Basic Components
The basic unit or building block for plants is the cell. It is the site of all physiological processes within the plant that are associated with growth. Groups of cells that are related in structure or function are called tissues. Tissues that occur in certain combinations or arrangements form the organs of a plant, such as: stems, leaves, roots, and reproductive structures. Each organ has a characteristic form and performs a major function in the plant. Organs are composed of several organelles.

Stems
The stem is the site of attachment for leaves, flowers, and fruits (Figure 1). It provides a path for the transport of carbohydrates, water, and minerals between the roots and the top of the plant. Located at the tip of the stem of woody plants and some herbaceous plants is a group of actively dividing cells called the apical meristem. Growth in length of the stem originates from the apical meristem and is called primary growth. Located around the stem of woody plants is another group of actively dividing cells called the secondary meristem; it is also called the vascular cambium (Figure 2). Growth in stem diameter or caliper originates from the secondary meristem or vascular cambium and is called secondary growth.

New cells produced on the inside of the vascular cambium become the xylem. Trees that have seasonal growth patterns form xylem in clearly defined rings, which are known as annual growth rings. Most of the conduction of water and dissolved minerals occurs in xylem tissue known as the sapwood. The rings on the inside of the stem, known as the heartwood, are xylem cells that no longer conduct water and minerals. Oils and resins are usually deposited in the heartwood, causing it to be darker in color and often harder than the sapwood. New cells produced on the outside of the vascular cambium become the phloem. Carbohydrates, other organic compounds produced in the leaves, and mobile inorganic nutrients are

Figure 1. The general structure of a plant stem.

Figure 2. Cross-section of a plant stem.
Phloem is found another lateral meristem called the cork cambium. It forms suberized, corky cells that provide protection for the stem. All tissues outside of the vascular cambium are collectively called bark.

Plant stems differ significantly between monocots, which have one cotyledon per seed, and dicots, which have two cotyledons per seed. The difference is in the arrangement of xylem, phloem, and cambium. In monocots, these three tissues make up “vascular bundles” which are scattered throughout the stem (Figure 3). In dicots and in gymnosperms, or cone bearing plants, the xylem is formed inside a large ring of cambium tissue, and phloem is formed on the outside of this cambium ring (Figures 4 and 5). Xylem created from the cambium adds to the heartwood. Phloem created from the cambium contributes to the bark. The annual cycle of xylem growth creates an observable ring in the heartwood. Differences between Monocotyledons and Dicotyledons include:

1. **Monocotyledons**
   a. Only one cotyledon or seed leaf is present.
   b. Generally have marked parallel leaf venation.
   c. Flower parts are typically in groups of three or multiples of three.
   d. Vascular bundles are scattered throughout the stem tissue.
   e. Generally have no vascular cambium.

2. **Dicotyledons**
   a. Two cotyledons or seed leaves are present.
   b. Generally have marked netted venations in leaves.
   c. Flower parts in groups of four or five.
   d. Vascular bundles usually arranged in the form of a cylinder.
   e. Vascular cambium present in Dicots having secondary growth.

Plants are woody if their basic stem structures are perennial and they have annual xylem growth rings in a cross section of the stem. As older xylem tissue becomes surrounded by new xylem layers, the older xylem no longer serves to transport water and becomes mainly a supporting structure. As older phloem tissue is underlain with new phloem of a greater circumference, it stretches and splits, often peeling off as bark does on many trees. The growing tissues of a woody stem form a relatively thin ring around the heartwood core, therefore, girdling the stem interrupts all downward conduction resulting in death of shoots above the injured area.

The point of leaf attachment on the stem is called a node. The portion of the stem between two leaves, or between two nodes is called an internode. The angle formed between a leaf petiole and the internode above is called the leaf axil. The bud at the apex or tip of a stem is called the apical or terminal bud. Buds along the stem are called lateral or axillary buds. All of these structures are illustrated in Figure 1. Pore-like structures known as lenticels are borne on stems and mediate gas exchange.

In most species, buds are embryonic stems enclosed by scale-like leaves called bud scales. When a bud begins to swell, open and grow, the bud scales peel away and leave a series of concentric lines or scars, called bud scale scars, around the stem. The distance between the tip of the stem and the first set of bud scale scars is a measure of the current year's lineal stem growth.

Not all plants have stems that meet the generalized example of trees or shrubs. Bulbous crops and related plants have stems modified in a variety of ways. A bulb such as an onion or tulip is a shortened stem surrounded by swollen leaf bases. A corm, such as gladiola, is a shortened and thickened stem with visible lateral buds. Rhizomes, as found in iris or cannas, are compressed stems that grow horizontally, and tubers as in potatoes are thickened fleshy stems whose "eyes" are modified lateral buds. Stolons occur in grasses and are above ground stems that grow horizontally.

**Leaves**

Most leaves arise from apical meristems. An exception is adventitious buds which arise on the main stem from an adventitious meristem. Leaves normally consist of a blade, a petiole and stipules (Figure 6).
Figure 3. Cross section of Monocotyledon stem. Note **random** distribution of vascular bundles in insert. From: Kendall/Hunt Publishing Company. Biology Plate Series Part II: Botany. Dubuque, IA.
Figure 4. Cross section of Dicotyledon stem. Note ring distribution of vascular bundles in insert.
Figure 5. Cross section of Woody Dicotyledon stem from a three-year Tilia (Basswood).
Some leaves are sessile, meaning that they attach directly to the stem and have no petiole or stipules. Stipules are small leaf-like appendages found at the base of the petiole. The petiole contains conducting tissues, xylem and phloem, for the transport of materials to and from the leaf.

Each leaf has an outer protective layer or layers of cells called the epidermis, which is covered by a waxy layer called the cuticle. Among the epidermal cells are small pores called stomata. Stomata are surrounded by a pair of crescent-shaped cells known as guard cells, which regulate the opening and closing of the stomata. Stomata serve as sites for the exchange of gases and water vapor.

The area between the upper and lower epidermis of a leaf is the mesophyll. It is composed of two parts: the palisade layer composed of one or more rows of vertically elongated cells, and the spongy mesophyll layer composed of irregularly shaped loosely associated cells. Vascular bundles for the conduction of materials to and from leaves are present in the mesophyll.

Figure 6. Leaf structure and its attachment to a stem.

One or more leaves can be borne at a node, giving leaf arrangements that are alternate with one leaf per node; opposite with two leaves per node; or whorled with three or more leaves per node (Figure 7). If the leaf blade is composed of a single unit, the leaf is a simple leaf; when it has two or more leaflets, it is called a compound leaf (Figure 8). The individual leaflets, or pinnae, are attached to a stalk called the rachis (Figure 9). If the leaflets are attached laterally along the rachis, the leaf is pinnately compound (Figure 8). If the leaflets radiate from the end of the rachis, the leaf is palmately compound (Figure 8). To determine if a leaf is simple or compound, examine the leaf from its apex to where it attaches to the stem. The point of attachment for a leaf will have a bud either in the leaf axil or beneath the petiole. Leaflets do not have buds at the base of the leaflet that attaches to the rachis. Also, true leaves will have an abscission layer at the base of the petiole; the leaflet will not have an abscission layer as all leaflets abscise with the rachis. Leaves have characteristic shapes; apices or leaf tips; bases or leaf bottoms; and leaf margins or the edges of a leaf. All of these are used in the identification of plants.

Figure 7. Arrangement of leaves on a stem:
A. Alternate. B. Opposite. C. Whorled.
Transpiration and photosynthesis are two important physiological processes that occur within the leaves. Transpiration is the loss of water vapor from plant surfaces. Transpiration cools plants in much the same manner as perspiration serves as a cooling mechanism in humans. Transpiration is greater from leaves than from any other portion of the plant.

The primary site of photosynthesis is in the leaves in structures within plant cells called chloroplasts. Chloroplasts contain a green pigment, chlorophyll, which is the catalyst for the process of photosynthesis.

**Roots**

The root is an organ typically located below ground. The root system anchors and supports the plant, serves as a storage site for carbohydrates and other plant products and absorbs moisture and inorganic nutrients or minerals from the soil.

Primary growth or elongation of the root occurs at the root's apical meristem just behind the root cap (Figure 10). The apical meristem of the root is covered by a root cap to protect the meristem as the root grows through the soil. Primary roots have an outer layer of cells called the epidermis.

After root cells divide, most elongate and then mature. Cell elongation primarily occurs directly behind the apical meristem. Cell expansion also occurs behind the apical meristem. After elongation, cells mature and
become part of the internal tissue structure of the root. In the region where cells become mature, epidermal cells develop hair-like protuberances called root hairs. Root hairs serve as the main sites of water and mineral absorption as do the white regions of roots near their tips.

Branch or secondary roots develop behind the area of cell maturation. Each branch root has the same structural organization as the primary root. As roots grow in diameter, they develop an anatomical structure similar to that found in stems.

Most common nursery plants have a fibrous root system as opposed to a tap root system. A fibrous root system consists of many branching roots that are fiber-like, no one root being more prominent than the others. A tap root system consists of one main root that grows directly downward from which branch roots extend. Tap roots penetrate the soil two to three times deeper than fibrous roots. This makes tap rooted trees such as butternut, oak and hickory much more difficult to transplant than trees with fibrous root such as ash, linden and elm.

Roots serve an important function as a site for the storage of carbohydrates, other plant metabolites and inorganic nutrients. Carbohydrates produced in the leaves in late summer or fall are translocated downward in the phloem to the root system for storage until they are needed for growth the next spring. In spring, when the days become longer and the temperatures warmer, carbohydrates are translocated back to the buds to provide energy for spring growth.

Certain stems will produce roots if separated from the plant or if injury occurs. This type of root is known as an adventitious root and is the structure that makes it possible to root cuttings from many shrubs. In contrast, crabapple, cherry, plum, quince, and hawthorn are examples of plants that may be propagated by root cuttings rather than stem cuttings, wherein adventitious stem buds will form on the root sections. This phenomenon is also responsible for the ability of the dandelion to produce an entire plant from a tiny piece of root.

**Flowers**
The flower is a modified stem and is the reproductive organ of angiosperms, which are flowering plants. There are two types of floral structures:

1. A Complete Flower.
2. An Incomplete Flower.

A complete flower is composed of the following organs: receptacle; sepal; petal; stamen which is the male organ composed of the anther and filament; and the pistil which is the female organ composed of the stigma, style and ovary (Figure 11). The ovary contains the ovule and placenta. An incomplete flower lacks one or more of the above floral organs.

![Figure 11. The floral organs in a complete flower.](image)


The receptacle is a swollen area at the base of the flower. In a complete flower, the sepals, petals, stamens, and pistil are attached to the receptacle. Moving up from the receptacle, the first structures encountered are the sepals. They are small, usually green, leaf-like structures. All of the sepals together compose the calyx. Above the calyx is a whorl of larger leaf-like structures called the petals. All of the petals combined form the corolla. The corolla is usually the showy part of the flower. Above the corolla are filamentous structures known as stamens. Stamens are the pollen-bearing or male component of the flower. In the center of the flower is a flask-like structure with a swollen base called the pistil. The pistil is the female component of the flower. It is composed of the stigma, style, and ovary.
Flowers that contain both stamens and pistils are called perfect. Imperfect flowers contain only the male stamens or the female pistils. A given species will generally have either perfect or imperfect flowers, but not both.

Two forms of imperfect flowers create two categories of plants: **monoecious plants and dioecious plants**. Species that have both male and female flowers on the same plant, such as corn, begonia, cucumber, and many woody plants, are called monoecious, meaning they have both the male and female flower in one house. Species that have the male and female flowers on separate plants are called dioecious, meaning they have the male and female flowers in separate or two houses. In dioecious species, such as maple, bittersweet, ash, and willow, there must be both a male and female plant in close proximity to each other if pollination and subsequent fruiting is to occur.

Flowers are borne on a plant in a characteristic arrangement called an inflorescence. The major function of flowers is the attraction of pollen transporting insects or birds which ensure sexual reproduction of the species. Many plants, including grasses and some woody species such as pine, are wind pollinated. Sexual reproduction involves pollen from one plant fertilizing the flowers of another. This is desirable because it combines characteristics to create offspring different from either parent which is a major component of the process of evolution. Flowers can be **self-pollinated**, wherein the pollen comes from the same species and the same plant. Or flowers can be **cross-pollinated**, wherein the pollen from the same species, but from a different plant. Plants use form, color, and scent to attract insects, birds, and humans to enhance and conduct pollination.

**Fruits**
The botanical term "fruit" refers to the mature or ripened ovary plus other flower parts associated with it. It may include the receptacle as well as withered remnants of the petals, sepals, stamens, and styylar portions of the pistil. It would also include any seeds or ripened ovules contained in the ovary.

Showy fruit displays are often a reason for planting trees and shrubs in the landscape. Achenes, capsules, berries, drupes, folicles, nuts, pods, pomes and samaras are examples of angiosperm fruit types.

Gymnosperms have dry strobili or cones as found on white pine; or fleshy fruits, such as the fleshy structure of ginkgo and the berry-like strobili of junipers.

For the production of fruit, some varieties need cross-pollination or pollen from another plant of the same type, but a different cultivar. For example, the Black Tartarian cherry is an excellent pollinator for all sweet cherries. Pears, American plums, and sweet cherries are dioecious and therefore, need cross-pollination. Italian plums, most peaches, and sour cherries are monoecious and therefore, are self-pollinating in that pollen from the same plant is used to produce fruit. Correct recommendations as to varieties are essential in fruit tree pollination.

**Seeds**
Seeds are ripened ovules. Seeds are composed of a seed coat, an embryo, and usually a storage structure for food reserves. The cotyledons and the endosperm are the food storage structures found in seeds. Cotyledons can be either fleshy or leaf-like in composition. Fleshy cotyledons are storage sites for food reserves. Seeds that have two cotyledons are called dicotyledonous or dicots, and those with one cotyledon are called monocotyledonous or monocots. The endosperm is another type of storage structure found in seeds. During the germination process and growth of the embryo, food reserves are transferred from either the cotyledons or the endosperm to the embryo.

Seed viability decreases with age of the seed. Best germination results are obtained with fresh, properly treated seeds. Dry cool storage of seeds will generally lengthen their life. Each species of plant has a specific set of physiological requirements that must be met for the seed to germinate. Seeds require proper temperature, moisture, and aeration to germinate. Light is required for germination in some species. Seeds have complex dormancy requirements that may be satisfied by providing cool moist, warm moist, dry followed by a cool moist period, or a combination of these. These treatments are called stratification. Other seeds have hard seed coats that require scarification treatments for germination to occur.

A seed is a miniature plant in an arrested state of development. Most seeds contain a "built-in" food supply. Structurally, the seed is a matured ovule, although various parts of the ovary may be
incorporated in the seed coat. Plants naturally perpetuate themselves through flowering and subsequent seed production. In the nursery industry, the flower and its color, beauty and fragrance is often of more importance than seed production. In fact, many plants have been bred to produce unreliable seed or no seed at all. This is especially true with annuals and vegetables as the hybrid seed from which they grew is a result of controlled pollinations. The seed from a hybrid petunia or tomato will produce a plant that resembles the original parental types without many of the desirable characteristics of the hybrid.

Since seeds are really whole plants in a miniature form and in a dormant state, it is understandable why seeds lose viability and will no longer grow after a prolonged period of time. The "miniature plant" has actually "outgrown" its dormant period without receiving the conditions for continued growth obtained from planting and therefore, has died. The period of time that different kinds of plants will stay alive in the dormant or seed stage ranges from a few hours to many years. Package dating is used by most seed firms to prevent sale of "old" seed. Proper care of seed lengthens its life considerably; for instance grass seed in vacuum-packaged containers adds months to its keeping quality. Conversely, seed exposed to dampness and temperature extremes, usually reduces the time seeds will remain viable.

The life-cycle of a seed-bearing plant is divided into two broad phases, vegetative and reproductive. The vegetative phase consists of two stages, germination of the seed or the rooting of a cutting, and vegetative growth. Although the germination or rooting phase may take only a few weeks, the period of vegetative growth may last for years with repeated growth cycles.

The reproductive phase begins with physiological changes including flower bud induction, followed by flower bud initiation and development, and then flowering and subsequent production of fruit and seed.