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Chapter 1

Basic Botany, Physiology and Environmental Effects on Plant Growth

Plant Classification

Plants have inhabited earth for hundreds of millions of years and are considered by many to be some of the first life forms. Virtually all other living creatures depend on plants for survival. Plants convert energy from the sun into food stored as carbohydrates through the process known as photosynthesis. Because animals are not capable of the same process, to survive they must eat plants or other animals that have vegetarian diets. Likewise, plants provide oxygen for humans and animals to breathe. In photosynthesis, plants pull carbon dioxide from the atmosphere and release oxygen into it.

There are three major differences between plants and animals:

- Plants have chlorophyll, a green pigment necessary for photosynthesis.
- Plant cell walls are made sturdy by a material called cellulose.
- Plants are generally rooted and do not move from place to place on their own.

In order to study the billions of different organisms living on earth, biologists have classified organisms since the time of Aristotle (384–322 B.C.). The first systems used artificial classification schemes and grouped organisms with similar physical characteristics such as leaf shape, plant size, flower color, etc. However, over time none of these systems proved workable. Early in the 17th Century, the Swedish naturalist Carolus Linnaeus sought to use a revolutionary approach and base classification on the flowers and/or reproductive parts of a plant. This has proven to be the best system because flowers are the plant part least influenced by environmental changes. Since then, biologists have emphasized natural systems of classification and have attempted to define morphological criteria that best reflect evolutionary relationships.

These relationships can be confusing for an amateur naturalist. For example, according to modern botany:

- A palm tree has more in common with a blade of grass than with other trees.
- A strawberry plant is more closely related to an apple or apricot tree than to a clover or geranium.
- A ginkgo tree is so different from other plants that it is classified by itself. But if you have to group it with other plants, it is more closely related to pine trees than to oaks, maples or sweetgum.

This system of classification is called taxonomy and usually uses both English and Latin names for the different divisions.

All plants are included in one so-called kingdom (Kingdom Plantae), which is then broken down into smaller divisions based on several characteristics. The five major kingdoms are as follows:

Monera – namely the bacteria including the blue-green bacteria, once called blue-green algae.

Plants – mainly terrestrial, possessing cell walls and capable of photosynthesis.

Animals – motile, the cells of which are not surrounded by cell walls.

Fungi – non-motile, cell wall-bound, spore-bearing and can be saprophytic or parasitic.

Protista – defined really as none of the above. It is comprised of microorganisms including protozoa, slime molds, and algae.

The Binomial Name

While the full taxonomic name of a plant might seem long and cumbersome, the real core of its name is the binomial name. Binomial literally means two names and refers to the two core names that are genus and species.

For example, the full name of the common annual sunflower is *Plantae Tracheobionta Spermatophyta Magnoliophyta Magnolipsida Asteridae Asterales Asteraceae Helianthus annuus L.*

Here is a description of what the various names represent.

Kingdom = *Plantae* – The plant kingdom.

Subkingdom = *Tracheobionta* – Vascular plants. Plants with a vascular system can transport nutrients throughout the organism. Plants without a vascular system are usually small and almost never exceed 1 inch in height. Good examples of nonvascular plants are the liverworts and mosses.

Superdivision = *Spermatophyta* – Seed plants. Seeded plants are higher on the evolutionary chain. Seeds carry all of the genetic information needed to make a new plant. They even carry a small food supply to help the plant get started. Ferns and mosses are quite primitive and reproduce using spores, not seeds. Individual spores do not carry a complete set of genes. Two spores of the same species must combine in perfect conditions to grow a new organism.

Seed plants are divided into two main groups:

Gymnospermae – Naked seeded plants. These include conifers (pines, cedars, fir trees etc.), cycads (ancient plants that look a little like palm trees with pine cones), ginkgo, and gnetophyta. These plants never flower.

Angiospermae – Flowering plants.

Division = *Magnoliophyta* – Flowering plants. The flowers of flowering plants are the most remarkable feature that distinguishes them from other seed plants. Flowers initiated the evolutionary split between gymnosperms and angiosperms and allowed them to eventually dominate terrestrial ecosystems.

Class = *Magnoliopsida* – The angiosperms (or flowering plants) can be divided into monocotyledons and dicotyledons.

Monocotyledons – One-seed-leaf plants (palms, grasses, lilies, orchids etc.)

Dicotyledons – Two-seed-leaf plants.

In traditional taxonomy, flowering plants that were not monocotyledons were classified as dicotyledons. These names describe how the plants start life as they sprout from seed. Monocots will always produce a single seed leaf, while dicots will usually produce two seed leaves – although they may occasionally produce three or more. Dicotyledon literally means two seed leaves.

Other differences include:

Flowers: The flower parts in monocots are usually multiples of three while in dicots are multiples of four or five.

Stems: In monocots the stem vascular bundles are scattered, while in dicots they are in a ring.

Secondary growth: In monocots stems rarely show secondary growth. In dicots, stems frequently have secondary growth.

Pollen: In monocots, pollen has one furrow or pore while in dicots they have three.

Roots: The roots are adventitious in monocots, while in dicots they develop from the radicle.

Leaves: In monocots, the major leaf veins are parallel. In dicots they are reticulated.

Subclass = Asteridae

Order = Asterales

Family = Asteraceae Aster Family

Genus = *Helianthus*

A genus is a group of related species of plants. In this case the genus is *Helianthus*, the sunflower, which contains approximately 70 spe-

cies. This number is subject to change from year to year as new species are discovered and/or old species are combined. Combining, or ‘lumping’ happens when, after much botanical debate, it is decided that two different species are not really different enough to justify being called separate, so instead they are lumped into a single species. Sometimes the opposite happens when a species is divided because two subspecies are considered to be different enough to actually be classified as separate species. If you have heard about the ‘lumpers’ and the ‘splitters’ arguing about how to classify plants, then this is an example. Classification is a living science, and like the organisms it studies, it must change and adapt over time.

Species = *Annuus*

In this case the name just means annual.

L – this ‘L’ refers to the botanist who scientifically described the plant – in this case, none other than Carl Linnaeus himself, the champion of the binomial system.

While all these names help to organize this species’ place in the whole system, it is the binomial name that is most often used. The unique binomial name for the common annual sunflower is ‘*Helianthus annuus*’, which translates from the Latin to ‘Sunflower, annual’. The genus and species names of plants have been compared to the first and last names of people – there are many Toms, but they are divided into Tom Smith, Tom Jones, Tom Johnson, and so on. Similarly, there are many species of *Quercus* (oaks) but only one *Quercus alba* (White Oak). The species name is a specific adjective or noun that narrows down an entire genus to one plant.

Learning the scientific names of plants can be a lot of fun. After working with these names awhile, you will begin to recognize certain prefixes, suffixes, and word roots and be able to identify plants by physical characteristics that match their names.

What differentiates plants from animals?

It is obvious that plants and animals are different. Because they cannot move, plants must be extremely responsive to the environment and have their life cycle in perfect synchrony with the seasons. Plants must survive inhospitable seasons or overwinter as seeds, some sort of underground structure, or in the case of deciduous trees and shrubs, in a “bare-bones” leafless state.

Another noted difference is that plants use water and carbohydrates — two easily found materials — to generate size. With no bones or proteins as with animals, they use rigid cell walls to attain height. Each plant cell contains a protoplast with a central vacuole that makes the cell larger than it would be otherwise. The protoplast is enclosed by a cell wall. The cell wall resists expansion as the protoplast takes in water by osmosis. This mutual antagonism between protoplast and cell wall makes each cell a turgid little box. By stacking one turgid box on top of

the other, herbaceous plants are able to rise several feet into the air with little or no strengthening material.

Likewise, because they cannot move—and are eaten by animals and insects and are attacked by disease and decay, plants have evolved a unique mode of development. Plant growth occurs at growing tips called meristems. And each plant cell is totipotent. That is it is capable of regenerating an entire plant with all of the needed cell types. These two features combined provide plants with the awesome power of regeneration, something few animals can do. A limb lopped off an animal can lead to disaster. For a plant it just regenerates the missing portion and continues to grow.

Plant Growth and Cell Division

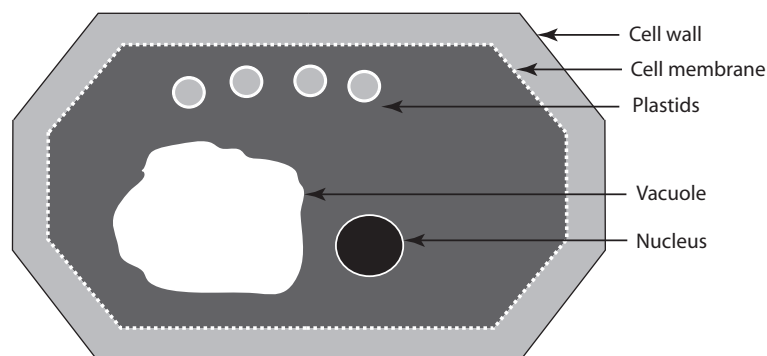
There are two types of cell division: mitosis and meiosis. Mitosis is a fundamental process for life. During mitosis, a cell duplicates all of its contents, including chromosomes, and splits to form two identical daughter cells. These cells are used for growth and development.

The other type of cell division, meiosis, ensures that plants and animals have the same number of chromosomes in each generation. It is a two-step process that reduces the chromosome number by half to form sperm and egg cells. When the sperm and egg cells unite at fertilization, each contributes half of the required chromosomes so the resulting embryo will have a full set. Meiosis also allows for genetic variation through a process of DNA shuffling while the cells are dividing. This is why not all animals and open-pollinated plants look the same.

Where Does Growth Occur?

In higher plants the process of forming new cells, mitosis, is restricted to special growth regions called meristems. These regions usually occur at the tips of stems or roots and in the vascular system. In general, during growth cells divide, elongate, and then differentiate into structures such as roots and shoots, xylem, or phloem. Meristems can also produce new meristems — these are called primordia. For example, an apical meristem in a bud produces new meristems called leaf primordia — each single primordium will grow into a new leaf. Root primordia grow into new roots.

Botany: Cell Structure



Cell wall: Gives strength and structure to the cell.

Cell membrane: Next to cell wall that forms a boundary for cell contents and is involved in material transport into and out of the cell.

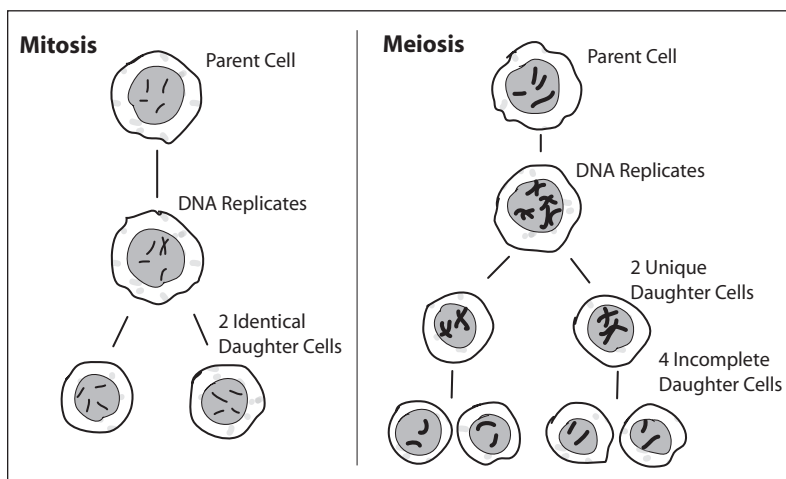
Plastids: Organelles that can produce carbohydrates. Most common is chloroplast which contains chlorophyll.

Vacuole: A large storage compartment to hold materials needed by the cell.

Nucleus: Contains the DNA and is the brain of the cell.

Fiber: Often dead cell that gives flexible support to the plant.

Sclerid: Living or dead cell that is harder than a fiber tissue. Example would be walnut shell.



Basic Botany, Physiology and Environmental Effects on Plant Growth

In order to gain a working knowledge of horticulture, it is necessary to understand the structure and function of plants and the environmental factors that affect plant growth. In the greatly diversified kingdom of plants, all flowering plants have certain structures and functions in common. These similarities are the basis for this chapter.

Plant Parts and Functions

The parts of a plant can be divided into two groups, sexual reproductive parts and vegetative parts. Sexual reproductive parts are those involved in the production of seed. They include flower buds, flowers, fruit and seeds. The vegetative parts include roots, stems, leaves, flowers, and fruit. Although the vegetative parts are not directly involved in sexual reproduction, they often are used in asexual or vegetative forms of reproduction, such as cuttings.

Roots

A thorough knowledge of the root system of plants is essential if their growth, flowering, and fruiting responses are to be understood. The structure and growth habits of roots have a pronounced effect on the size and vigor of the plant, method of propagation, adaptation to certain soil types, and response to cultural practices and irrigation. 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 bear leaves or flowers directly. The principal functions of roots are to absorb nutrients and moisture, to anchor the plant in the soil, to furnish physical support for the stem, and to serve as food storage organs. In some plants, they may be used as a means of propagation.

Types of Roots

A **primary** (radicle) root originates at the lower end of the embryo of a seedling plant. When the primary root continues to elongate downward into the soil, it forms a taproot and becomes the central and most important feature of the root system, with a limited amount of secondary branching. Some trees, especially nut trees like pecan, have a long taproot with very few lateral or fibrous roots. This makes them

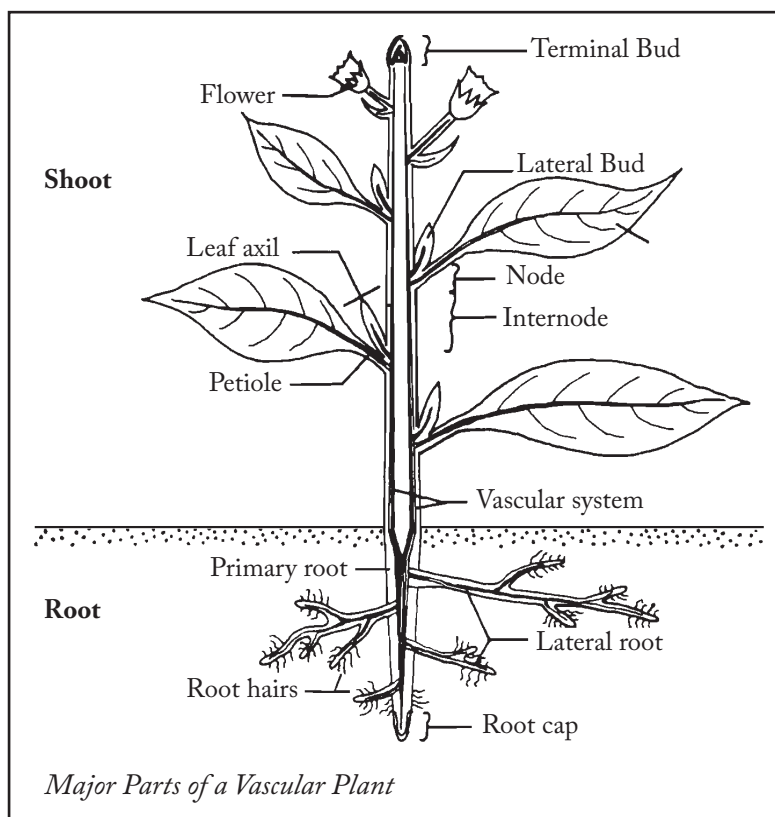
difficult to transplant and necessitates planting only in deep, well-drained soil. The taproot of carrot, parsnip, and salsify is the principal edible part of these crops.

A **lateral**, or secondary, root is a side or branch root which arises from another root.

A **fibrous** root system is one in which the primary root ceases to elongate, leading to the development of numerous lateral roots, which branch repeatedly and form the feeding root system of the plant. A fibrous root is one which remains small in diameter because of a lack of significant cambial activity. One factor, that causes shrubs and dwarf trees to remain smaller than standard trees, is the inactivity of the cambium tissue in the roots.

If plants that normally develop a taproot are undercut so the taproot is severed early in the plant's life, the root will lose its taproot characteristic and develop a fibrous root system. Nurseries do this so trees, which naturally have tap roots, will develop a compact, fibrous root system. This allows a higher rate of transplanting success.

The quantity and distribution of plant roots is very important because these two factors have a major influence on the absorption of moisture and nutrients. The depth and spread of the roots is dependent on the inherent growth



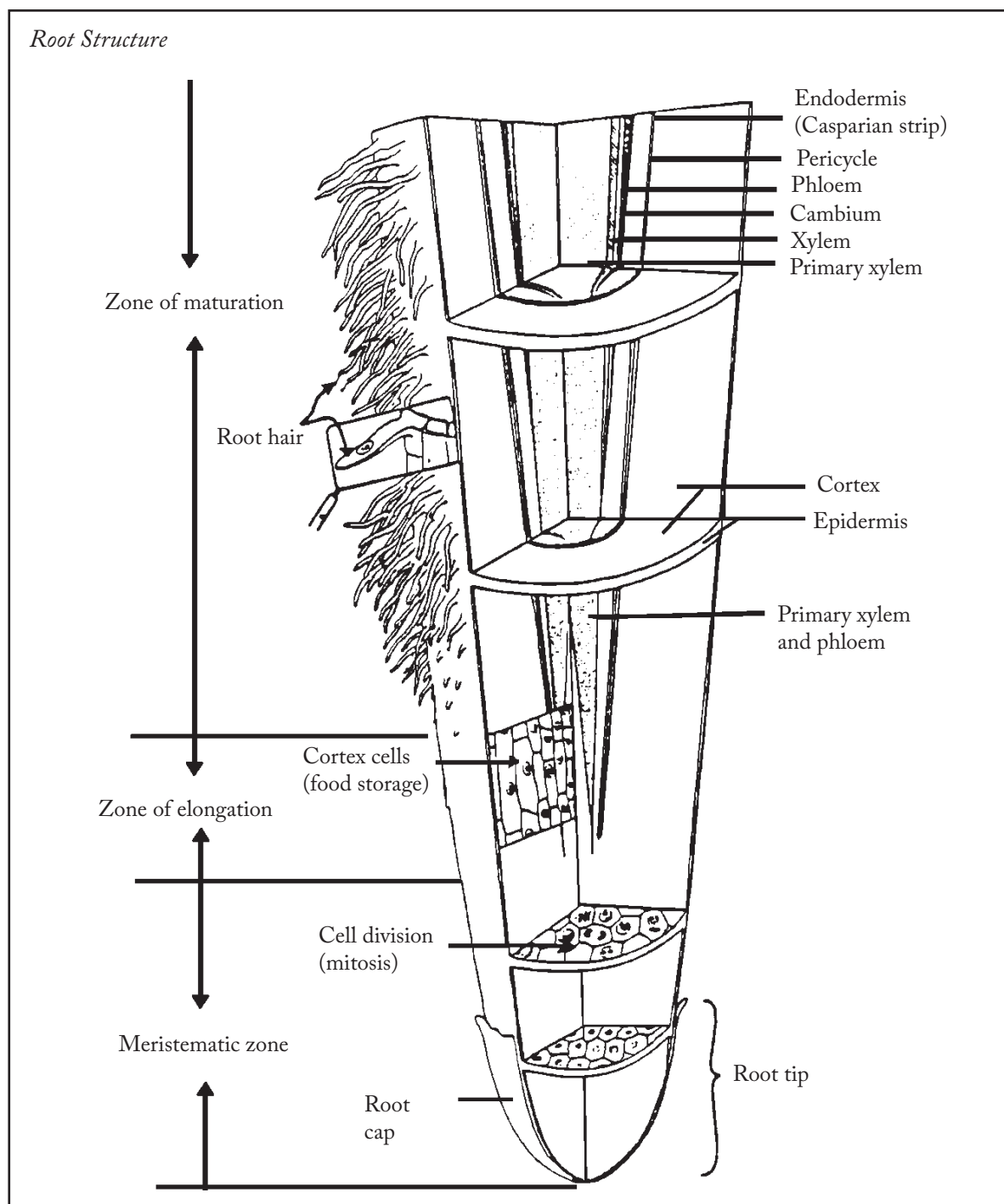
characteristics of the plant and the texture and structure of the soil. Roots will penetrate much deeper in a loose, well-drained soil than in a heavy, poorly-drained soil. A dense, compacted layer in the soil will restrict or stop root growth.

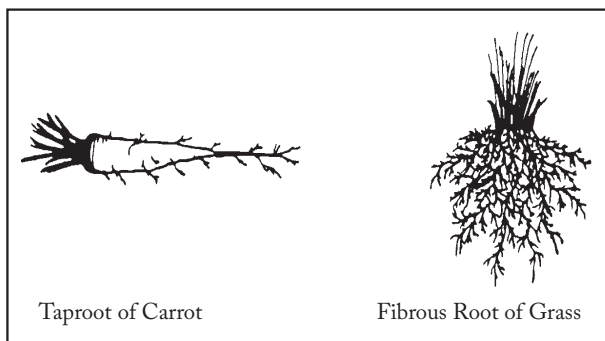
During early development, a seedling plant absorbs nutrients and moisture from the few inches of soil surrounding it. Therefore, the early growth of most horticultural crops which are seeded in rows benefits from band applications of fertilizer, placed several inches to each side and slightly below the seeds.

As plants become well-established, the root system develops laterally and usually extends far 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

Internally, there are three major parts of a root. The **meristem** is at the tip and manufac-





tures new cells; it is an area of cell division and growth. Behind it is the **zone of elongation**, in which cells increase in size through food and water absorption. These cells, by increasing in size, push the root through the soil. The third major root part is the **maturation zone**, in which cells undergo changes in order to become specific tissues such as epidermis, cortex, or vascular tissue. The epidermis is the outermost layer of cells surrounding the root. These cells are responsible for the absorption of water and minerals dissolved in water. Cortex cells are involved in the movement of water from the epidermis and in food storage. Vascular tissue is located in the center of the root, and conducts food and water.

Externally, there are two areas of importance. **Root hairs** are found along the main root and perform much of the actual work of water/nutrient absorption. The **root cap** is the outermost tip of the root and consists of cells that are sloughed off as the root grows through the soil. The root cap covers and protects the meristem.

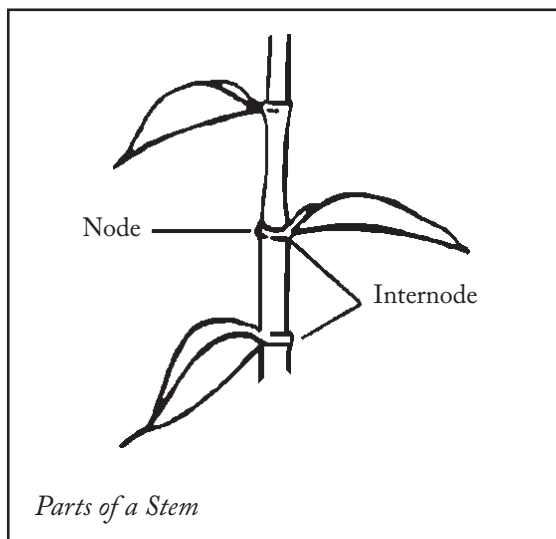
Roots as Food

The enlarged root is the edible portion of several vegetable crops. The sweet potato is a swollen root, called a tuberous root, which serves as a food storage area for the plant. Carrot, parsnip, salsify, and radish are elongated 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. The vascular system transports food, water, and minerals and offers support for the plant. Xylem tubes conduct water and minerals, while phloem tubes conduct food.

The vascular systems of monocots and dicots differ. While both contain xylem and phloem, they are arranged differently. In the



stem of a monocot, the xylem and phloem are paired into bundles; these **bundles** are dispersed throughout the stem. But in the stem of a dicot, the vascular system forms **rings** inside the stem. The ring of phloem is near the bark or external cover of the stem and is a component of the bark in mature stems. The xylem forms the inner ring; it is the sapwood and heartwood in woody plants. The difference in the vascular system of the two groups is of practical interest to the horticulturist because certain herbicides are specific to either monocots or dicots. An example is 2,4-D, which only kills dicots.

The cambium is a meristem, which is a site of cell division and active growth. It is located between the xylem and phloem inside the bark of a stem 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 or leaves (fruit spurs, crowns of strawberry plants, dandelions). Stems can be above ground like most stems we are familiar with, or below ground (potatoes, tulip bulbs). 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, where auxiliary buds develop into leaves or flowers. The area between nodes is called the internode.

The length of an internode may depend on many factors. Decreasing fertility will decrease internode length. Internode length varies with the season. Too little light will result in a long internode, causing a spindly stem. This situation is known as stretch or etiolation. Growth

produced early in the season has the greatest internode length. Internode length decreases as the growing season nears its end. Vigorously growing plants tend to have greater internode lengths than less vigorous plants. Internode length will vary with competition from surrounding stems or developing fruit. If the energy for a stem has to be divided between three or four stems, or if the energy is diverted into fruit growth, internode length will be shortened.

Modified Stems

Although typical stems are above-ground trunks and branches, modified stems can be found above ground and below ground. The above-ground modified stems are crowns, stolons and spurs, and the below-ground stems are bulbs, corms, rhizomes, and tubers.

Above-Ground Stems

Crowns (strawberries, dandelions, African violets) are compressed stems having leaves and flowers on short internodes.

Spurs are short, stubby, side stems that arise from the main stem and are common on such fruit trees as pears, apples and cherries, where they may bear fruit. If severe pruning is done close to fruit-bearing spurs, the spurs can revert to a long, nonfruiting stem.

A **stolon** is a horizontal stem that is fleshy or semi-woody and lies along the top of the ground. Strawberry runners are examples of stolons. Remember, all stems have nodes and buds or leaves. The leaves on strawberry runners are small, but are located at the nodes, which are easy to see. The nodes on the runner are the

points where roots begin to form. The spider plant has stolons.

Below-ground stems such as the potato tuber, the tulip bulb, and the iris rhizome are underground stems that store food for the plant.

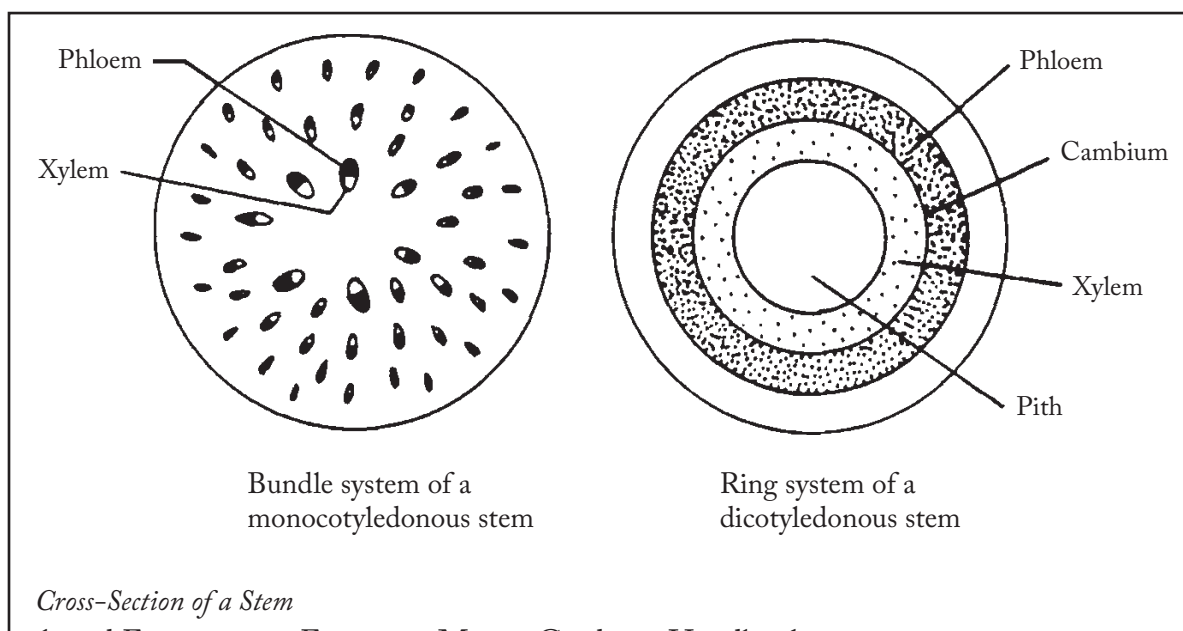
The **tuber**, like any other stem, has nodes that produce buds. The eyes of a potato actually are the nodes on the stem. Each eye contains a cluster of buds.

Rhizomes are similar to stolons, but grow underground. Some rhizomes are compressed and fleshy such as those of iris; they also can be slender with elongated internodes such as Kentucky bluegrass. Johnsongrass is a hated weed principally because of the spreading capability of its rhizomes.

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 tip of the stem. If you cut through the center of a tulip or daffodil bulb in November, you can see the flower parts in miniature within the bulb. Many bulbs require a period of low-temperature exposure before they begin to send up the new plant. Both the temperature and length of this treatment are of critical importance to commercial growers who force bulbs for holidays.

Corms are not the same as bulbs. They have shapes similar to bulbs, but do not contain fleshy scales. A corm is a solid, swollen stem whose scales have been reduced to a dry, leaflike covering.

Some plants produce a modified stem that is referred to as a tuberous stem. Examples



are tuberous begonia and cyclamen. The stem is shortened, flattened, enlarged, and underground. Buds and shoots arise from the 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 often is confused with bulbs and tubers. However, these are roots, not stems, and have neither nodes or internodes.

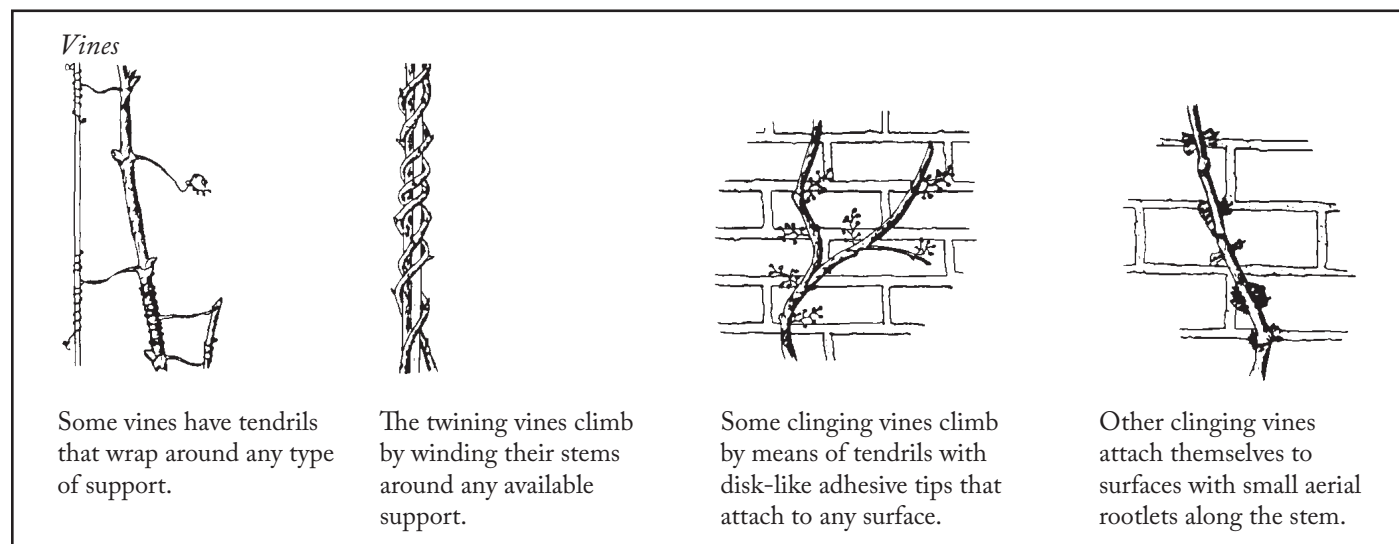
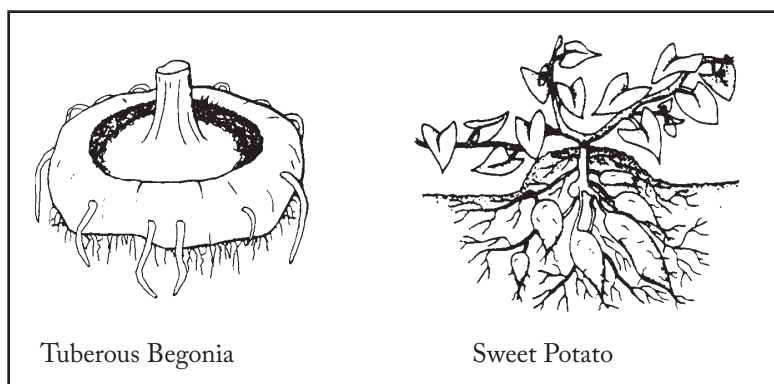
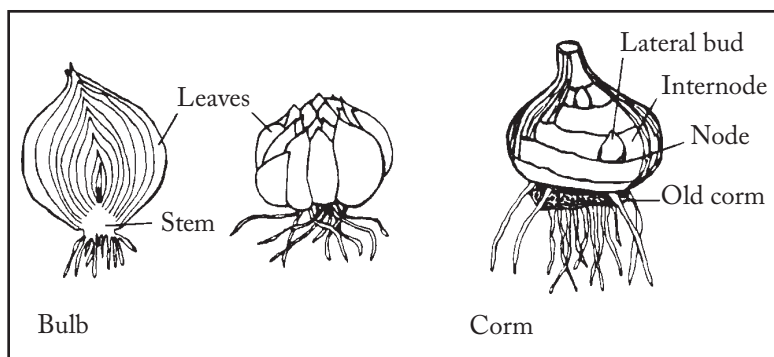
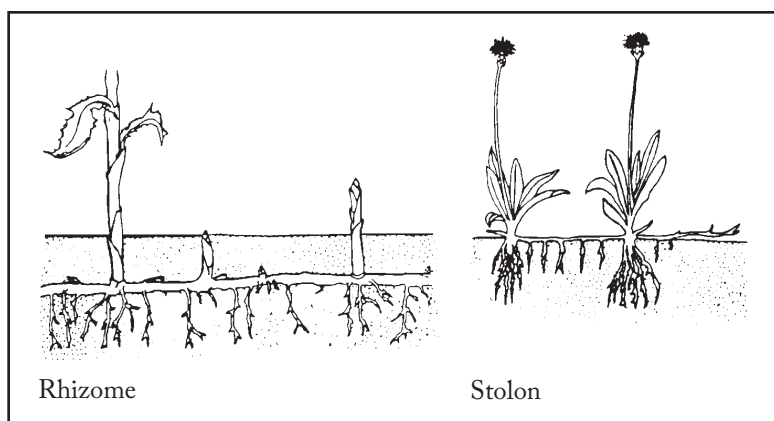
Stems are commonly used for plant propagation. Above-ground stems can be divided into sections that contain internodes and nodes. They are referred to as cuttings and will produce roots to form a new plant. Below-ground stems also are good propagative tissues: rhizomes can be divided into pieces; bulbs form small bulblets at the base of the parent bulb; corms 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 sometimes may be difficult to distinguish between roots and stems, but one sure way is to look for the presence of nodes. Stems have nodes; roots do not.

Types of Stems

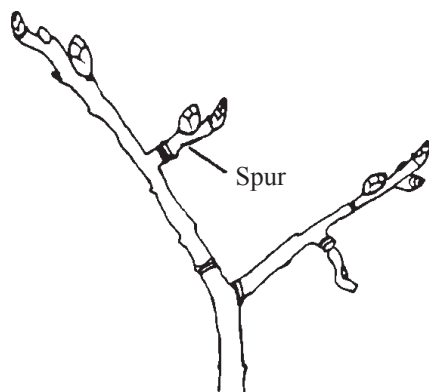
A **shoot** is a young stem with leaves present. A **twig** is a stem that is less than 1 year old and has no leaves, since it is still in the winter-dormant stage. A **branch** is a stem that is more than 1 year old, and typically has lateral stems. A **trunk** is a main stem of a woody plant. Most trees have a single trunk.

Trees are perennial woody plants, usually have one main trunk, and are usually more than 12 feet tall at maturity.



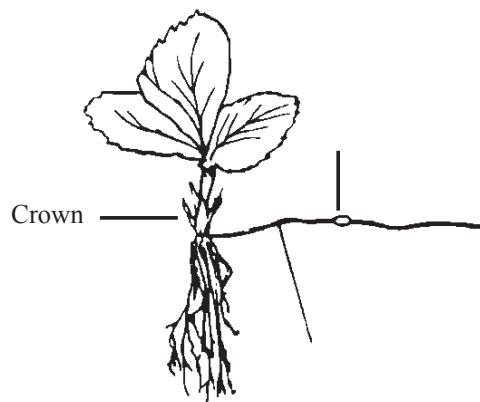
Diversified Stem Development

Above-ground modifications



A **branch** is a stem that is more than 1 year old.

A **spur** is a compressed fruiting branch.



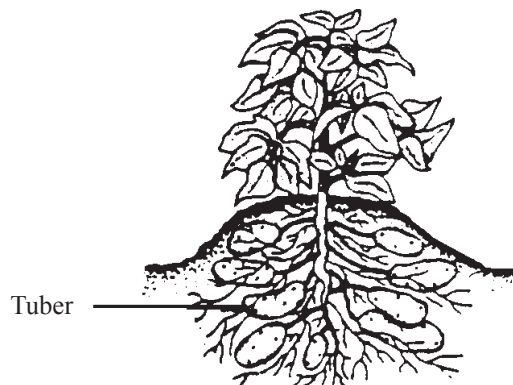
A **crown** is a region of compressed stem tissue from which new shoots are produced, generally found near the surface of the soil.

A **runner** is a type of stolon. It is a specialized stem that grows on the soil surface and forms a new plant at one or more of its nodes.

Below-ground 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 **corm** is a compressed stem with reduced scaly leaves.



A **bulb** is composed of a short stem plate, closely spaced bds, and fleshy leaves.

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

A vine is a plant that develops long, trailing stems that grow along the ground unless they are supported by another plant or structure. Some twining vines circle their support clockwise (hops or honeysuckle) while others circle counterclockwise (pole beans or Dutchman's pipe vine). Climbing vines are supported by aerial roots (English ivy or poison ivy), slender tendrils that encircle the supporting object (cucumber, gourds, grapes, and passion-flowers), or tendrils with adhesive tips (Virginia creeper and Japanese creeper).

Texture and Growth of Stems

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

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

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

Plants are classified 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 and produce vegetative structures and food storage organs the first season. During the first winter, a hardy evergreen rosette of basal leaves persists. During the second season, flowers, fruit, and seeds develop to complete the life cycle. The plant then dies. Carrots, beets, cabbage, celery, and onions are biennial plants. Hollyhock, Canterbury Bells, and Sweet William are biennials that are commonly grown for their attractive flowers.

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

seasons, in a single growing season. This phenomenon is referred to as bolting.

Perennial plants live for many years, and after reaching maturity, typically produce flowers and seeds each year. 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.

Stems as Food

The edible portion of 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 potato is a fleshy underground stem called a tuber. Although the name suggests otherwise, the edible part of the cauliflower is proliferated stem tissue.

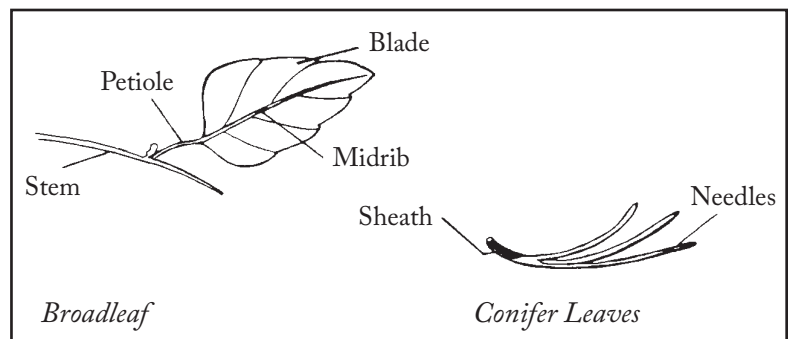
Leaves

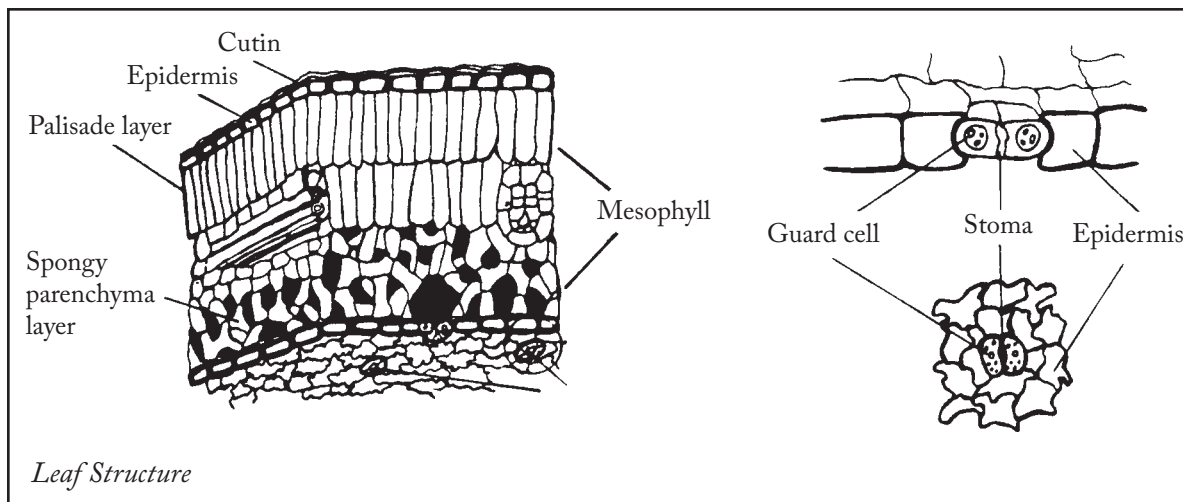
Parts of a Leaf

The **blade** of a leaf is the expanded, thin structure on either side of the midrib. The blade is usually the largest and most conspicuous part of a leaf. The **petiole** is the stalk that supports the leaf blade. It varies in length, and may be lacking entirely in some cases where the leaf blade is described as sessile or stalkless.

The principal function of leaves is to absorb sunlight for the manufacturing of plant sugars in a process called photosynthesis. Leaves develop as a flattened surface in order to present a large area for efficient absorption of light energy. The leaf is supported away from the stem by a stem-like appendage called a petiole. The base of the petiole is attached to the stem at the node. The small 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. On the top and bottom is a layer of thickened, tough cells called the epidermis. The primary function of the epidermis is protection of leaf tissue. The way in which the cells in the epidermis are arranged determines the texture of the leaf surface. Some leaves have hairs that are an extension of certain cells of the epidermis. The African violet has so many hairs that the leaf feels like velvet.

Part of the epidermis is the cuticle, which is composed of a waxy substance called cutin that protects the leaf from dehydration and prevents penetration of some diseases. The amount of cutin is a direct response to sunlight, increasing with increasing 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 spreader-sticker agents or soaps are not used. This is the reason many pesticide manufacturers include some sort of spray additive to adhere to or penetrate the cutin layer.

On the underside of leaves, some epidermal cells are capable of opening and closing. These cells guard the interior of the leaf and regulate the passage of water, oxygen, and carbon dioxide through the leaf. These regulatory cells are called guard cells. They protect openings in the leaf surface called stoma. The opening and closing of the cells is determined by the weather. Conditions that would cause large water losses from plants (high temperature, low humidity) stimulate guard cells to close. Mild weather conditions leave guard cells in an open condition. Guard cells will close in the absence of light.

The middle layer of the leaf is the mesophyll and 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 spongy lower layer that contains a great deal of air space, called the parenchyma layer. The cells in these two layers contain chloroplasts that are the actual site of the photosynthetic process.

Leaf Parts

Types of Leaves

A number of rather distinct types of leaves occur on plants. Leaves commonly referred to as **foliage** are the most common and conspicuous, and, as previously stated, serve as the manufacturing centers where the photosynthetic activity of the plant occurs. **Scale leaves** or cataphylls are found on rhizomes and are also the small, leathery, protective leaves which enclose and protect buds. **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, are specialized modified leaves that protect the plant or assist in supporting the stems. **Storage leaves**, as are found in bulbous plants and succulents, serve as food storage organs. Other specialized leaves include **bracts**, which often are brightly colored. The showy structures on dogwoods and poinsettias are bracts, not petals.

Venation of Leaves

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

Parallel-veined leaves are those in which there are numerous veins which run essentially parallel to each other and are connected laterally by minute, straight veinlets. Possibly the most common type of parallel-veining is that found in plants of the grass family where the veins run from the base to the apex of the leaf. Another type of parallel-venation is found in plants such as banana, calla, and pickerel-weed, where the parallel veins run laterally 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(s) 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, as in apple, cherry and peach. **Palmate** venation occurs in grape and maple leaves, where the principal veins extend outward, like the ribs of a fan, from the petiole near the base of the leaf blade. 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 shape of the leaf blade and the type of margin are of major importance as identifying characteristics.

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 leaf-stalk, the leaf is considered to be compound. Some leaves may be doubly compound, having divisions of the leaflets.

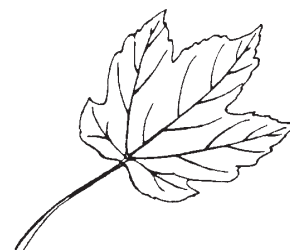
Types of Venation



Parallel



Pinnate



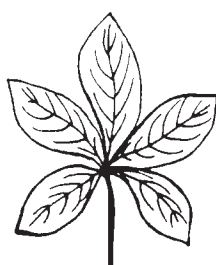
Net-veined

Palmate

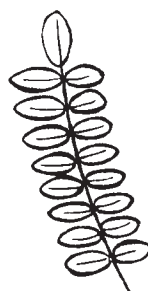
Leaf Types



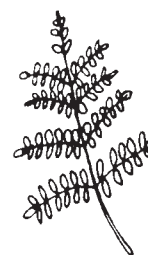
Simple
Palmate



Compound



Pinnate Compound



Double Pinnate
Compound

Leaf Arrangement



Rosulate



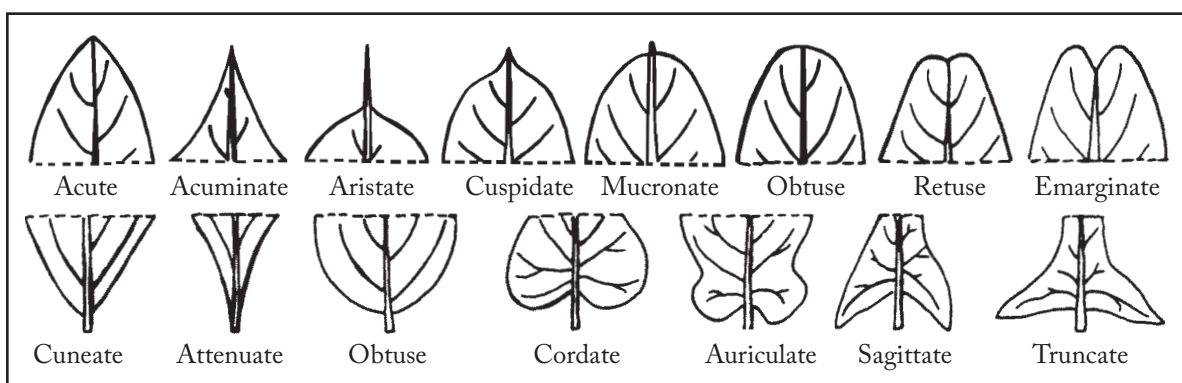
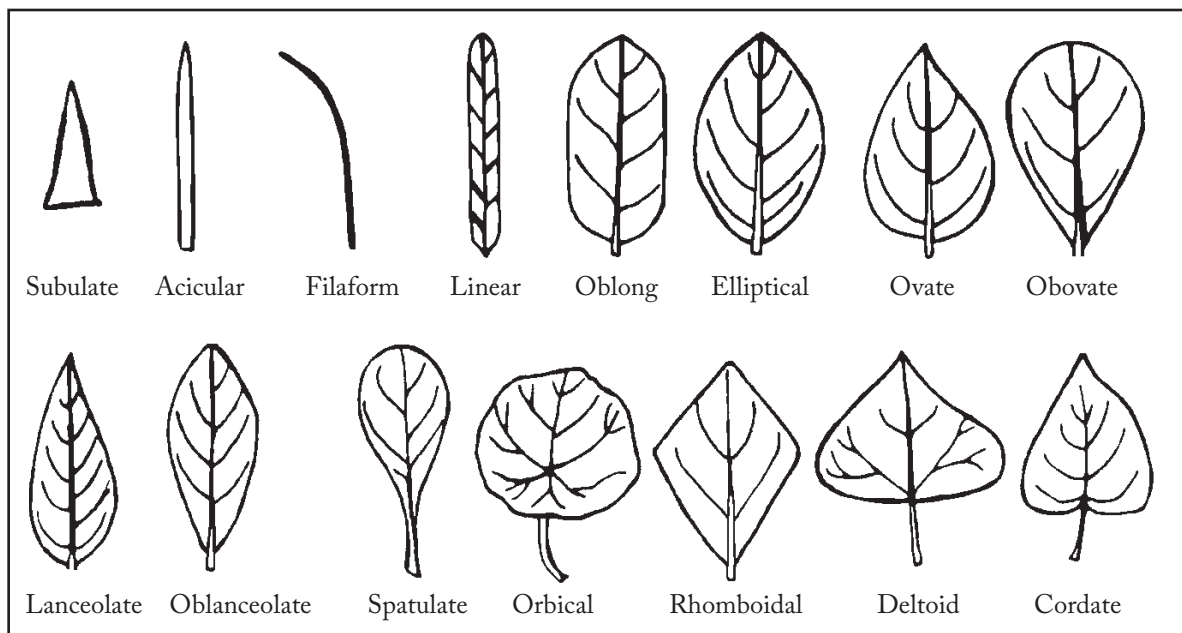
Alternate



Opposite



Whorled



Shape of the leaf blade:

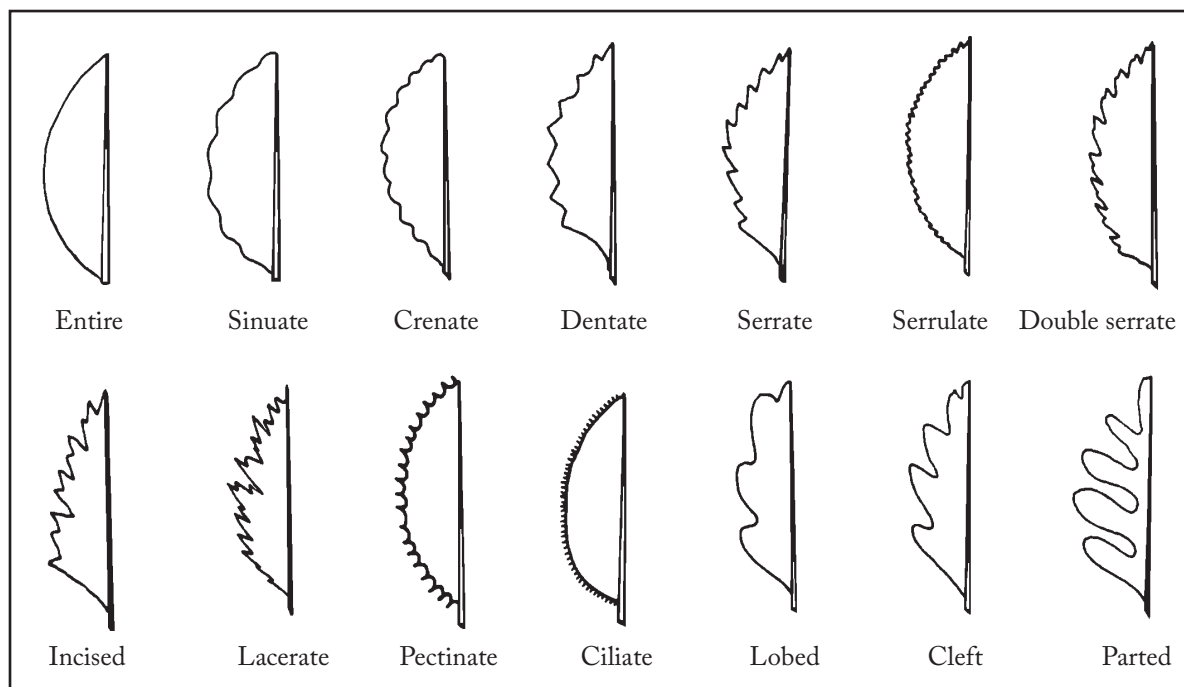
The following are some common shapes that are found in leaves and leaflets.

- Linear:** Narrow, several times longer than wide; approximately the same width throughout.
- Lanceolate:** Longer than wide; tapering toward the apex and base.
- Elliptical:** 2 or 3 times longer than wide; tapering to an acute or rounded apex and base.
- Ovate:** Egg-shaped, basal portion wide; tapering toward the apex.
- Cordate:** Heart-shaped, broadly ovate; tapering to an acute apex, with the base turning in and forming a notch where the petiole is attached.

Shape of the leaf apex and base:

The following are common shapes found in leaves.

- Acuminate:** Tapering to a long, narrow point.
- Acute:** Ending in an acute angle, with a sharp, but not acuminate, point.
- Obtuse:** Tapering to a rounded edge.
- Sagittate:** Arrowhead-shaped, with two pointed lower lobes.
- Truncate:** Having a relatively square end.



Leaf margins:

Studying leaf margins is especially useful in the identification of certain varieties of fruit plants.

Entire:	A smooth edge with no teeth or notches.
Serrate:	Having small, sharp teeth pointing toward the apex.
Dentate:	Having teeth ending in an acute angle, pointing outward.
Crenate:	Having rounded teeth.
Sinuate:	Having a pronounced sinuous or wavy margin.
Incised:	Margin cut into sharp, deep, irregular teeth or incisions.
Lobed:	Incisions extend less than half-way to the midrib.
Cleft:	Incisions extend more than half-way to the midrib.

Leaf arrangement along a stem

The various ways leaves are arranged along a stem also are used to help identify plants.

Rosulate arrangement is one in which the basal leaves form a rosette around the stem with extremely short nodes. **Opposite** leaves are positioned across the stem from each other, two leaves at each node. **Alternate** or 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.

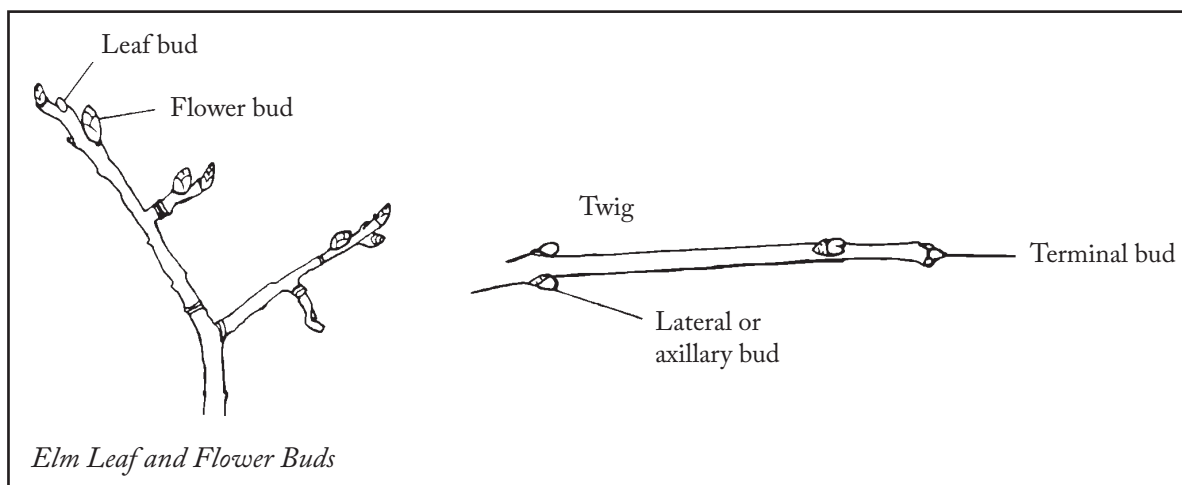
Leaves as Food

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, onion, and Florence fennel is a cluster of fleshy leaf bases. The petiole of the leaf is the edible product in celery and rhubarb. In plants like Brussels sprout, cabbage, and head lettuce, the leaves — in the form of a large, naked bud — are the edible product.

Buds

A bud is an undeveloped shoot from which embryonic leaves or flower parts arise. The buds of trees and shrubs 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) before they will resume growth in the spring. This time 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 from 700 to 1,000 hours of temperatures below 45°F (7°C) before they will resume



growth. During rest, dormant buds can withstand very low temperatures, but after the rest period is satisfied, buds become more susceptible to weather conditions and can be damaged easily by cold temperatures or frost.

A **leaf bud** is composed of a short stem with embryonic leaves, with bud primordia 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.

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 because, although flowers have the potential for developing into fruit, this development may never occur because of adverse weather conditions, lack of pollination, or other unfavorable circumstances. The structure is a flower bud, and should be so designated because it may never set fruit.

Types of Buds

Buds are named for the location they inhabit on the stem surface. **Terminal buds** are those located at the apex of a stem. **Lateral buds** are borne on the sides of the stem. Most lateral buds arise in the axis of a leaf and are called **axillary buds**. In some instances, more than one bud is formed. **Adventitious buds** are those that arise at sites other than in the terminal or axillary position. Adventitious buds may develop from the internode of the stem, 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 a plant.

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 of Brussels sprouts become the edible part of this plant. In the case of globe artichoke, the fleshy basal portion of the bracts of the flower bud are eaten along with the solid stem portion of the bud. Broccoli is the most important horticultural plant in which edible flower buds are consumed. In this case, portions of the stem and small leaves associated with the flower buds are eaten.

Flowers

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

Parts of the Flower

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

Sepals are small, green, leaf-like structures on the base of the flower that protect the flower bud. The sepals collectively are called the calyx.

Petals are highly colored portions of the flower. They may contain perfume as well as nectar glands. The number of petals on a flower often is used in the identification of plant families and genera. The petals collectively are called the corolla. Flowers of dicots typically have sepals and/or petals in multiples of four or five. Monocots typically have these floral parts in multiples of three.

The **pistil** is the female part of the plant. It is generally shaped like a bowling pin and located in the center of the flower. It consists of the stigma, style, and ovary. The stigma is located at the top, and is connected to the ovary by the style. 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 (anther) and a long, supporting filament. This filament holds the anther in position so the pollen it contains may be disbursed by wind or carried to the stigma by insects or birds.

Types of Flowers

If a flower has a stamen, 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. (Stamen and pistils are considered the essential parts of a flower.) If either of the essential parts is lacking, the flower is **imperfect**.

Pistillate (female) flowers are those which possess a functional pistil(s) 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 are usually more successful than self-pollinated plants. Consequently, more plants reproduce by cross-pollination than self-pollination.

As previously mentioned, there are plants that bear only male flowers (staminate plants)

or bear only female flowers (pistillate plants). Species in which the sexes are separated into staminate and pistillate plants are called **dioecious**. Most holly trees are dioecious; therefore, to obtain berries, it is necessary to have a female tree. **Monecious** plants are those that have separate male and female flowers on the same plant. Corn plants and pecan trees are examples. Some plants bear only male flowers at the beginning of the growing season, but later develop flowers of both sexes; examples are cucumbers and squash.

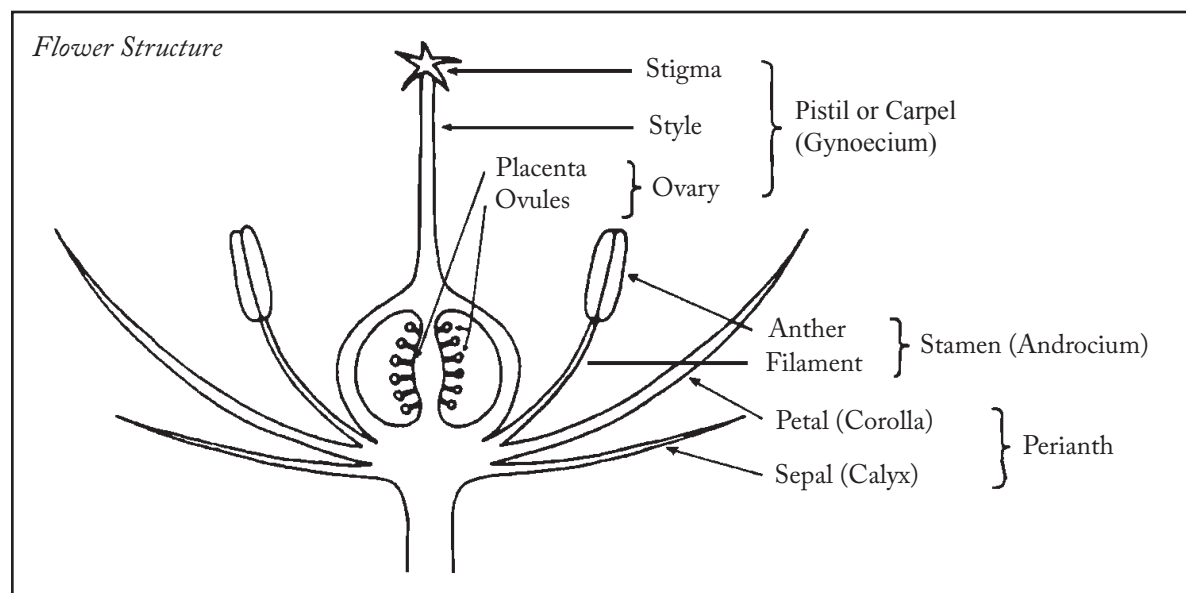
How Seeds Form

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

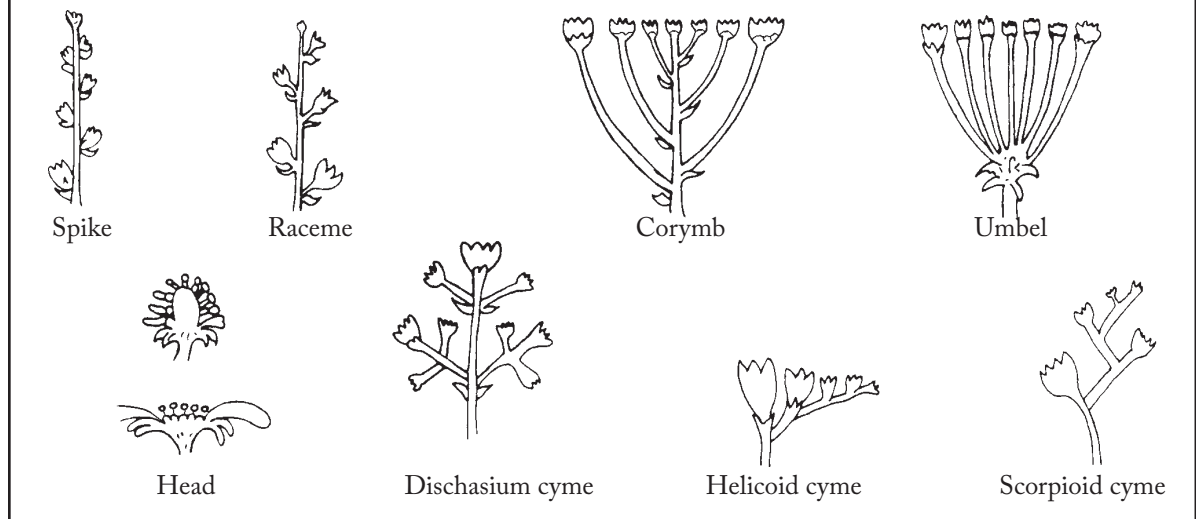
The stigma contains a chemical that excites the pollen, causing it to grow a long tube, down the inside of the style, to the ovules inside the ovary. The sperm is released by the pollen grain and fertilization typically occurs. Fertilization is the union of the male sperm nucleus (from the pollen grain)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

Types of Inflorescences

Some plants bear only one flower per stem and are called solitary flowers. Other plants produce an **inflorescence**, a term that refers to a



Inflorescences



cluster of flowers and how they are arranged on a floral stem. Most inflorescences may be classified into two groups, racemes, and cymes.

In the **racemose** group, the florets, which are 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, corymb, umbel, and head. A spike is an inflorescence in which many stemless florets are attached to an elongated flower stem, or peduncle, an example being 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, pedicels, are arranged at random 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. Dill has an umbel inflorescence. A head, or composite, inflorescence is made up of numerous stemless florets which is characteristic of daisy inflorescence.

In the **cyme** group, the top floret opens first and blooms downward along the peduncle. A dischidium cyme has florets opposite each other along the peduncle. Baby's breath inflorescence is an example. A helicoid cyme is one in which the lower florets are all on the same side of the peduncle, examples being freesia and statice inflorescences. A scorpioid cyme is one in which the florets are alternate to each other

along the peduncle. Examples are tomato and potato inflorescences.

Fruit

Parts of Fruit

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

Types of Fruit

Fruits can be classified as simple fruits, aggregate fruits, or multiple fruits.

Simple fruits are those that develop from a single ovary. These include cherries and peaches (drupe), pears and 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. Examples are peanut (legumes), poppy (capsule), maple (samara), and walnut (nut).

Aggregate fruits, such as raspberries, come from a single flower that has many ovaries. The flower appears as a simple flower, with one

corolla, one calyx, and one stem, but with many pistils or ovaries. The ovaries are fertilized separately and independently. If ovules are not pollinated successfully, the fruit will be misshapen and imperfect. Strawberry and blackberry are aggregate fruits with the addition of an edible, enlarged receptacle. For this reason, they may be termed aggregate-accessory fruits.

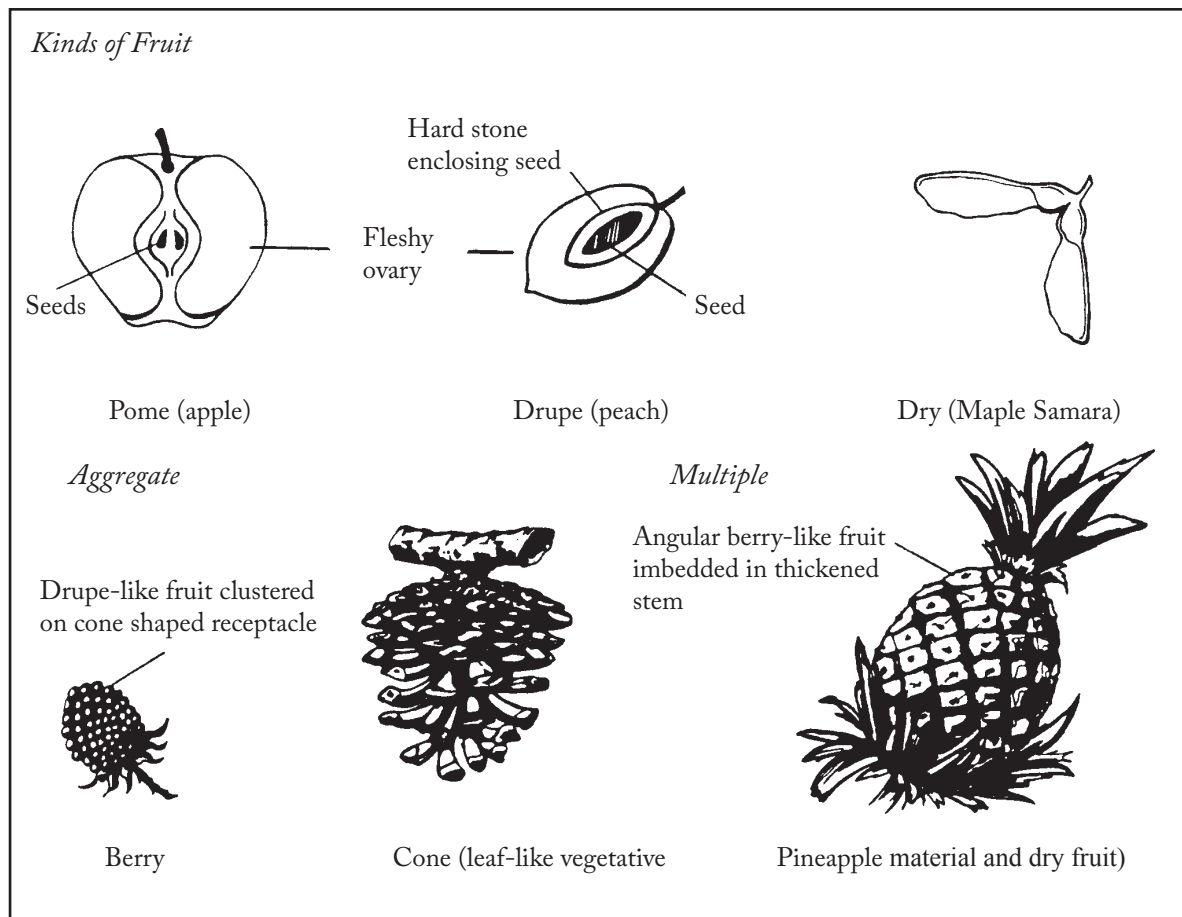
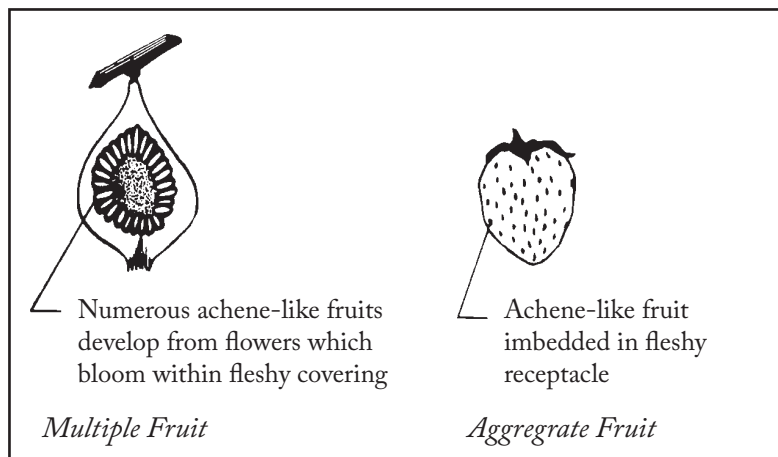
Multiple fruits are derived from a tight cluster of separate, independent flowers borne on a single structure. Each flower will have its own calyx and corolla. Examples of multiple fruits are pineapple, fig, and the beet seed.

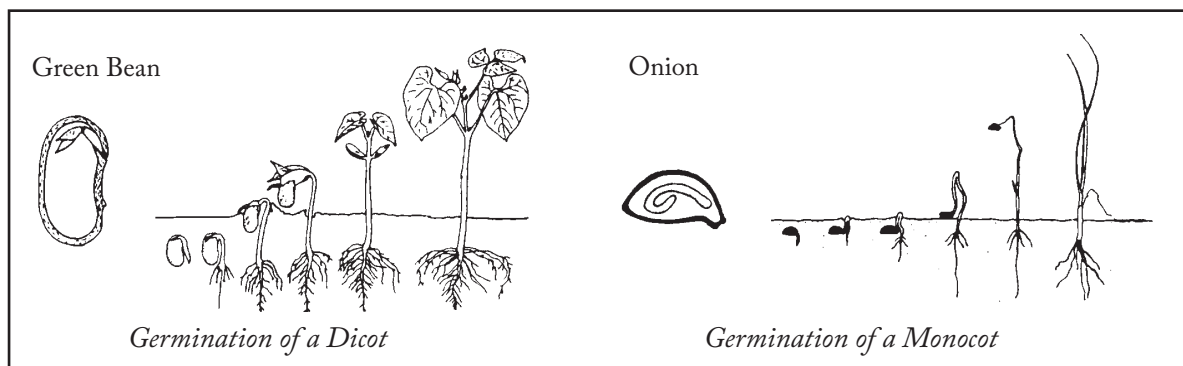
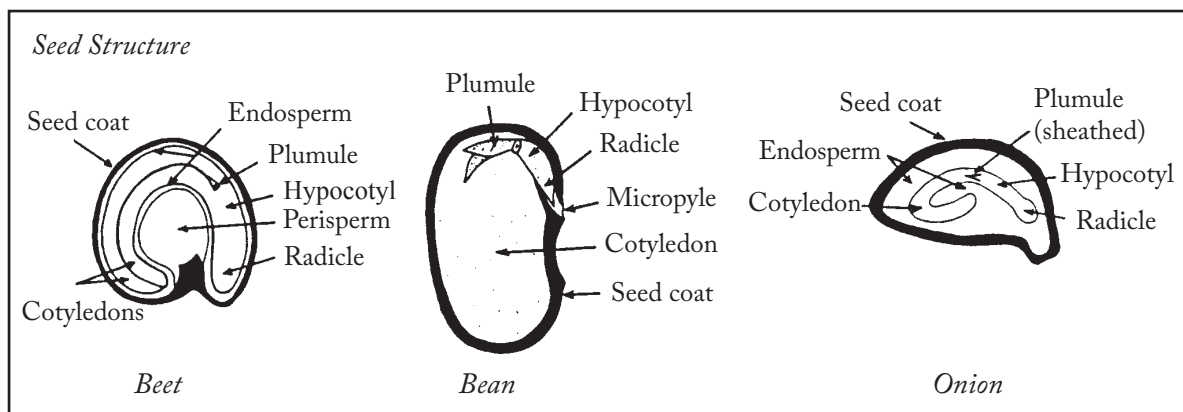
Seed

The seed, or matured ovule, is made up of three parts. The **embryo** is a miniature plant in an arrested state of development. Most seeds contain a built-in food supply called the **endosperm** (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 and prevents water from entering the seed (this would initiate the germination process before the proper time).

Parts of a Seed

Seedlings. Germination is the resumption of active embryo growth. Prior to any visual signs of growth, the seed must absorb water through the seed coat. In addition, the seed must be in the proper environmental conditions; that is, exposed to oxygen, favorable temperatures, and for some, correct light. The radicle is the first part of the seedling to emerge from the seed. It will develop into the primary root from which root hairs and lateral roots will develop. The portion of the seedling between the radicle and the first leaf-like structure is





called the hypocotyl. The seed leaves, cotyledons, encase the embryo and usually are different in shape from the leaves that the mature plant will produce. Plants producing one cotyledon fall into the group of monocotyledons or monocots. Plants producing two seed leaves are called dicotyledons or dicots.

Physiology: Plant Growth and Development

The three major plant functions that are the basics for plant growth and development are photosynthesis, respiration, and transpiration.

Photosynthesis

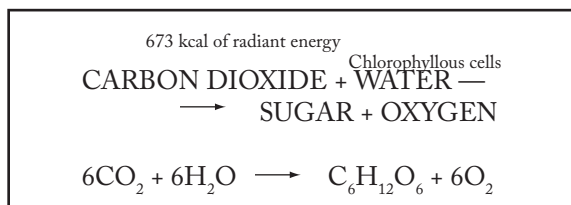
One of the major differences between plants and animals is the ability of plants to internally manufacture their own food. To produce food for itself, a plant requires energy from sunlight, carbon dioxide from the air, and water from the soil. If any of these ingredients is lack-

ing, photosynthesis, or food production, will stop. If any factor is removed for a long period of time, the plant will die. Photosynthesis literally means "to put together with light."

Plants store the energy from light first in simple sugars, such as glucose. This food may be converted back to water and carbon dioxide, releasing the stored energy through the process called respiration. This energy is required for all living processes and growth. Simple sugars are converted to other sugars and starches (carbohydrates) that may be transported to the stems and roots for use or storage, or they may be used as building blocks for more complex structures, e.g. oils, pigments, proteins, cell walls, etc.

Any green plant tissue is capable of photosynthesis. Chloroplasts in these cells contain the green pigment, which traps the light energy. However, leaves are generally the site of most food production because of their special structure. The internal tissue (mesophyll) contains cells with abundant chloroplasts in an arrangement that allows easy movement of water and air. The protective upper and lower epidermis (skin) layers of the leaf include many stomata that regulate movement of the gases involved in photosynthesis into and out of the leaf.

Photosynthesis is dependent on the availability of **light**. Generally speaking, as sunlight



Photosynthesis

1. Produces food.
2. Stores energy.
3. Occurs in cells containing chloroplasts.
4. Releases oxygen.
5. Uses water.
6. Uses carbon dioxide.
7. Occurs in sunlight.

Respiration

1. Uses food for plant energy.
2. Releases energy.
3. Occurs in all cells.
4. Uses oxygen.
5. Produces water.
6. Produces carbon dioxide.
7. Occurs in darkness as well as light.

increases in intensity, photosynthesis increases. This results in greater food production. Many garden crops, such as tomatoes, respond best to maximum sunlight. Tomato production is cut drastically as light intensities drop. Only two or three varieties of “greenhouse” tomatoes will produce any fruit when sunlight is minimal in late fall and early spring.

Water plays an important role in photosynthesis in several ways. 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 energy of the sun that has been absorbed by the chlorophyll in the plant leaves. The oxygen is released into the atmosphere and the hydrogen is used in manufacturing carbohydrates. Third, water dissolves minerals from the soil and transports them up from the roots and throughout the plant, where they serve as raw materials in the growth of new plant tissues. The soil surrounding a plant should be moist, not too wet or too dry. Water is pulled through the plant by evaporation of water through the leaves (transpiration).

Photosynthesis also requires **carbon dioxide** (CO_2) which enters the plant through the stomata. Carbon and oxygen are used in the manufacture of 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 let in enough outside air to maintain an adequate carbon dioxide level. Under these conditions, improved crops of roses, carnations, tomatoes, and certain other crops can be produced if the carbon dioxide level is raised with CO_2 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 in the temperature range 65 to 85°F (18 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 into energy. This energy is used in the process of building new tissues (plant growth). The chemical process by which sugars and starches produced by photosynthesis are converted into energy is called respiration. It is similar to the burning of wood or coal to produce heat (energy). This process in cells is shown



most simply as:

This equation is precisely the opposite of that used to illustrate photosynthesis, although more is involved than just reversing the reaction. However, it is appropriate to relate photosynthesis to a building process, while respiration is a breaking-down process.

By now, it should be clear that respiration is the reverse of photosynthesis. 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 occurs through the stomata.

Transpiration

Transpiration is the process by which a plant loses water, primarily from leaf stomata. Transpiration is a necessary process that involves the use of about 90 percent of the water

that enters the plant through the roots. The other 10 percent of the water is used in chemical reactions and in plant tissues. Transpiration is necessary for mineral transport from the soil to the plant parts, for the cooling of plant parts through evaporation, to move sugars and plant chemicals, and for the maintenance of turgor pressure. The amount of water lost from the plant depends on several environmental factors such as temperature, humidity, and wind or air movement. An increase in temperature or air movement decreases humidity and causes the guard cells in the leaf to shrink, opening the stomata and increasing the rate of transpiration.

Environmental Factors That Affect Plant Growth

Plant growth and distribution are limited by the environment. If any one environmental

factor is less than ideal, it will become a limiting factor in plant growth. Limiting factors 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. It is important to understand the environmental aspects that affect plant growth. These factors are light, temperature, water, humidity, and nutrition.

Light

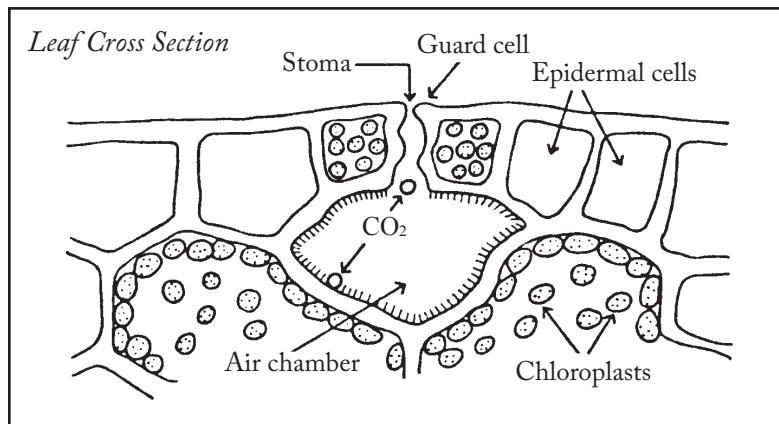
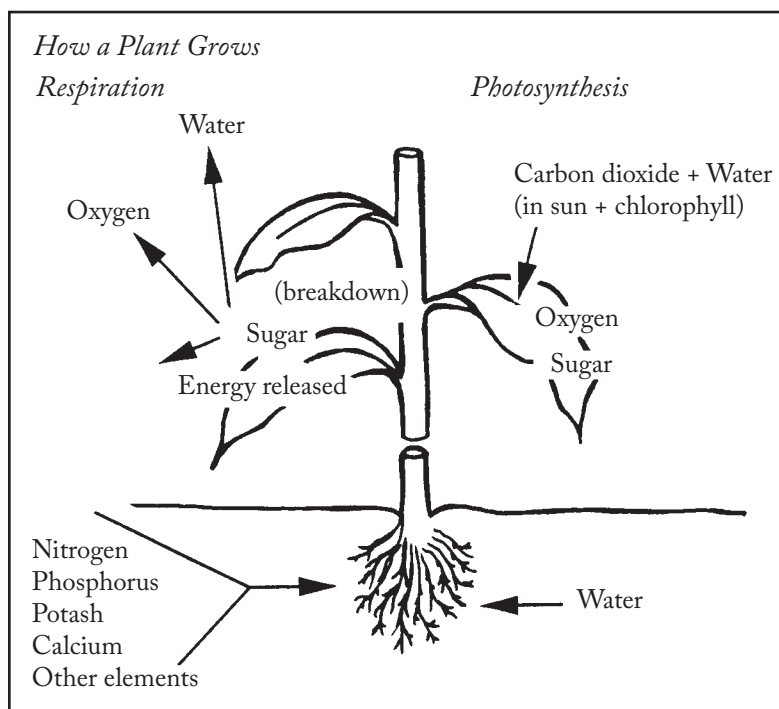
Light has three principal characteristics that affect plant growth: quantity, quality, and duration.

Light **quantity** refers to the intensity or concentration of sunlight and varies with the season of the year. The maximum is present in the 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 sunlight quantity 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 white or reflective material, or supplemental lights.

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 as they reflect green light and absorb none. 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. Fluorescent, or cool-white, light is high in the blue range of light quality and is used to encourage leafy growth. Such light would be 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. Fluorescent "grow" lights have a mixture of red and blue colors that attempts to imitate sunlight as closely as possible, but they are costly and generally not of any greater value than regular fluorescent lights.



Light **duration**, or photoperiod, refers to the amount of time that a plant is exposed to sunlight. When the concept of 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 photoperiod. Plants can be classified into three categories, depending upon their flowering response to the duration of darkness. These are short-day, long-day, or day-neutral plants.

Short-day plants form their flowers only when the 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 when day lengths exceed 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 really fit into any category but may be responsive to combinations of day lengths. The petunia will flower regardless of day length, but flowers earlier and more profusely under long daylight. Since chrysanthemums flower under the short-day conditions of spring, or fall, the method for 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 present longer than 12 hours, artificial light is added until flower buds are initiated.

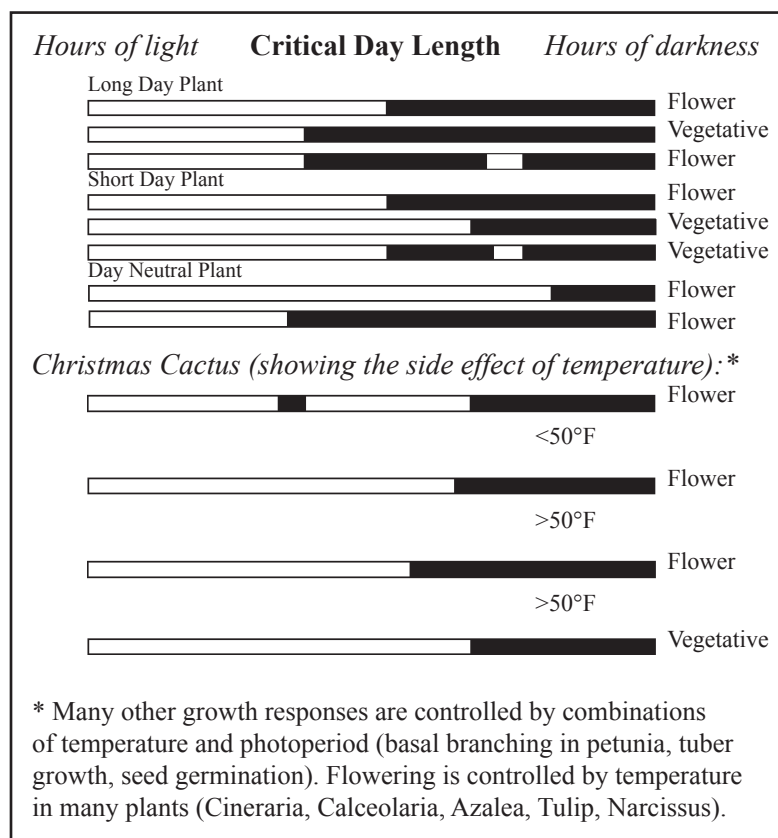
Temperature

Temperature affects the productivity and growth of a plant, depending upon whether the plant variety is a warm- or cool-season crop. If temperatures are high and day length is long, cool-season crops such as spinach will bolt rather than produce the desired foliage. Temperatures that are too low for a warm-season crop such as tomato will prevent fruit set. Adverse

temperatures also cause stunted growth and poor quality; for example, the bitterness in lettuce is caused by high temperatures.

Sometimes temperatures are used in connection with day length to manipulate the flowering of plants. 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 influence flowering. Daffodils are forced to flower by putting the bulbs in cold storage in October at 35 to 40°F (2 to 4°C). The cold temperatures allow the bulb to mature. The bulbs are transferred to the greenhouse in midwinter where growth begins. The flowers are then ready for cutting in three to four weeks.

Thermoperiod refers to daily temperature change. Plants produce maximum growth when exposed to a day temperature that is about 10 to 15°F higher than the night temperature. This allows the plant to photosynthesize (build up) and respire (break down) during an optimum daytime temperature, and to curtail the rate of respiration during a cooler night. High temperatures cause increased respiration, sometimes above the rate of photosynthesis. This means that the products of photosynthesis are being



used more rapidly than they are being produced. For growth to occur, photosynthesis must be greater than respiration.

Low temperatures can result in poor growth. Photosynthesis is slowed down at low temperatures. Since photosynthesis is slowed, growth is slowed, and this results in lower yields. Not all plants grow best in the same temperature range. For example, snapdragons grow best when nighttime temperatures are 55°F (12°C); the poinsettia prefers 62°F (17°C). Florist cyclamen does 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 was previously believed. This has meant a conservation in energy for greenhouse growers.

However, in some cases, a certain number of days of low temperatures are needed by plants to grow properly. This is 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 growth. Lilies need six weeks at 33°F (1°C) before blooming.

Plants can be classified as either hardy or nonhardy, depending upon their ability to withstand cold temperatures. Winter injury can occur to nonhardy plants if temperatures are too low or if unseasonably low temperatures occur early in the fall or late in the spring. Winter injury also may occur because of desiccation

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.
Dormancy:	Warmth, after a period of low temperature, will break dormancy and the plant will resume active growth.

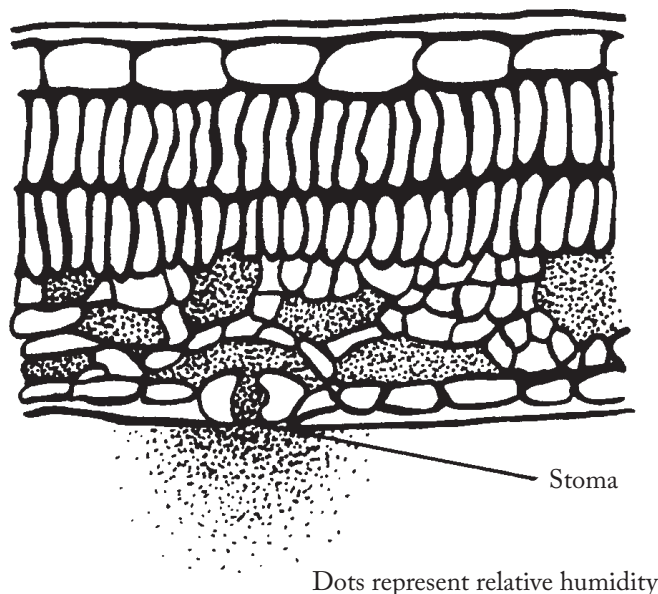
(drying out)—plants need water during the winter. When the soil is frozen, the movement of water into the plant is severely restricted. On a windy winter day, broadleaved evergreens can become water-deficient in a few minutes; the leaves or needles then turn brown. Wide variations in winter temperatures can cause premature bud break in some plants and consequent 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 the freezing and splitting of plant cells and tissue.

Water

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

Relative humidity is the ratio of water vapor in the air to the amount of water the air

Leaf Cross Section



could hold at a given temperature and pressure, expressed 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 relative humidity (RH) is 75%.

Warm air can hold 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,

$$\text{RH} = \frac{\text{water in the air}}{\text{water the air could hold}} \\ \text{(at constant temperature and pressure)} \\ \text{so, RH} = \frac{3}{4} = .75 \text{ expressed as a \%} = 75\%$$

water vapor rushes out. As the vapor moves out, a cloud of high humidity is formed around the stomate. This cloud of humidity helps slow down transpiration and cool the leaf. If air movement blows the humid cloud away, transpiration will increase as the stomata keep opening to balance the humidity.

Plant Propagation

Plant propagation is the process of multiplying the numbers of a species, perpetuating a species, or maintaining the youthfulness of a plant. There are two types of propagation, sexual and asexual. Sexual reproduction is the union of the pollen and egg, drawing from the genes of two parents to create a new, third individual. Sexual propagation involves the floral parts of a plant.

Asexual propagation involves taking a part of one parent plant and causing it to regenerate itself into a new plant. Genetically, it is identical to its one parent. Asexual propagation involves the vegetative parts of a plant: stems, roots, or leaves.

The advantages of sexual propagation are that it may be cheaper and quicker than other methods; it may be the only way to obtain new varieties and hybrid vigor; in certain species, it is the only viable method for propagation; and it is a way to avoid transmission of certain diseases.

Asexual propagation has advantages, too. It may be easier and faster in some species; it may be the only way to perpetuate some cultivars; and it bypasses the juvenile characteristics of certain species.

Plant Nutrients

Plants need 17 elements for normal growth. Carbon, hydrogen, and oxygen (which come from air and water), and nitrogen (which is in the soil) make up 95 percent of plant solids. Although the atmosphere is 78 percent nitrogen, it is unavailable for plant use. However, certain bacteria that live in nodules on the roots of legumes are able to fix nitrogen from the air into a form available to plants.

The other 13 essential elements are iron, calcium, phosphorus, potassium, copper, sulphur, magnesium, manganese, zinc, boron, chlorine, cobalt and molybdenum. These elements come from the soil. With the exception of calcium, magnesium, phosphorus, and potassium, there usually is a large enough quantity of each of these elements in the soil for cultivation of crops. Each of the nutrients has a specific effect on plant growth and are discussed in more detail in Chapter 2, Soils, Water, and Fertilizer.