The type of leaf margin is especially useful in identifying certain plant varieties (fig. 21).

Leaves as Food

The leaf blade is the principal edible part of several horticultural crops, including chive, collard, dandelion, endive, kale, leaf lettuce, mustard, parsley, spinach, and Swiss chard. The edible part of leek, Florence fennel, and onion is a cluster of fleshy leaf bases. The leaf's petiole is the edible product in celery and rhubarb.

Sexual Plant Parts and Functions

The sexual plant parts include the flowers and fruits. These parts are involved in the plant's reproductive processes.

Flowers

The flower, generally the showiest part of the plant, has sexual reproduction as its sole function. Its attractiveness and fragrance have not evolved to please man but to ensure that the species continues. Fragrance and color are devices to attract pollinators (insects that play an important role in the reproductive process).

Parts of the Flower

As the plant's reproductive part, the flower contains either the male pollen or the female ovule plus accessory parts, such as petals, sepals, and nectar glands.

Sepals are small, green, leaflike structures on the flower's base that protect the flower bud. The sepals are collectively called the calyx.

Petals are the flower's brightly colored parts. They may contain perfume and nectar glands. The number of petals on a flower often is used to identify plant families and genera. Petals collectively are called the corolla. Flowers of dicots typically have sepals and/or petals in numbers of four or five or multiples thereof. Monocots typically have these floral parts in threes or multiples of three.

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

The stamen is the male reproductive organ. It consists of a pollen sac called the anther and a long supporting filament, which holds the anther in position. The pollen contained in the anther may be dispersed by wind or carried to the stigma by pollinating insect, birds, or other animals.

Types of Flowers

If a flower has stamens, pistils, petals, and sepals, it is called a complete flower. If one of these parts is missing, the flower is designated incomplete. If a flower contains functional stamens and pistils, it is called a perfect flower. These are considered the essential flower parts and are involved in the seed-producing process. If either of the essential parts is lacking, the flower is imperfect. Pistillate (female) flowers are those that possess a functional pistil or pistils but lack stamens. Staminate (male) flowers contain stamens but no pistils.

Because cross-fertilization combines different genetic material and produces stronger seed, cross-pollinated plants usually are more successful than self-pollinated plants. More plants reproduce by cross-pollination than by self-pollination.

There are plants that bear only male flowers (staminate plants) or female flowers (pistillate plants). Species in which the sexes are separated into staminate and pistillate plants are called dioecious. Most holly trees are either male or female plants. Therefore, in order for a female tree to produce berries, it is necessary to have a male tree nearby to provide pollen. Monecious plants are those that have separate male and female flowers on the same plant, such as corn plants and pecan trees. Some plants, like cucumbers and squash, bear only male flowers at the beginning of the growing season, but later develop both sexes.

How Seeds Form

Pollination is the transfer of pollen from an anther to a stigma. It may occur by wind or by pollinators. Wind-pollinated flowers lack showy floral parts and nectar, since they don't need to attract pollinators. Flowers are brightly colored or patterned and contain a fragrance or nectar when they must attract pollinators, such as insects, animals, or birds. In the process of searching for nectar, these pollinators will transfer pollen from flower to flower.

The stigma contains a chemical that excites the pollen, causing it to grow a long tube down the inside of the style to the ovules inside the ovary. The sperm is released by the pollen grain and fertilization typically occurs. Fertilization is the union of the male sperm nucleus from the pollen grain and the female egg found in the ovary. If fertilization is successful, the ovule will develop into a seed.

Types of Inflorescence

Some plants bear only one flower per stem and are called solitary flowers. Other plants produce an inflorescence, a term that refers to a cluster of flowers and how they are arranged on a floral stem. Most inflorescences may be classified into two groups, racemes and cymes (fig. 22). In the racemose group, florets (individual flowers in an inflorescence) bloom from the bottom of the stem and progress toward the top. Some examples of racemose inflorescence include spike, raceme, umbel, corymb, and head.

A spike is an inflorescence in which many stemless florets are attached to an elongated flower stem or peduncle. An example is gladiolus. A raceme is similar to a spike except the florets are borne on small stems attached to the peduncle. An example of a raceme inflorescence is the snapdragon. A corymb is made up of florets whose stalks or pedicels are arranged ran-

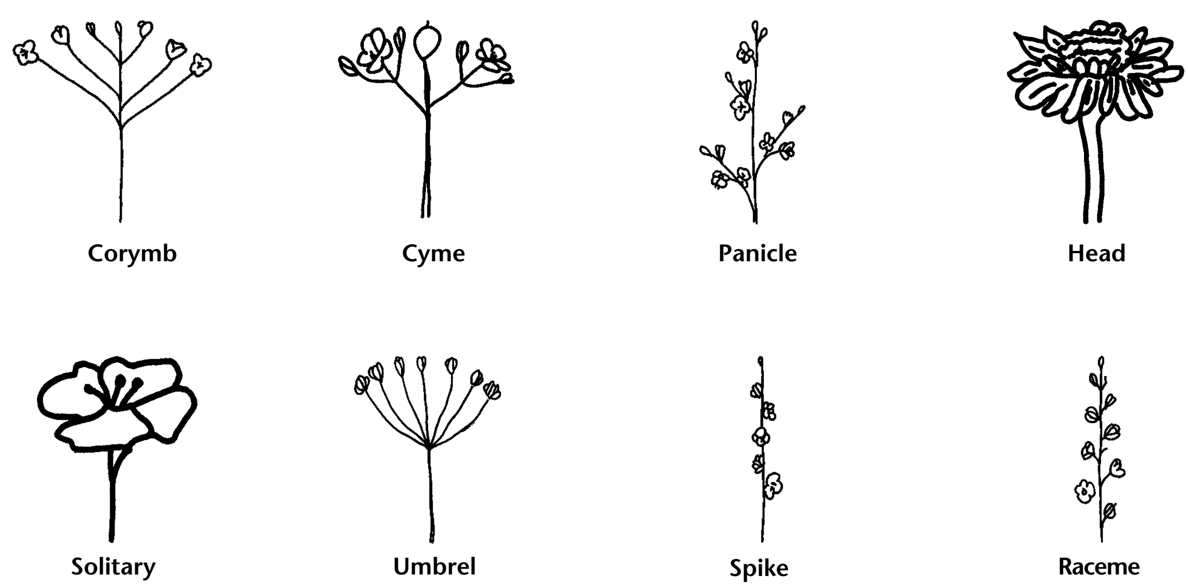


Figure 22. Types of inflorescences.

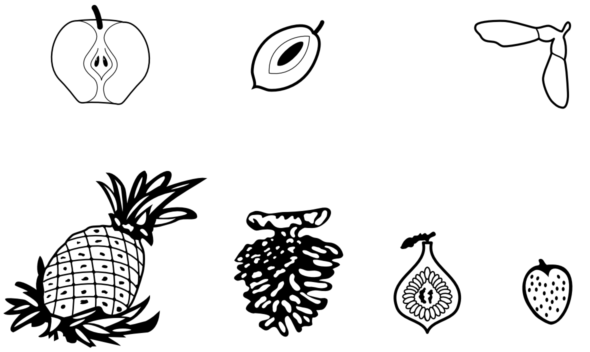


Figure 23. Types of fruits.

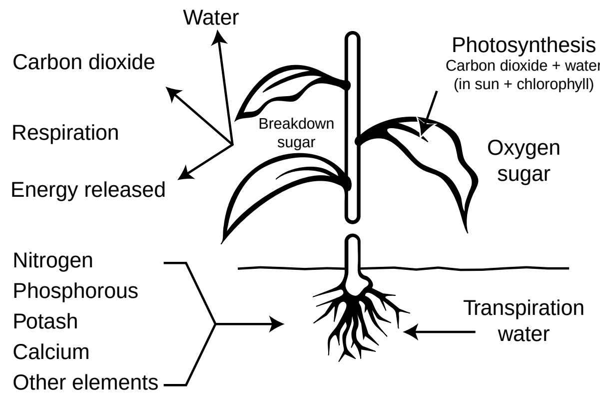


Figure 24. Plant growth process.

domly along the peduncle in such a way that the florets create a flat, round top. Yarrow has a corymb inflorescence. An umbel is similar except that the pedicels all arise from one point on the peduncle, such as dill. A head or composite inflorescence is made up of numerous, stemless florets, which are characteristic of daisy inflorescence.

Cyme is the second group of inflorescences. In this case, the top floret opens first and blooms downward along the peduncle. A dischasium cyme has florets opposite each other along the peduncle, such as Baby's-breath inflorescence. A helicoid cyme is one in which the lower florets are all on the same side of the peduncle as in freesia and statice inflorescences. A scorpioid cyme is one in which the florets are opposite each other along the peduncle as in tomato and potato inflorescences.

Fruits

Parts of Fruit

Fruit consists of the fertilized and mature ovules (seeds) and the ovary wall. The wall may be fleshy, as in an apple, or dry and hard, as in a maple fruit. The only parts of the fruit which are genetically representative of both the male flower and female flower are the seeds (mature ovules). The rest of the fruit arises from the maternal plant and is, therefore, genetically identical to that parent plant. Some fruits have seeds enclosed within the ovary, such as apples, peaches, oranges, squash, and cucumbers. Others have seeds that are situated on the periphery of fruit tissue, such as corn and strawberries.

Types of Fruit

Fruits can be classified as simple fruits, aggregate fruits or multiple fruits (fig. 23). Simple fruits develop from a single ovary, such as cherries, peaches (drupe), pears, apples (pome), and tomatoes (berries). Tomatoes are a botanical fruit, since they develop from the flower, as do squash, cucumbers, and eggplant. All of these fruits develop from a single ovary.

Other types of simple fruit are dry. The fruit wall becomes papery or leathery and hard as opposed to the fleshy examples just mentioned. Examples are peanut (legume), poppy (capsule), maple (samara) and walnut (nut). An aggregate fruit comes from a single flower that has many ovaries. The flower appears as a simple flower with one corolla, one calyx, and one stem but many pistils or ovaries. The ovaries are fertilized separately and independently. Examples are strawberry, raspberry, and blackberry. If ovules are not pollinated successfully, the fruit will be misshapen and imperfect. Multiple fruits are derived from a tight cluster of separate, independent flowers borne on a single structure. Each flower will have its own calyx and corolla. Pineapple, fig, and the beet seed are examples of multiple fruits.

The seed or matured ovule is made up of three parts . The embryo is a miniature plant in an arrested development state. Most seeds contain a built-in food supply called the endosperm (the orchid is an exception). The endosperm can be made up of proteins, carbohydrates, or fats. The third part is the hard outer covering, called a seed coat, which protects the seed from disease and insects. The seed coat also prevents water from entering the seed and initiating the germination process before the proper time.

Plant Processes

The three major processes in plant growth and development are photosynthesis, respiration, and transpiration (fig. 24).

Photosynthesis

Photosynthesis literally means "to put together with light." One of the major differences between plants and animals is the plant's ability to manufacture its own food. To produce food for itself, a plant requires energy from sunlight, water from soil and carbon dioxide from air. If any of these ingredients is lacking, photosynthesis (or food production) will stop. If any factor is removed for a long period of time, the plant will die. The photosynthetic reaction is shown in equation 1.

Plants can store the energy from light in carbohydrates, such as sugars and starches, for use during days when light is limited. They also can transport these chemicals to the roots. Sugars and starches are converted back to water and carbon dioxide (CO_2), and the stored energy is released to perform activities necessary for growth in a process called respiration.

Only cells in the mesophyll layer of the plant leaves and stems can manufacture energy. These cells, which contain chloroplasts, are located between and protected by the leaf's upper and lower epidermis (fig. 25). The green pigment, chlorophyll, is found in the chloroplasts and traps light energy, so it can be used to manufacture sugar and starches.

Photosynthesis depends on the availability of light. Generally speaking, as sunlight increases in intensity, photosynthesis increases. This means greater food production. Many garden crops, such as tomatoes, respond best to maximum sunlight. As light intensity decreases, tomato production decreases drastically. Only two or three tomato varieties will produce any fruit at all in greenhouses in late fall and early spring months when sunlight is minimal.

Water plays several important roles in photosynthesis. First, it maintains a plant's turgor, or the firmness or fullness of plant tissue. Turgor pressure in a cell can be compared to air in an inflated balloon. Water pressure or turgor is needed in plant cells to maintain shape and ensure cell growth. Second, water is split into hydrogen and oxygen by the sun's energy that has been absorbed by the chlorophyll in the plant leaves. The oxygen is released to the atmosphere and the hydrogen is used to manufacture carbohydrates. Third, water dissolves minerals from the soil and transports them from the roots throughout the plant. These minerals serve as raw materials in the growth of new plant tissues. The soil surrounding a plant should be moist, but not too wet or too dry. Water is pulled through the plant by evaporation of water through the leaves, a process known as transpiration. When the guard cells in leaves inflate, opening the stomata, water is lost from the leaf.

Photosynthesis also requires carbon dioxide, which enters the plant through the stomata. Carbon dioxide is split into carbon and oxygen, which are used to manufacture carbohydrates. Carbon dioxide in the air is plentiful enough so that it is not a limiting factor in plant growth. However, since carbon dioxide is consumed in making sugars and is not replenished by plants at a rapid rate, a tightly closed greenhouse in midwinter may not allow enough outside air to enter the greenhouse to maintain an adequate carbon

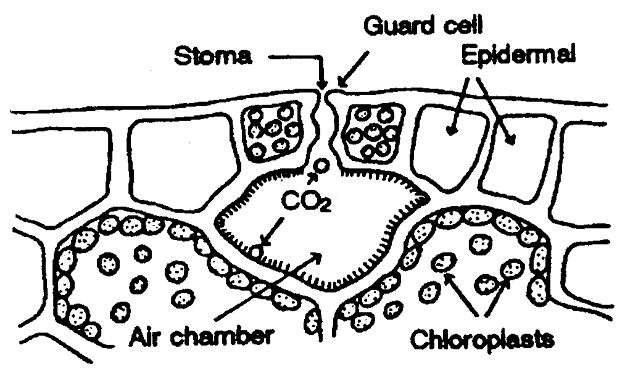


Figure 25. Cross section of a leaf.

Equation 1.

$$\text{Carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll cells}]{\text{673 kg of radiant energy}} \text{sugar} + \text{oxygen}$$

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Equation 2.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Heat}$$

dioxide level. Under these conditions, improved roses, carnations, tomatoes, and certain other crops are produced if the carbon dioxide level is raised with carbon dioxide generators or, in small greenhouses, with dry ice.

Although not a direct component in photosynthesis, temperature is an important factor. Photosynthesis occurs at its highest rate at temperatures ranging from 65° to 85° F (18° F to 27° C), and decreases when temperatures are above or below this range.

Respiration

Carbohydrates made during photosynthesis are of value to the plant when they are converted to energy. Plants use this energy to build new tissues or to grow. Oxidation is the chemical process by which sugars and starches produced by photosynthesis are converted to energy. It is similar to burning wood or coal to produce heat. Controlled oxidation in a living cell is known as respiration and is shown by equation 2.

This equation is the opposite of that used to illustrate photosynthesis. Therefore, photosynthesis can be called a building process, while respiration is a breaking-down process.

By now it should be clear that respiration is the reverse of photosynthesis (table 1). Unlike photosynthesis, respiration occurs at night as well as during the day. Respiration occurs in all life forms and in all cells. The release of accumulated carbon dioxide and the uptake of oxygen occurs at the cell level. In animals, blood carries both carbon dioxide and oxygen to and from the atmosphere by means of the lungs or gills. In plants, there is simple diffusion into the open spaces within the leaf and exchange through the stomates.

Transpiration

Transpiration is the process by which a plant loses water primarily from leaf stomata. Transpiration is a necessary process that uses about 90 percent of the water that enters the plant through the roots. The other 10 percent of water is used in chemical reactions and in plant tissues. Transpiration is necessary to transport minerals from the soil to the plant parts, cool plant parts through evaporation, move sugars and plant chemicals, and maintain turgor pressure. The amount of water lost from the plant depends on several environmental factors, such as temperature, humidity, and wind or air movement. As temperatures or air movement increase, transpiration increases. As humidity decreases, transpiration increases.

Plant Hormones

Plant hormones are naturally occurring chemicals produce in one part of the plant and translocated to another part of the plant, where it performs its physiological function. The function of many hormones may be mimicked by synthetically produced plant growth regulators. The class of plant hormone/plant growth regulator most commonly used by gardeners are the auxins. The hormone indole acetic acid is produced in plant buds and translocates to the roots where it stimulates root growth. Indole butyric acid and napthelene acetic acids are among several commonly produced auxin plant growth regulators available in nurseries as powders applied to the base of stem cuttings to stimulate root formation. Natural auxins also are responsible for the phenomenon called apical dominance, which refers to the fact that the auxin produced in a terminal bud inhibits the growth of lateral buds below the terminal bud. When the terminal bud is lost due to pruning or injury, the lower buds are released from this control and begin to grow.

Gibberillins also are important hormones, but are rarely used by home gardeners. Its natural function within the plant is to stimulate flowering in some plants and to cause stem elongation observed in bolting of lettuce and other biennial plants. It is used commercially to cause enlargement of some varieties of seedless grapes.

Ethylene gas also has hormonal properties and is produced in some plants. It causes flowering in some plants and fruit ripening in others.

Environmental Factors Affecting Plant Growth

Plant growth and distribution are limited by the environment. If any single environmental factor is less than ideal, it becomes a limiting factor in plant growth. Limiting factors also are responsible for the geography of plant distribution. For example, only plants adapted to limited amounts of water can live in deserts. Most plant problems are caused by environmental stress, either directly or indirectly. Therefore, it is important to understand the environmental aspects that affect plant growth. These factors are light, temperature, water, humidity, and nutrition.

Light

Light has three principal characteristics that affect plant growth. These are light quality, light quantity, and light duration.

Light quality refers to the color or wavelength reaching the plant surface. Sunlight can be broken up by a prism into respective colors of red, orange, yellow, green, blue, indigo, and violet. On a rainy day, raindrops act as tiny prisms and break the sunlight into these colors, producing a rainbow. Red and blue light have the greatest effect on plant growth. Green light is least effective to plants, because it is reflected not absorbed. It is this reflected light that makes them appear green to us. Blue light is primarily responsible for vegetative growth or leaf growth. Red light, when combined with blue light, encourages flowering in plants.

Table 1. Comparison of photosynthesis and respiration.

Photosynthesis	Respiration
1. Produces food	1. Uses food for plant energy
2. Stores energy	2. Releases energy
3. Occurs in cells that contain chloroplasts	3. Occurs in all cells
4. Releases oxygen	4. Uses oxygen
5. Uses water	5. Produces water

Fluorescent light or cool white light is high in the blue range of light quality and is used to encourage leafy growth. Such light is excellent for starting seedlings. Incandescent light is high in the red or orange range, but generally, it produces too much heat to be a valuable light source. Fluorescent grow lights have a mixture of red and blue colors that attempt to imitate sunlight as closely as possible, but they are costly and generally are not of any greater value than regular fluorescent lights.

Light quantity refers to the intensity or concentration of sunlight and varies with the season of the year. The maximum is present in summer, and the minimum in winter. The more sunlight a plant receives, up to a point, the better capacity it has to produce plant food through photosynthesis. As the quantity of sunlight decreases, the photosynthetic process decreases. Light quantity can be decreased in a garden or greenhouse by using cheesecloth shading above the plants. It can be increased by surrounding plants with reflective material, white backgrounds, or supplemental lights.

In addition to seasonal variations in light intensity, global latitude directly affects sunlight intensity. Light intensity is greatest near the equator and lessens with distances both north and south of the equator. For example, the increased light intensity in New Mexico versus Kansas may explain why some plants (bluegrass) thrive in Kansas' summers and burn up in New Mexico's, even though air temperatures are equal. The dry air, higher elevation, and more southerly latitude result in higher light levels. Even in New Mexico, there are differences in light intensity and climate. According to the U. S. Department of Agriculture's Plant Hardiness Zone Map, New Mexico has five distinct hardiness zones. The hardiness values assigned to these zones also are accompanied by varying degrees of light intensity. However, elevation and cloudiness will have the greatest influence on light intensity in New Mexico.

Light duration refers to the amount of time a plant is exposed to sunlight and is designated as the photoperiod. When the photoperiod was first recognized, it was thought that the length of periods of light triggered flowering. The various categories of response were named according to the light length (i.e., short day and long day). It was then discovered that it is not the length of the light period but the length of uninterrupted dark periods that is critical to floral development. The ability of many plants to flower is controlled by the photoperiod.

Plants can be classified into three categories depending on their flowering response to the duration of light or darkness. These are short-day, long-day or day-neutral plants. Short-day plants form their flowers only when day length is less than about 12 hours in duration. Short-day plants include many spring and fall flowering plants, such as chrysanthemum and poinsettia. Long-day plants form flowers only at day lengths exceeding 12 hours (short nights). They include almost all of the summer flowering plants, such as rudbeckia and California poppy, as well as many vegetables including beet, radish, lettuce, spinach, and potato. Day-neutral plants form flowers regardless of day length. Some plants do not fit into any category but may be responsive to combinations of day lengths. The petunia will flower regardless of day length, but it will flower earlier and more profusely under long daylight. Since chrysanthemums flower under the short days of spring or fall, the method of manipulating the plant into experiencing short days is very simple. If long days are predominant, a shade cloth is drawn over the chrysanthemum for 12 hours daily to block out light until flower buds are initiated. To bring a long-day plant into flower when sunlight is not longer than 12 hours, artificial light is added until flower buds are initiated.

Temperature

Temperature affects the plant's growth and productivity. The degree of this effect depends on whether the plant is a warm- or cool-season crop. If temperatures are high and day length is long, cool-season crops like spinach will flower. Temperatures that are too low for a warm-season crop like tomato will prevent fruit set. Adverse temperatures also stunt growth and produce poor quality vegetables. For example, bitterness in lettuce is caused by high temperatures.

Sometimes, temperatures are used in connection with day length to manipulate plant flowering. Chrysanthemums will flower for a longer period of time, if daylight temperatures are 59° F (15° C). The Christmas cactus forms flowers as a result of short days and low temperatures. Temperatures alone also can influence flowering. Daffodils are forced to flower by putting the bulbs in cold storage at 35° to 40° F (2° to 4° C) in October. Cold temperatures allow bulbs to mature, and then the bulbs are transferred to the greenhouse where growth begins in midwinter. The flowers are then ready for cutting in 3 to 4 weeks.

Thermoperiod refers to a daily temperature change. Plants respond and produce maximum growth when exposed to a day temperature that is about 10 to 16 degrees higher than a night temperature. This allows the plant to photosynthesize (build up) and respire (break down), during an optimum daytime temperature and to curtail the respiration rate during a cooler night. Temperatures higher than needed cause increased respiration, sometimes above photosynthesis rate. This means that the products of photosynthesis are used more rapidly than they are produced. For growth to occur, photosynthesis must be greater than respiration.

Referring back to the bluegrass example used for the effect of light intensity on plants, bluegrass also may thrive in Taos and not in Las Cruces because of an imbalance of photosynthesis and respiration. With relatively hot nighttime temperatures in Las Cruces compared to Taos, respiration of the bluegrass plant may exceed photosynthesis and thus lead to unhealthy or dead grass.

Low temperatures can produce poor growth. Photosynthesis is slowed by low temperatures. Since photosynthesis is slowed, growth is slowed, resulting in lower yields. Not all plants grow best under the same temperature range. For example, snapdragons grow best at nighttime temperatures of 66° F (12° C) and the poinsettia at 62° F (17° C). Florist cyclamen does very well under very cool conditions, while many bedding plants prefer a higher temperature. Recently, it has been found that roses can tolerate much lower nighttime temperatures than previously believed. This has resulted in energy conservation for greenhouse growers.

In some cases, however, a certain number of days of low temperature are needed by plants in order to grow properly. This is especially true of crops growing in cold regions of the country. Peaches are a prime example. Most varieties require 700 to 1,000 hours below 45° F (7° C) and above 32° F (0° C) before they break their rest period and begin to grow. Lilies need 6 weeks of temperatures at 33° F (1° C) before blooming.

Plants can be classified as either hardy or nonhardy, depending upon their ability to withstand cold temperatures. This is the basis of the U. S. Department of Agriculture's Plant Hardiness Zone Map. It should be mentioned this map does not consider the plant's ability to withstand various soil types (alkaline versus acidic, clay versus sand).

Winter injury can occur to nonhardy plants, if temperatures are too low or if unseasonably low temperatures occur early in fall or late in spring. Winter injury also may occur because of desiccation or drying out. Plants need water during winter. When the soil is frozen, water moving into the plant is severely restricted. On a windy winter day, broadleaf evergreens can become water-deficient after a few minutes; then the leaves or needles turn brown. Wide variations in temperatures can cause premature bud break in some plants, causing fruit bud freezing damage. Late spring frosts can ruin entire peach crops. If temperatures drop too low during the winter, entire trees of some species are killed by freezing and splitting plant cells and tissue. A review of the effect of temperature on plant growth is provided (table 2).

Table 2. Review of temperature effects on plant growth.

Photosynthesis:	Increases with temperature to a point.
Respiration:	Rapidly increases with temperature.
Transpiration:	Increases with temperature.
Flowering:	May be partially triggered by temperature.
Sugar storage:	Low temperatures reduce energy use and increase sugar storage; high temperatures deplete sugar storage.
Break dormancy:	After a period of low temperature, dormancy is broken and the plant resumes active growth.

Water

As mentioned earlier, water is a primary component in photosynthesis. It maintains the turgor pressure or tissue firmness and transports nutrients throughout the plant. In maintaining turgor pressure, water is the major constituent of the cell's protoplasm. With turgor pressure and other changes in the cell, water regulates the opening and closing of stomates, thus regulating transpiration. Water also provides the pressure to move a root through the soil. A critical role of water is that of solvent for plant nutrients and for moving carbohydrates to their site of use or storage. Water is important in the chemical reactions of photosynthesis and respiration. By its gradual evaporation (transpiration) from the leaf surface near the stomate, water helps stabilize plant temperature.

Relative humidity greatly affects the transpiration rate and water use by the plant. Relative humidity, expressed as a percentage, is the ratio of water vapor in the air at a given temperature and pressure to the amount of water the air could hold at that temperature and pressure. 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 relative humidity (RH) is:

RH = **water in air/water air could hold**
(at constant temperature and pressure)

or

RH = **3/4 = .75 expressed as a percentage,**
this equals 75 percent.

Warm air holds more water vapor than cold air. Therefore, if the amount of water in the air stays the same and the temperature increases, the relative humidity decreases. Water vapor will move from an area of high relative humidity to one of low relative humidity. The greater the difference in humidity, the faster water will move.

The relative humidity in the air space between the cells within the leaf approaches 100 percent. Therefore, when the stomate is open, water vapor rushes out. As water moves out, a bubble of high humidity is formed around the stomate (fig. 26). This humidity bubble helps slow down transpiration and cools the leaf. If winds blow the humidity bubble away, transpiration will increase.

Movement of Water through the Plant

The cohesion theory best explains how water moves into and through a plant. It is through this theory you can begin to understand how water moves from the root system of a California redwood through the vascular system and ultimately to the tips of the leaves some 350 feet above ground. There are three basic elements of the cohesion theory—the driving force, hydration of the pathway, and the cohesion of water.

The driving force for the movement of water through the plant is the tremendous affinity dry air has for water. Discussed earlier in terms of relative humidity, water moves from an area of high water concentration to an area of lower concentration. For example, air at a relative humidity of 50 percent will pull moisture from plant tissue, which is near 100 percent saturation. This process was discussed earlier and is known as transpiration.

The hydration component refers to water's ability to adhere with great strength to the surface of cell walls. As water is literally sucked through the plant by transpiration, hydration keeps the water moving up, preventing it from receding back down the plant due to gravity forces.

Cohesion of water is the theory's key component. Water is highly resistant to changes in volume and can be subjected to strong suction or tension. The driving force of transpiration can pull water from the soil into the roots and up into the plant. Through the properties of hydration and cohesion, water can then be pulled to the top of even a 350 foot redwood tree.

Plant Response to Lack of Water

When plants experience a lack of water in the soil, several responses can occur. The most common sign of drought stress is wilting. However, plants also show other signs, including leaf rolling, color changes, leaf burning, and leaf loss.

Most of the turf grasses show stress by wilting, as indicated when footprints are seen after a walk across

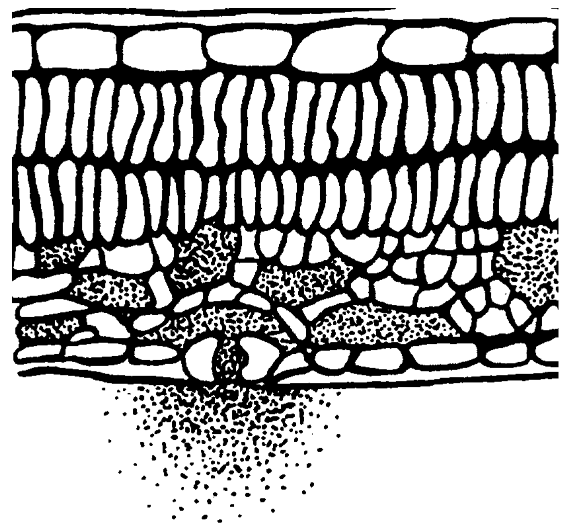


Figure 26. Cross section of a leaf.

the lawn. Turf grasses with wider leaves will roll their leaves lengthwise in an attempt to reduce the leaf area and water loss. Lawn grasses often show a dullness versus the shiny green of a healthy plant.

Many vegetables, flowers, and shrubs will show these signs and/or burning of the leaf edges or margins. The crispy margins occur when less than adequate supplies of water are flowing through the plant. Some plants in the landscape and garden also will drop leaves or fruit during drought stress. The plant is simply attempting to lighten the demand for water and increase its ability to survive drought. Two examples of this plant response follow: ocotillo (*Fouquieria splendens*), a desert plant that drops its leaves under water stress, and the common fig, which drops its fruit at the first sign of water shortage.

Managing Plant Water Stress

The goal of the home gardener is to reduce plant water stress in order to maintain a quality landscape and/or a productive garden. When adequate moisture is available to the plant, a continuous flow of water exists from the root hairs to the leaves. If inadequate moisture is present in the soil or if the evaporation rate from the leaves exceeds the rate at which the plant can move water upwards, then water stress ensues.

During hot and dry summer months, moderate stress can be tolerated by most plants on a daily basis, as long as moisture is replenished during the low-stress night period. However, severe or prolonged moisture stress will result in permanent wilting and damage.

Plants differ greatly in their ability to extract water from the soil and in the absolute amount of water required for normal plant growth and development. Some plants, in fact, are classified as "drought tolerant," because they can function with dry soil conditions. Drought tolerance can be due to several physical features: deep and well-developed root systems; waxy leaf surfaces; leaf hairs, which reduce air flow past the leaf surface; shiny surfaces which reflect light; leaves that fold up or drop under stress conditions.

Too much water in the root zone also can be damaging to the plant due to a reduction in oxygen in the area around the root hairs. This can occur when irrigation is performed too frequently or in too great an amount for the plant to remove and use water from the root zone.

Thus, the objective of a proper irrigation schedule is to supply the right amount of water before harmful stress occurs and to supply enough water at that time to replenish the amount of water used since the last irrigation.

Notes