Chapter 2

Introduction to Horticulture

Learning Objectives

1. Identify the basic vegetative parts of plants and their main functions
2. Identify the basic reproductive parts of plants and their main functions
3. Identify different types of leaves or buds by shape, margin, position and/or venation
4. Differentiate types of inflorescences in plants and fruit formation
5. Explain the basic steps to seed formation and germination
Horticulture is the science, business and art of growing and promoting plants. 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. Botany is the study of plants. Understanding plant function and physiology is critical for successful horticulture. In the greatly diversified kingdom of plants, all flowering plants have certain structures and functions in common. Higher order flowering plants are divided into two groups: monocots and dicots. Although monocots and dicots are similar in many ways, differences with respect to the number of seed leaves, the number of flower parts, the leaf vein pattern and the root structure exist. In addition, physiological differences exist that result in different responses when plants are subjected to natural or synthetic factors. Corn, grass, lilies and orchids are examples of monocots. Sunflowers, pea plants and roses are examples of dicots.

**Classification of Plants**

**Growth Habit**

The number of growing seasons that are required to complete a life cycle classifies plants as annual, biennial or perennial. Annuals pass through their entire life cycle from seed germination to seed production in one growing season and then die. Annuals mature quickly producing an abundance of flowers and are normally planted after the last frost in the spring and generally live until the killing frost in fall. Most annuals require little effort to establish in the garden and are rarely troubled by disease. Generally, annuals bloom more than biennials and perennials with the goal of setting seeds to perpetuate its species. Deadheading – continually removing the faded flowers – is a method that will prevent seed formation and signal the plant to continue blooming.

Some annuals are characterized as cool-season plants and others as warm season plants. Cool-season annuals perform their best in the cool weather conditions of spring and fall and tend to slack off during the summer heat. Sweet Alyssum is one example of a cool-season annual. On the other hand, warm season annuals flower best in the hot summer sun. Zinnia, cosmos and marigolds are examples of warm season annuals.

In the South, some annuals are winter hardy and will provide winter color and interest in the garden. A hardy annual refers to a plant that can tolerate cold temperatures. Annuals viable through our Tennessee winters include Pansies, *Violas,* *Dianthus chinensis,* Snapdragons, and Ornamental Cabbage and Kale.

Biennials are plants that take two years to complete their life cycle. They germinate from seeds and produce vegetative structures and food-storage organs in the first season. During the first winter, a hardy evergreen rosette of basal leaves persists. During the second season, flowers, fruit and seed develop to complete the life cycle. The plant then dies. The bloom period of the biennial is usually much shorter than the annual, typically two to three weeks. Some biennials can be unpredictable and behave as short-lived perennials, blooming for two or even three years, consecutively, before dying. Other biennials may 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 pass through the equivalent of two growing seasons physiologically, in a single growing season. This phenomenon is referred to as bolting. Foxgloves, hollyhocks, carrots and onions are examples of biennial plants.

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. Some perennials are referred to as tender perennials. This means that they are plants that are technically classified as perennials, but may not be able to withstand winter conditions in Tennessee. Blue salvia, heliotrope and zonal geraniums are examples of tender perennials. Most perennials bloom for only a few weeks, but some will have a second flowering, or will continue to have scattered flowering, through-
out the season. Many perennials spread, forming larger clumps, and need to be dug up and divided every few years or they will lose their vigor. When growing perennials, a good rule to teach gardeners is: The first year they sleep, the second year they creep and the third year they leap. Therefore, patience is usually required for the full beauty of a perennial to be reached. Hostas, roses and dahlias are examples of perennials.

Structure or Form

The basic size, structure and form of plants can be used to classify or group them in broad descriptive terms. Plants that are fibrous, rigid or hard are classified as woody. Plants with succulent or tender stems are considered herbaceous plants.

Woody plants can be further classified as vines, shrubs or trees, referring to their growth habit. A vine is a plant that develops long trailing stems that grow along the ground, or must be supported by another plant or structure. Some twining vines circle the support clockwise (hops or honeysuckle), while others circle counterclockwise (pole beans or Dutchman’s pipe vine). Aerial roots, such as in English ivy or poison ivy, support climbing vines by slender tendrils that encircle the supporting object. Tendrils may also have adhesive tips that support vine growth.

Shrubs are perennial woody plants that may have one or several main stems and are usually less than 12 feet tall at maturity. Trees are perennial woody plants with one, or sometimes several, main trunk(s) that are usually more than 12 feet tall at maturity. Trees may be further defined as the shape of their canopy (oval, vase, weeping and columnar)

Leaf Retention

Perennial plants (including woody plants) usually fall into one of two categories: deciduous or evergreen. Deciduous plants usually lose their leaves to prepare for dormancy. Evergreen plants retain their leaves seemingly year round; however, they cast off older leaves and grow newer leaves during the growing season. Evergreen plants are further divided into broadleaf (azalea, holly) or needle-leaved plants (pines, junipers).

Climatic Adaptation

Herbaceous plants are classified according to minimum temperature requirements or hardiness. Tropical plants tolerate temperatures from 32 degrees F, or 0 degrees C. Subtropical plants, plants typically native to Tennessee, tolerate short day exposures to slightly below freezing and night temperatures to around freezing. Most native plants in Tennessee are subtropical. Temperate plants are well adapted to prolonged subfreezing temperatures and can endure temperatures well below freezing.

Vegetables, fruits and flowers that can tolerate cool weather are considered cool-season crops. Those that do not tolerate colder temperature should be grown as warm season crops. Cool-season crops typically grow best in daytime temperature ranges of 55 to 75 degrees F (13 to 24 degrees C) and warm season crops grow best at daytime temperature ranges of 65 to 95 degrees F (18 to 35 degrees C).

Uses

Plants are often categorized by their use or by the part of the plant consumed. Ornamental plants are cultivated for aesthetic beauty or for environmental enhancement values. Horticultural plants grown for edible parts are referred to as fruits, nuts, herbs or vegetables. Botanically, a fruit is any part of the plant structure

Fruit or Vegetable?

When a tomato is on the plant, it is considered a fruit; when it is on the table, it is considered a vegetable, based on its nutritional value. Tomatoes contain seeds but are used or consumed in pasta sauces or salads during the main course; therefore, they are considered to be a vegetable.
that contains a seed. However, from a use perspective, a fruit is consumed for its dessert qualities; a fruit is called a vegetable or herb when it is consumed during the main portion of the meal.

**Botanical or Scientific Classification**

Binomial nomenclature is the scientific system of giving a double name to each plant or animal. The first name (genus) is followed by a descriptive or species name. Modern plant classification, or taxonomy, is based on

## Rules of Nomenclature

Nomenclature governs how plants are named, which then determines how they are written and pronounced.

- Botanical Latin follows most, but not all, rules of Latin pronunciation. Words are pronounced in the English method, which is easier on the modern ear than classical Latin.
- Plant names consist of two words: the genus name and the species name.
- The genus name is a noun in the nominative singular case.
- The genus name is always capitalized, for example: **Acer**
- The species name is an adjective describing or modifying the noun. It agrees in case and number. The species name is usually not capitalized, for example: **Acer palmatum**
- The species name may be capitalized if it is derived:
  - Directly from a person’s name
  - From a vernacular name
  - From the name of a genus
  - For example: **Picea Breweriana**
- The species name may be followed by a word indicating another level of scientific classification, for example, **Acer palmatum dissectum**
  - **Subspecies**: A significant geographic race of a species: ssp. or susp.
  - **Variety**: A minor race not deserving subspecies status: var. or v.
  - **Form**: A seedling variation, used when a percentage of seedlings exhibit a distinctive characteristic: f.
- Botanic names are always either italicized or underlined. This is the general rule for writing foreign words in English text.
- The species may be followed by a cultivar name. Cultivar is a contraction of the words, cultivated variety. Cultivars are most often propagated by vegetative means rather than by seed. They are defined by published descriptions that indicate the particular features of the plant that makes it unique. Cultivar names are:
  - Always surrounded by single quotes
  - Always capitalized
  - Never in italics
  - For example: **Acer palmatum dissectum ‘Bloodgood’**

The Importance of Cultivars:

Being given a cultivar name indicates that the plant is a product of:
- Human selection
- Genetic mutation
- Breeding or hybridization
- For example: *Camellia japonica ‘Kumasaka.’* This plant is dark pink, incomplete double flower, blooming late season and cold hardy.
- Another example: *Camellia japonica ‘Chojo Haku.’* This plant is white, single, fall-blooming and not especially cold hardy.

### Hybrids

- Hybrid plants result from a sexual cross between two different species or between clearly defined varieties within a species, for example: **Lagerstroemia farrii x Lagerstroemia indica**
- The immediate result of a sexual cross is one or more seeds. Plants that result from the germination of these seeds are the progeny of the cross. This group of plants may be called a **grex** and given a grex name, or they may not, for example: **Clematis lanuginosa x Clematis vitacella = Clematis x jackmanii.** Jackmanii is the grex name for this group of seedlings. From this group of seedlings, selections may be made for superior color or growth habit, etc. For example, **Clematis x jackmanii ‘Niobe’** has a dark red flower. **Lagerstroemia farrii x Lagerstroemia indica** has no grex name. Selections from this cross are written this way: **Lagerstroemia x Natchez.**
- It is seldom possible to cross plants from different genera, for example: **Canus x Felis or Buxus x Juniperus** or bi-generic Hybrids. However, sometimes with diligent effort, it is possible to hybridize closely related genera. For example: **Cupressus macrocarpa x Chamaecyparis nookatensis = X Cupressocyparis leylandii, Leyland Cypress,** and bi-generic Hybrids. In this case, the plant gets a genus name made up of parts of the two parent genera and the name is preceded by a capital **X**
  - **X Cupressocyparis leylandii**
  - **X Mahoberberis**
  - **X Chitalpa taskentensis**
a system of binomial nomenclature developed by the Swedish physician, Carl von Linne (Linnaeus). Prior to Linnaeus, people tried to base classification on the leaf shape, plant size, flower color, etc. None of these systems proved workable. Linnaeus’ revolutionary approach was to base classification on the flowers and/or reproductive parts of a plant and to give plants a genus and species name. This has proven to be the best system, since flowers are the plant part least influenced by environmental changes. For this reason, knowledge of the flower and its parts is essential for anyone who is interested in plant identification. Although plants are very diverse in nature, they are grouped together by functions and characteristics that they have in common.

**Plant Structure**

Plants cells are independent units with specialized purposes and structures to help carry out the processes essential to life. Plant parts can be divided into two very basic groups: vegetative and sexual reproductive parts. The vegetative parts include: meristems, roots, stems, shoots, leaves, leaves and buds. The vegetative parts are not directly involved in sexual reproduction. Sexual reproductive parts are those involved in the production of seed. They include: flowers, flower buds, seeds and fruits.

### Table 1. Meaning of Specific Epithets

<table>
<thead>
<tr>
<th>Epithets</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adpressus</td>
<td>Pressed against; lying flat against, as the hairs on the stems of some plants</td>
</tr>
<tr>
<td>Angustifolius</td>
<td>Narrow leaved</td>
</tr>
<tr>
<td>Arboreus</td>
<td>Tree-like</td>
</tr>
<tr>
<td>Aristosus</td>
<td>Bearded</td>
</tr>
<tr>
<td>Asperimus</td>
<td>Very rough</td>
</tr>
<tr>
<td>Asiaticus</td>
<td>Asian</td>
</tr>
<tr>
<td>Atripupureus</td>
<td>Dark purple</td>
</tr>
<tr>
<td>Aureus</td>
<td>Golden yellow</td>
</tr>
<tr>
<td>Australis</td>
<td>Of the Southern Hemisphere</td>
</tr>
<tr>
<td>Avium</td>
<td>Of the birds</td>
</tr>
<tr>
<td>Azureus</td>
<td>Sky blue</td>
</tr>
</tbody>
</table>

**Figure 2A. Principal Parts of a Vascular Plant**

Vegetative

**Meristems**

Meristems, or growing points, are plant tissue in which cells divide to reproduce, grow and develop new tissue. The most common meristems are terminal (apical) and lateral. Found in shoot tips, root tips and buds, apical meristems are responsible for the increase in length of these plant parts. The increase in stem and root diameter or thickness is due to the lateral meristems, called the cambium. In many grasses, the meristem is responsible for shoot growth and is found near the base of the plant. Therefore, mowing turfgrass at the proper height does not injure or remove the growing point of the plants.

Meristematic areas, which are normally just a few cells deep, may produce shoots (vegetative growth) or flowers (reproductive growth), depending on when and where the meristems are active. All active meristems receive priority for food materials and minerals available within the plant. For this reason, they are often referred to as sinks.
Roots

The functions of the root system are absorption, anchorage, conduction and storage. In land plants, large amounts of water are absorbed through millions of thin-walled root hairs that are in close contact with the soil particles. Each root hair is formed from a single epidermal cell near the growing tip of the root. Each one lasts only a short time and many are killed during transplanting. Anchorage is gained by the extensiveness of the root system, both spread and depth. Plants are more resistant to being blown over by the wind and are less susceptible to damage by cultivation when soil conditions allow roots to grow into the soil.

A primary root originates at the lower end of the embryo of a seedling plant. A taproot is formed when the primary root continues to elongate downward into the soil and becomes the central and most important feature of the root system with a somewhat limited amount of secondary branching. Some trees, especially nut trees like pecans, have a long taproot with very few lateral or fibrous roots. As a result, these trees are difficult to transplant. Additionally, because of the long taproot, these trees must be planted only in deep, well-drained soil.

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

A fibrous root system is one in which the primary root ceases to elongate and numerous lateral roots develop. The lateral roots branch repeatedly and form the feeding root system of the plant. Most nursery plants have this type of root system.

If plants that normally develop a taproot are undercut so that the taproot is severed early in the plant’s life, the root will lose its taproot characteristic and develop a fibrous root system. This is done commercially in nurseries so that trees, which naturally have taproots, will develop a compact, fibrous root system. This allows a high rate of transplanting success in the field.

The quantity and distribution of plant roots are very important to plant health because
these factors have a major influence on the absorption of moisture and nutrients by roots. The depth and spread of the roots are 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 one. A dense compacted layer in the soil will restrict or terminate root growth.

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

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

Internally, there are three major parts of a root, the meristem, the zone of elongation and the maturation zone. The meristem is at the tip and manufactures new cells; it is an area of cell division and growth. Behind it is the zone of elongation. In this area, cells increase in size through food and water absorption. These cells, by increasing in size, push the root through the soil. The third is the maturation zone where cells undergo changes 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 and the root cap. Root hairs are found along the main root and perform much of the actual work of water nutrient absorption. The root cap is the outmost tip of the root and consists of cells that are sloughed off as the root grows through the soil. The meristem, the area of cell division, is protected behind the root cap.

**Stems and shoots**

The primary functions of the stems and shoots are support, conduction and storage. Shoot refers to the tissue of developing stems and leaves (leafy shoots) and stems and flowers (flowering shoots). The stem holds the leaves up so they receive more light, which is important in the manufacture of plant food. Some plants have a single stem, often called a trunk. Other plants have many stems arising from the crown.

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

The area of the stem where leaves are located is called the node. Nodes are areas of great cellular activity and growth. It is at the node that buds develop into leaves or flowers. The area between nodes is called an internode. The length of an internode depends on many factors, including fertility, amount of daylight and competition from other plants. If fertility is decreased, the internode length will be shortened. If light is low, the internode will elongate, causing a spindly stem. This situation is known as stretch or etiolation. Additionally, if there is competition from surrounding stems or developing fruit, the internode length will be shortened. 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 length than less vigorous plants.

Photosynthetically manufactured food moves out of the leaves through stem tissues called phloem. Materials can move up or down in the phloem. Soil water and mineral solutions are conducted upward from roots to the leaves through inner tissues called xylem. Together, the xylem and phloem form a continuous, pipe-work system (vascular system) sending nutrients and water from every root tip to every shoot and leaf tip in the plant.
Between the xylem and the phloem in some plants is a tissue called the cambium layer. The cambium layer forms new xylem and phloem that may be required by the plant. The cambial layer is responsible for the increased diameter growth of stems and roots. In grasses, or monocots (single-seed leaf) plants, the three tissues are formed in bundles scattered in a discontinuous vascular system throughout the stem. In woody plants, the xylem and phloem occur as concentric zones separated by the cambium, which is a few cells wide. The two types of cambium in woody plants are active xylem (sapwood) and inactive xylem (heartwood). Sapwood is the younger, outermost wood. It is not very thick. Heartwood is in the inner part of the wood. It is usually thicker than sapwood.

Herbaceous or non-woody plants and stems have a thin outer protective tissue. This protective tissue is called an epidermis. Herbaceous or succulent stems contain water-filled cells (turgid cells) that provide adequate strength to support the plant. In large, herbaceous plants, a stiffening process called secondary growth occurs as the plant becomes semi-woody (sometimes referred to as a sub-shrub). Woody stems, such as those in trees and shrubs, may develop a thick or tough protective exterior tissue called bark. In woody plants, specialized tissues (fibers) begin to form as the stem elongates and the stem becomes more or less rigid.

### Measuring Plant Health

Internode length is a great measuring stick for plant health. Short internodes may indicate slowed growth due to water stress, heat or damage. Extremely long internodes may indicate lack of light.
a short distance below the apical meristem. Because the stem cannot elongate in growth below the meristem, it is limited to growing in diameter. Thus the length of the nodes remains constant for the life of the plant.

**Leaves**

Two principal functions of leaves are to absorb sunlight for photosynthesis (which creates food for the plant) and to transpire water from the plant to the atmosphere. Leaves develop into a flattened surface 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 smaller angle formed between the petiole and the stem is called the leaf axil. An active or dormant bud or cluster of buds is usually located in the axil.

The leaf blade is composed of several layers. The tough cells of the epidermis make up both the top and the bottom layers of the leaf. 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 that the leaf feels like velvet.

Part of the epidermis is the cuticle that produces a waxy layer called cutin. The cutin protects the leaf from dehydration and prevents penetration of some diseases. The amount of protective cutin increases with increasing light intensity. The waxy cutin 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 to penetrate the cutin layer.

On the underside of the 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 stomata. The opening and closing of the cells are 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 an airy lower layer called the parenchyma layer. The cells in the lower layers contain chloroplasts. The chloroplast is the actual site of the photosynthetic process.

The veins, which form a network throughout the leaves, are part of the vascular system described earlier. Water movement from the roots through the stem to the leaves depends on lower water pressure at the top of the plant. This pressure difference occurs as a result of transpiration, which is the process in which the plant gives off water to the atmosphere.

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 have numerous veins that run essentially parallel to each other and are connected laterally by minute straight veinlets. Possibly the most common type of parallel veining is found in plants of the grass family, where the veins run from the base to the apex of the leaf. Parallel-veined leaves occur on plants that are part of the monocots group.

Net-veined leaves, also called reticulate-veined, have veins that branch from the main

**Moving Plants from Shade to Sun**

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 sun scald.
Plant Identification

Leaf and bud characteristics are useful in identifying different species and varieties of plants. Plant identification keys can be used to identify different plant species. When keying out a plant, pay close attention to: bud orientation (opposite, alternate, whorled) and shape; bark color; pubescence; and leaf blade shape, venation, margin.

- rib or ribs and then subdivide in finer veinlets that unite in a complicated network. This system of enmeshed veins gives the leaf more resistance to tearing than most parallel-veined leaves.

- Net-venation may be either pinnate or palmate. In pinnate venation, the veins extend laterally from the midrib to the edge, such as in apple, cherry and peach tree leaves. In palmate venation, the principal veins extend outward from the petiole near the base of the leaf blade. Net-veined leaves occur on dicot plants such as grape and maple.

- The leaves of plants have characteristic shapes that may be used in identifying species and varieties. Simple leaves are those in which the leaf blade is a single continuous unit. Compound leaves are composed of several separate leaflets arising from the same petiole. A deeply lobed leaf may appear similar to a compound leaf but if narrow bands of blade tissue connect the leaflets, 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 a compound leaf. Some leaves may be doubly compound, having divisions of the leaflets. The type of margin of a leaf or leaflet is especially useful in the identification of species or varieties of fruit, nut or ornamental plants. The most common forms of leaf margins are entire, lobed, serrated and spined.

- A number of rather distinct types of leaves occur on plants, each having special characteristics that aid in a plant’s survival. Leaves,
commonly referred to as foliage, are the most common and conspicuous, and as previously stated, are the sites of the photosynthetic activity of the plant. Scale leaves, or cataphylls, are found on rhizomes and are also the small leathery protective leaves that are found on the embryonic plant. Scale leaves commonly serve as storage organs. Spines and tendrils, as found on barberry and pea plants, are specialized leaves that protect the plant or assist in supporting the stems. Storage leaves, as are found in bulbous and succulent plants, serve as food-storage organs. Other specialized leaves include bracts that are often brightly colored. These are the showy structures on dogwood and poinsettias.

**Buds**

Buds are meristematic structures along the stem that are composed of compresses, immature shoots, leaves and/or flowers. The buds of dormant trees and shrubs in the Temperate Zone typically develop a protective outer layer of small leathery bud scales. 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. 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 by cold temperatures or frost.

Buds are named for their location on the stem surface. Terminal or apical buds are located at the tip of a stem or shoot. Lateral buds are borne on the sides of the stem. Most lateral buds arise in the axils of a leaf and are called axillary buds. In some instances, more than one bud is formed. Adventitious buds may develop from the internode of the stem, the edge of a leaf blade, the callus tissue at the cut end of a stem, the root or laterally from the roots of plants.

The arrangement of buds and resulting shoots around a stem occurs in a particular pattern for each plant species. These patterns and appearances are particularly useful for plant identification. The most common arrangements are alternate, opposite and whorled. In the alternate arrangement, singular buds occur on one plane but alternate from one side to the other in a zigzag pattern. Buds in an opposite arrangement occur in pairs, with one bud on opposite sides of the plane. A whorled arrangement occurs when three or more buds arise in different planes at one point on a stem or when single buds emerge in three or more planes along a stem.

**Sexual/Reproductive Structures**

**Flowers**

Horticulturally important plants, with few exceptions, produce seeds. This characteristic puts them in the most highly developed group of the plant kingdom. This group is subdivided into two groups; the angiosperms, meaning covered seed; and the gymnosperms, meaning naked seed. Plants in the first group bloom and develop fruit, which enclose the seed, while those in the second group have no true flowers or fruit but bear their seeds uncovered in cones or similar structures. This group includes conifers, ginkgos and a few significant others.

The flower may be thought of as a specialized stem with leaves adapted for reproduction, which is their function in the plant. They come in many sizes and shapes as well as colors. Some are conspicuous, while others are hardly noticed. People often do not realize that grass blooms! Flowers are borne on an enlarged portion of the stem called the receptacle. Their principal value to the retail nursery producer and the customer is ornamental. Flowers are also used extensively in the description of the species. Their structure is less visibly affected
by environment than is the structure of leaves and stems. Fragrance and color attract pollinators. Insects, animals and birds play an important role in the reproductive process.

If a flower has 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. These are considered the essential parts of a flower and are involved in the seed-producing process. If either of the essential parts is lacking, the flower is imperfect. Pistillate (female) flowers are those that possess a functional pistil or pistils but lack stamens. Staminate (male) flowers contain stamens but no pistils.

Some plants bear only male flowers (staminate plants) or bear only female flowers (pistillate plants). Species in which the sexes are separated are called dioecious. Most holly trees are either male or female plants. Therefore, to get berries, it is necessary to have a female tree and a male tree nearby that will provide pollen. Monocious plants are ones 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 both sexes. Cucumber and squash plants are examples.

Some plants bear only one flower per stem and are called solitary flowers. Other plants produce an inflorescence, a term that refers to how a cluster of flowers is arranged on a floral stem. Most inflorescences may be classified into two groups: racemose/raceme 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. Gladiolus is an example of a spike inflorescence. A raceme is similar to a spike except the florets are borne on small stems attached to the peduncle. Snapdragon is an example of a raceme inflorescence. 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 is an example of corymb inflorescence. An umbel is similar except that the pedicels all arise from one point on the peduncle. Dill is an example of umbel inflorescence. A head or composite inflorescence is made up of numerous stemless florets. A daisy is an example of that characteristic of head inflorescence.

The second group of inflorescences is called a cyme. In this group, the top floret opens first and blooms downward along the peduncle. A dischasium cyme has florets opposite each other along the peduncle. Baby’s breath is an example of dischasium cyme inflorescence. A helicoid cyme has lower florets that are all on the same side of the peduncle. Freesia and statice are examples of helicoid cyme inflorescences. A scorpioid cyme has florets that alternate only along the peduncle. Tomato and potato are examples of scorpioid inflorescences.

Figure 12. Basic Flower Structures

An outer set of green floral leaves, called sepals, encloses the other parts of the flower until these are nearly mature. Collectively, the sepals comprise the calyx. An inner set of colored or white floral leaves is called petals. The entire set of petals is called the corolla. In many flowers, the petals are showy and may aid in attracting the attention of insects that assist in pollination. One or more sets of stamens are located within the petals. Stamens are composed of pollen-bearing anthers. The pistil is the female part of the flower. Pistils consist of an ovule-bearing base, an ovary, a style and a stigma. The mature pollen grains are deposited here and the male gametes move down the style to the female gametes contained in the ovule. The ovule gives rise to the seed following fertilization. The mature ovary becomes the fruit.
Seeds

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, since they do not 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. Because cross-pollination (or cross-fertilization) combines different genetic material and produces stronger seed, cross-pollinated plants are usually more successful than self-pollinated plants. Consequently, more plants produce by cross-pollination than by self-pollination.

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

A cone can also be considered a specialized stem with leaves adapted for reproductive purposes. However, it does not have the typical flower parts. Ovules and pollen are borne on separate cones, which are quite different in appearance. The conspicuous cones are the ovule-bearing, or female cones. The ovules on one of the modified leaves, called a cone scale, are not surrounded by ovary tissue. Pollen is borne on much smaller cones and is carried by wind to the ovule. Following pollination, the scales of the cone are so close that the ovule is protected while the pollen grain germinates and fertilization of the egg cell occurs. This may take as long as a year! When the ovule matures into a seed, the scales again open and the seed is released, as from a pinecone. Not all cones are woody. Surprisingly, the ginkgo is a gymnosperm and its fleshy fruits are really cones.

Some plants, such as ferns, do not have flowers, fruit or seed but instead reproduce from spores. Each spore is a single cell. The spores germinate to form small plants that are usually quite different from the final plants. The first plant sends up new growth that is the form we recognize and use.

The seed or matured ovule is made up of three parts: the embryo, the endosperm and the seed coat. 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 is 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...
Germination is the resumption of active growth of the embryo. Prior to any visual signs, the seed must imbibe water through the seed coat. For germination to occur, the seed must be in the proper environmental conditions: exposed to oxygen, favorable temperatures and for some, correct light. The radical 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 radical and first leaf-like structure is called the hypocotyl. The seed leaves (cotyledons) encase the embryo and are usually different in shape from the leaves that the mature plant will produce. Plants producing one cotyledon fall into the group of monocots. Plants producing two seed leaves are called dicots.

Ferns and Moss Reproduction

Mosses and ferns are both primitive plants. Unlike ferns and higher plants, mosses lack a vascular system and roots. They grow low to the ground because their leaves and stems lack supportive tissues. Mosses grow from haploid cells, single chromosome cells that divide by mitosis. The male structures of a moss produce sperm called antheridia and eggs called archegonia. The antheridia and archegonia are united by rainwater splashes. In contrast to mosses, ferns have a well-formed vascular system. They also have leaves, roots and stems. Ferns are evolutionarily higher than mosses. They reproduce by spores that are in clusters called sori, usually on the underside of a leaf. These clusters produce through meiosis and are usually found in brown spots or stripes. When the spores mature, the sori breaks open and a dust of spores fall on the ground and grow into fern gametophytes- heart-shaped fragile plants. As gametophytes, they produce antheridia and archegonia like the mosses, but on the same plant. The diploid, (two sets of chromosomes) grows roots and shoots from the gametophyte.
Fruits

Fruit consists of the fertilized, mature ovules called seeds and the ovary wall that 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 flower and female flower are the seeds (mature ovules). The rest of the fruit arises from the maternal plant and is therefore genetically identical to the parent plant. Some fruits have seeds that are situated on the periphery of fruit tissue (corn cob, strawberry flesh).

Fruits can be classified as simple fruits, aggregate fruits or multiple fruits. Simple fruits develop from a single ovary. These include cherries, peaches, pears, apples and tomatoes. 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 not fleshy examples as just mentioned. Examples are peanut, poppy, maple and walnut.

An aggregate fruit comes from a single flower that has many ovaries. The flower appears as a simple flower with one corolla, one calyx and one stem, but it has many pistils and ovaries. Examples are strawberry, raspberry and blackberry. The ovaries are fertilized separately and independently. If ovules are not pollinated successfully, the fruit will be misshapen and imperfect.

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

Plant Growth

Plant growth is an irreversible increase in plant size caused by an increase in cell number and/or cell size while a plant is developing new organs and tissues. The process of growth is regulated by a plant’s genetic material and surrounding environmental conditions. Plant growth requires water, air, carbohydrates, chemical energy and mineral nutrients. In green plants, the essential physiological processes responsible for producing and using these items are carried out in individual cells, multicellular tissues and organs. Three major plant processes for plant growth and development are photosynthesis, respiration and transpiration.

Photosynthesis

Photosynthesis is the process by which green plants manufacture their own carbohydrates (food) or nutrients and obtain a source of chemical energy. To manufacture carbohydrates, a plant cell must have chlorophyll and light to convert carbon dioxide (CO2 from the air) and water (H2O) into carbohydrates (simple sugars). This process transforms energy from light into stored chemical energy. Oxygen (O2) is released as a by-product of this process.
process. Photosynthesis literally means, “to put together with light.”

Photosynthesis occurs in tiny, green cell bodies called chloroplasts. Photosynthesis requires that the stomates are open and that carbon dioxide enters the leaf. Photosynthesis also requires that adequate light strikes the leaf and that water is available to the plant. Plants store energy from light first as simple sugars such as glucose. Simple sugars may be converted to other sugars and starches and transported to storage areas (roots). Simple sugars are used as building blocks for more complex structures or broken down during respiration to provide energy to maintain living processes.

When photosynthesis stops, plants eventually stop growing. If photosynthesis is stopped long enough, plants die. Any of the factors required for photosynthesis (carbon dioxide, water, light or suitable temperature) can limit this process. Much horticultural wisdom centers on providing plants with these four items. Houseplants are placed in sun or shade or near windows according to their light preferences. Irrigation systems supply water and mulches retain it. Planting dates provide information on when temperatures will be suitable. Climatic zones give information on where certain plants can survive. Equipment to supplement carbon dioxide in greenhouses is even available.

**Respiration**

Respiration is the process by which chemical energy is acquired by breaking down carbohydrates made during photosynthesis. Respiration is essentially the opposite of photosynthesis. In actuality, more is involved than just reversing the reaction. Respiration rates increase as night temperatures increase. In Tennessee, respiration rates are highest in the summer night temperatures. Stored sugars and other compounds give some root vegetables their flavor. Carrots or parsnips grown in Tennessee in the fall when respiration is low can be significantly sweeter than those grown in the summer. Likewise, northern-grown carrots have better flavor than southern-grown carrots because lower night temperatures lower the rate of respiration.

**Cycling of Photosynthesis and Respiration**

The processes of photosynthesis and respiration form a cycle by which plants create and use food for energy necessary for growth and development. The photosynthetic process requires light, which usually peaks during the day and ceases at night. In the meantime, respiration occurs all the time at variable rates, depending on temperature. For plants to grow at a normal rate, photosynthesis must happen at a rate exceeding the rate of respiration so that there is enough stored energy and carbohydrates to support a plant during the night. An imbalance of these processes can occur for many different reasons. For example, water may become too limited during a drought or due to a damaged root system; temperature may stay the same and allow respiration rates to exceed the photosynthetic production of nutrients. The plant will lose vigor and stored carbohydrates will be depleted. Without these reserved starches, a plant may fail to develop shoots, buds, flowers or seeds. The plant may even fail to store food energy for the next season.

**Water and Nutrition Uptake**

Plant nutrient uptake depends on the availability of water and several essential nutrients and minerals (see Chapter 3, Soils). Water and nutrients are necessary for many different processes, including photosynthesis and respiration. Plants obtain most of their water
and nutrients through their roots by a process called osmosis. Osmosis is the passive transport of solutes and water by diffusion across the plant cell.

Plant nutrients must be in a soluble form so they can be transported and/or utilized throughout the plant for growth and development.

Any plant receiving fertilizer should be well watered so that the fertilizer is diluted throughout the root zone. An excess of fertilizer can result in root damage and burning or browning of the foliage. The burning/browning of the foliage occurs because the roots cannot absorb enough water to compensate for the excess fertilizer. Thus, the foliage is actually dried out.

Translocation

Translocation is the movement of water, minerals, nutrients, food and other dissolved parts from one part of a plant to another. This process can occur from cell to cell or from one part of a plant to another (shoot to root or vice versa) via a plant’s vascular system (xylem or phloem). It is important to note that certain external substances (i.e., applied systemic pesticides) may enter some plant parts and be moved to others in the process of translocation.

Root : Shoot

In a normal healthy plant, there is a balance between the shoot system and the root system. This balance is disturbed by root loss during transplanting or through improper cultivation. Pruning some of the top (shoot) growth of the plant can restore balance. If balance is not restored, the plant may be set back or die because the roots are unable to supply the tops with adequate moisture and nutrients.

Plant Development

Internal Regulation of Growth and Development

Growth and development of a plant are influenced by light, water, carbohydrates, chemical energy and mineral nutrients. Hormones within the plant direct the internal regulation of these growth processes. Plant hormones (often called growth regulators in the green industry) are substances produced in one part of a plant and moved to another to initiate or regulate a development process. The five major groups of plant hormones are: abscisic acid, auxins, cytokinins, ethylene and gibberellins (see Table 4 for a description of their effects on growth and development). The production of plant hormones usually occurs in the meristematic tissue or in the new growth regions of a plant. The production of plant hormones is prompted by environmental conditions. Different hormones and the varying concentrations of the hormones produce different effects in a plant.
For example, at low concentrations auxins will produce adventitious roots on a stem. In high concentrations auxins are used as a broadleaf herbicide. Additionally, some growth hormones activate different processes in vegetative growth from reproductive growth.

**Dormancy**

Plant growth is not always continuous. Shoots, buds, (leaves and flowers) and other vegetative parts of a plant may be alive but not actively growing. Dormancy is a mechanism by which a plant can survive unfavorable conditions. Seeds lie dormant until environmental conditions are favorable for germination (soil moisture, temperature, light and oxygen). In many cases, plants use stored starches and carbohydrates to maintain low-levels of respiration during dormancy.

Seed dormancy may be physical, physiological or both, depending on the species of the seed and its environment. A physical dormancy is a result of a hard seed coat that does not allow water or oxygen to permeate the seed. For these seeds to germinate, a seed treatment may be applied to break dormancy (see Chapter 6, Plant Propagation). Special internal processes take place from the plant hormones and enzymes present in the fruit or seed, allowing physiological dormancy. Sometimes an embryo must complete an after-ripening phase before breaking a physiological dormancy. For example, seeds of fruits might need to be exposed to the hormone abscisic acid, specific temperatures or water to trigger germination.

Dormancy of plants (seeds, buds and shoots) is usually triggered by a series of unfavorable conditions such as short days, cool weather, drought or heat. Once these conditions subside, the plant or seed is triggered by specific favorable environmental conditions that allow that plant species to resume growth.

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**Plant Growth**

Have you ever noticed a plant growing toward the lighted window in a dark room? Auxins are the hormone responsible for this growth response. Auxins gather in the stem cells on the dark side of the plant and signal them to elongate and bend the plant to the light. This response is called phototropism. Phototropism allows the plant to move a petiole and arrange its leaves for the most efficient light absorption.

**Figure 17. Phototropism**

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**Table 4. Five Groups of Plant Hormones**

<table>
<thead>
<tr>
<th>Hormone Group</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscisic Acid</td>
<td>Regulates and promotes dormancy in shoots and seeds. Responsible for abscission (dropping-off) of leaves on deciduous plants and closing the stoma on leaves of plants under severe stress.</td>
</tr>
<tr>
<td>Auxin</td>
<td>Regulates cell enlargement (as in phototropism). Suppresses laterals bud development, creating apical dominance of main buds and shoots. Directs horizontal growth upward. Suppresses fruit- or leaf- drop mechanisms. Promotes formation of adventitious root from stems and leaves. Low concentrations promote root or root formation. High concentrations kill broadleaf weeds. Promotes fruit set and development or fruit adsorption, depending on the plant species.</td>
</tr>
<tr>
<td>Cytokinin</td>
<td>Stimulates cell division, frequently in conjunction with auxins and gibberellins, to regulate processes associated with each.</td>
</tr>
<tr>
<td>Ethylene</td>
<td>Accelerates fruit ripening. Induces flowering in some species. Hastens senescence and abscission of leaves and fruits. Interacts with auxins in certain processes often produced by plants or plant parts that have been injured.</td>
</tr>
<tr>
<td>Gibberellin</td>
<td>Regulates cell division and stem elongation (internode length in stems). Promotes flowering in some plant species. Activates enzymes in germinating seeds.</td>
</tr>
</tbody>
</table>
Vegetative Development

For annual, biennial and some perennial plants, the vegetative development begins with seed germination, or the breaking of new leaf buds, and ends with flower development (seed development). In wood perennials, vegetative and reproductive phases often present at the same time.

Seed Germination

Plants begin their lifecycle at seed germination. Germination starts when a seed begins to absorb water through the seed coat and ends when the seedling is self-sustaining. For germination to occur, the environmental conditions must be suitable. Environmental factors include temperature, light and a continuous supply of water and air. Seeds will not initiate growth until temperatures are within a specific range. The closer the temperature is to optimum for a species, the more rapidly seeds germinate. Table 5 illustrates germination at various temperatures for some common vegetables.

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Soil Temp (degrees F)</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lima beans</td>
<td>85</td>
<td>7-10</td>
</tr>
<tr>
<td>Snap beans</td>
<td>75-80</td>
<td>7</td>
</tr>
<tr>
<td>Cabbage</td>
<td>68-75</td>
<td>5-10</td>
</tr>
<tr>
<td>Carrot</td>
<td>75</td>
<td>12-15</td>
</tr>
<tr>
<td>Corn</td>
<td>75-85</td>
<td>7-10</td>
</tr>
<tr>
<td>Cucumber</td>
<td>70-85</td>
<td>7-10</td>
</tr>
<tr>
<td>Lettuce</td>
<td>65-70</td>
<td>7-10</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>80-85</td>
<td>5-10</td>
</tr>
<tr>
<td>Okra</td>
<td>80-85</td>
<td>7-14</td>
</tr>
<tr>
<td>Peppers</td>
<td>78-85</td>
<td>10-14</td>
</tr>
<tr>
<td>Radish</td>
<td>65-70</td>
<td>5-7</td>
</tr>
<tr>
<td>Tomato</td>
<td>75-80</td>
<td>7-14</td>
</tr>
<tr>
<td>Turnip</td>
<td>65-70</td>
<td>7-14</td>
</tr>
<tr>
<td>Watermelon</td>
<td>75-85</td>
<td>7-14</td>
</tr>
</tbody>
</table>

*This vegetable does not germinate at this temperature.

Juvenility

A plant is considered juvenile from the time it is a seedling until it is mature and capable of initiating flowers. Juvenility is marked by relatively vigorous, uninterrupted growth (except for normal dormancy). In annual species, juvenility generally lasts for a few weeks to a few months. In some perennial plants, like fruit trees, juvenility may last a few years. A small number of plants, such as bamboo and agave (century plant) remain juvenile for 10 years or more.

Some species exhibit distinctly different morphological features during juvenility and maturity. Juvenile pears may have thorns, whereas mature trees do not. The leaves on the Hedera helix (English Ivy) are trailing and do not support themselves enough to grow upright; where as mature stems grow upright with no support. To compensate for weak support, juvenile plants readily initiate adventitious roots more readily than mature plants. Juvenile plant parts are also more easily grafted than older sections of a plant.

Maturity

Maturity is reached when a plant is fully developed and is capable of initiating flowers. Certain morphological and physiological changes must occur in mature plants. During the mature phase of vegetative growth, bulbs, tubers and runners are produced. Some plants may be mature enough to reproduce, but because of environmental conditions, may not do so. Environmental conditions will determine if a plant is able to flower.

Reproductive Development

Flower Induction

In flowering plants, the reproductive growth phase begins when certain vegetative meristems (actively growing buds or tips) are induced to produce reproductive organs (flowers) and ends with the formation of fruit or senescence of a plant. Once the meristem induces flowering, it follows a process of initiating cells that form new tissues of a flower or a flower cluster, known as inflorescence. The process is normally irreversible after it is initiated. This means the meristem will no longer initiate vegetative cells of shoots it previously initiated.
The length of time needed to induce a meristem to become reproductive and the length of time needed for a meristem to produce flowers vary among species from weeks to months. These time frames may also vary slightly within a species, depending on temperature or other factors. The number of meristems on a plant that are induced to flower may also vary widely from plant to plant.

The time of year when flower induction occurs and the length of time from induction to flowering for a given species are important for home gardeners to know. Many perennials initiate cells of flowers tissue within the meristems months before flowers develop. Flower buds of spring-flowering woody plants, for example, are usually initiated the previous summer (azalea, rhododendron). Pruning such species during the winter months would remove the next season’s flower. However, annual plants may reach maturity and flower within several weeks of seed germination.

**Flower and Fruit Development**

Some plants are genetically predisposed to self-induced flowering and other species are more sensitive to environmental factors. The primary factors for fruit and flower development are day length (photoperiod), light intensity, temperature, soil moisture and the internal nutritional status of the plant.

As a flower opens and develops fully, a number of events must take place for fruit to develop. The ovary of the flower (and sometimes other parts) forms the fruit. For normal development, the flower’s stigma must receive viable pollen, which must fertilize the ovule(s). Fertilization is not assured even when pollination takes place. Each ovule must be fertilized by a separate pollen grain. During pollination several physiological processes are initiated that result in fruit set, or the inhibition of flower or fruit drop. Fertilization does not always occur, even though pollination and fruit set take place.

Pollination and fertilization are different complex processes that require precise environmental conditions. After ovules in the flower are fertilized, the size of the developing fruit increases rapidly. Photosynthesis supplies the raw materials of energy and nutrients to carry out the growth processes. This nutritional status and availability of moisture are important in fruit size and quality. Therefore, there must be a sufficient number of leaves to support the process. For example, a minimum of 40 illuminated leaves are needed to support the growth of one apple on a mature tree. Adequate moisture must be available for the same reason.

It is possible for fruit to develop without fertilization. No viable seed will develop in this situation, which results in seedless fruits. A few crops may fruit without fertilization: banana, persimmon, grapes, navel oranges and some cucumbers (seedless varieties).

Normally, only a fraction of flowers on a fruit-producing crop produce mature fruit. A significant number of fruit from tree fruit crops drop just after petal fall or 4 to 6 weeks later known as June drop. Fruit drop can be a normal reaction for the plant to adjust to the fruit load level that a plant can adequately support.
Fruit Quality and Ripening
Sugars and aromatic compounds in a fruit will begin to accumulate, giving a fruit its flavor, color and tenderness. Some fruits need to be attached to the plant to fully ripen for optimal flavor and quality. Others are harvested prior to being physiologically mature and will develop to maturity detached from the parent plant; bananas, tomatoes, apples, and pears are examples. These fruits may need specific environmental factors to complete ripening. Tomatoes are often exposed to ethylene gas to ripen in commercial production.

Short-day plants include many spring- and fall-flowering plants such as chrysanthemum and poinsettia. They flower only when the day length is less than about 12 hours. Most summer-flowering plants and vegetables are long-day plants. Short-day plants can be forced to flower by covering them with a black cloth to block out light for the required dark period. Even a minute or two of light during the dark period will stop some short-day plants from flowering. Artificial light can be used to initiate flowering in many long-day plants. There are strawberry varieties that are day-neutral and bear repeatedly throughout the spring, summer and fall.

How Plants Function

Plant Responses to Day length
Knowledge of a plant's response to environmental factors such as light and temperature aids one in choosing the right plants for the right location and in giving the proper care to the established plants. Light has three principal characteristics that affect plant growth: quantity, quality and duration. Light duration or photoperiod refers to the amount of time a plant is exposed to light. It was once thought that the length of the light period triggered flowering in many plants. It is now known that it is the length of the uninterrupted dark period that is important. Thus, a plant that is referred to as a short-day plant is really a long-night plant and will flower when it receives uninterrupted long nights. There are short-day, long-day and day-neutral plants.

Cross-pollination of different species cannot affect the flavor of this year's fruit. Cucumbers planted near cantaloupes will not make cantaloupe bitter. Nor will a yellow apple tree planted near a red apple tree make your apples off color. The seed generation within that fruit might have genetics from both plants, giving rise to a new cross or variety (see Chapter 11, Vegetable Gardening).

Plants Responses to Light Intensity
Light quantity refers to intensity or brightness. The brightness of sunlight varies with atmospheric conditions, season and time of day. Increasing the light intensity increases photosynthesis and growth of all plants, up to a point.

Some plants require relatively low light intensity. These plants must be placed in low light levels such as shade or the natural light intensity must be reduced artificially. Shadecloth is designed to do this. cheesecloth may also suffice.

Most plants grow best in full sunlight. Young plants may grow tall and leggy even in a south-facing window because the light is not bright enough for long enough. Light from a window may be increased by using supplemental artificial light or by surrounding plants with white or reflective material.

When light is brighter on one side of a plant, many plants grow toward the light. This response is called phototropism. Houseplants may grow more evenly if they are turned one-quarter turn every few days to eliminate the effect of phototropism.

Plants Responses to Light Quality
Light quality refers to its colors or wavelengths. Sunlight can be separated by a prism into the primary colors of red, orange, yellow, green, blue, indigo and violet. You can see these colors in a rainbow. Red and blue light are the most effective for plant growth.
Green light is reflected by plants and is the least effective. Incandescent light is generally high in red and orange light but produces too much heat to be effective as a lighting source for plants. Cool white fluorescent lights are high in blue light and encourage leafy growth. There are special grow lights that mimic sunlight more closely and are a better source of light for plants. Because of the low light intensity of fluorescent lights, the light source needs to be within a few inches of the plants. Special high-intensity light sources designed for growing plants are also available. These systems are expensive but can work quite well.

**Plant Responses to Temperature**

Temperature is the main environmental factor affecting plant growth. It determines planting dates, growing season and which plants can be grown in a locale. It also contributes to the rate of plant growth and plant quality.

Plant hardiness refers to whether a plant or a plant part will survive outdoors in a given locale. There are two components of hardiness. First, a plant must be able to withstand the coldest temperature to which it is exposed. Second, a plant must be able to withstand fluctuating temperatures. Not all parts of a plant are equally hardy. Roots are frequently not as hardy as the rest of a plant. Dormant plants may have their roots killed in shipment if exposed to extreme temperatures. When planted, these plants begin to leaf out because the stems are alive, and then die because the roots are dead. Flowers and flower buds are also very tender. These buds may freeze without the entire plant being killed. The plant then grows normally but fails to bloom. Peaches and other fruit trees may fail to bear and ornamentals may fail to flower for this reason.

Winter injury can occur from low temperatures directly or indirectly from desiccation (drying out). Plants require water even in the winter because water continues to be lost, especially on windy days. If the soil is frozen or very cold, water movement into the plant is restricted. The result can be death of part or all of the plant.

A similar phenomenon occurs when sunlight shines on the southwest side of a plant during winter days. The cells warm, come out of dormancy and begin to grow. They are then susceptible to low temperatures or desiccation. Maples and some fruit trees are often painted up to the lower limbs with a white, interior, water-based paint to prevent bark on the southwest side of the trunk from being killed.

Annual plants can be classified as either cool- or warm season plants. Cool-season plants require cool temperatures to germinate, grow and mature properly. They are shallow-rooted and susceptible to drought. They can usually withstand considerable frost. Examples of cool-season plants include pansies, daffodils, cabbage, English peas and spinach.

Warm season plants require warm temperatures to germinate, grow and mature properly. They are deep-rooted and resistant to drought. Frost kills most warm season plants. Examples of warm season plants include zinnias, vinca, okra, peppers and Southern peas.

Extremes of temperature reduce photosynthesis and thus growth rate. Extremes of temperature can also cause bud, blossom or fruit drop in many crops such as tomatoes or peppers. This is why these crops become unproductive for a time during the summer. A growing season that is too short can also prevent maturity of late-season apples and pecans in Tennessee.

**Interactions of Photoperiod and Temperature**

Temperature can interact with light to modify plant responses to a given photoperiod. Poinsettias initiate flowers in 65 days when grown in short-days at 70 degrees F (21 degrees C) but require 85 days if the temperature is 60 degrees F (16 degrees C). Christmas cactus has a short-day response, but plants will flower at any day length if the temperatures are below 65 degrees F (18 degrees C).
Plant Responses to Soil Moisture Conditions

As previously mentioned, water is a primary requirement of photosynthesis. It maintains turgor pressure and transports nutrients throughout the plant. Water is the main component of protoplasm, the living part of a cell. Water also provides the pressure to move a root through the soil. Water is the solvent that moves minerals into the plant and sugars to their site of use or storage. Water helps stabilize plant temperature as it evaporates from leaf surfaces near stomates. Maintenance of proper levels of water throughout the plant is essential for numerous plant functions.

Plants acquire most of their water from the soil through root hairs. Seedlings will be quickly killed by a lack of water. Larger plants suffering from lack of water will wilt and cease growing, yellow, drop leaves, become stunted and finally die.

Vast amounts of time, effort and money are devoted to supplying plants with proper amounts of water. Soil is allowed to remain fallow, plantings are timed and spaced, irrigation systems are designed and utilized and mulches are applied to supply plants with soil moisture. Too much moisture can prevent oxygen from reaching roots and can increase soil-borne diseases. This may kill plants by stopping water uptake. Thus, farmers and gardeners avoid floodplains, plant on raised beds or ridges, drain fields and/or supply drainage holes in containers.

Salts or minerals in water may destroy plants if they are too concentrated. Improper soil acidity (pH) can also kill roots or even entire plants, as well as affect the uptake of minerals. Cold water may chill plants and hot water can kill them. Cold water causes spots in African violet leaves.

Plants lose water through all of their parts, but most water is lost through leaves. This is because water loss is proportional to the surface area exposed to air. Most of a plant’s surface area is leaf area. Leaves also lose water through stomates as discussed previously.

Plants reduce water loss by closing stomates. Long periods of water loss result in wilting, which reduces turgor pressure and further slows water loss.

Some plants have modified their leaves into thorns or developed fleshy leaves or stems to assist with maintaining proper amounts of water. This not only reduces the plant’s surface area, but may also provide storage areas for water.

Loss of water from a plant is strongly affected by relative humidity. Relative humidity is the ratio of water vapor in the air to the amount of water the air can hold at a given temperate and pressure, expressed as a percent. For example, if a kilogram of air at 75 F could hold 4 grams of water and there are only 3 grams of water in the air, then the relative humidity (RH) is:

\[
\text{RH} = \frac{\text{water in the air}}{\text{water air can hold}} = \frac{3}{4} = 75\%
\]

Warm air can hold more water vapor than cool air. Thus increasing temperature allows more water to be held. Water vapor moves from areas of high humidity to areas of low humidity.

When the relative humidity in the air spaces between the cells in a leaf approach 100 percent, the stomates open and water rushes out. A cloud of high humidity forms around the leaf and transpiration slows. Wind removes this area of moist air and greatly increases transpiration and water loss. Increasing the temperature increases the water the air can hold and increases transpiration. Plants require more water on warm and windy days, just when the soil is losing water most rapidly.

Plants Responses to Carbon Dioxide and Oxygen Concentration

Carbon dioxide is an essential factor in the process of photosynthesis and oxygen is essential to the process of respiration. Air surrounding plants can usually supply the necessary amounts of these two gases to the roots and the shoots. However, the soil does not always have enough air space to sustain the roots. When soils are too wet, extremely compacted or artificially deepened; roots may not be able to acquire enough air. Germinating seeds also require oxygen as they respire. Propagation soil should always be loose and light for seedling emergence. Remember that even plants in dormant phases need to respire at low levels and oxygen is necessary (even for seeds and tubers).
Relationship of Nitrogen Nutrition to Plant Growth and Development

Abundant levels of nitrogen can stimulate excessive root and shoot growth, which can lead to pest and disease problems in the plant. The presence of new vegetative growth will inhibit the development of flowers and reproductive cycles. The plant can use nitrogen as it grows, using chemical energy and stored carbohydrates. After the nitrogen levels subside, the plant will initiate a normal reproductive cycle. If nitrogen levels are too low, a plant can neither produce effective vegetative or reproductive growth.

Plant Response to Stress

Non-optimal growing conditions are referred to as stresses. Stresses can include: extreme temperature variances, too much or too little water, low or high light levels, wind, poor soil aeration, damage or any combinations of these factors. Stress can cause a plant to have a weak or tough vegetative growth, a loss of vigor or a shorter life phase. A stressed plant may respond to stress by dropping leaves, blossoms or fruit. If exposed to stress for a long period of time, a plant could yield poor-quality fruit, fewer viable seeds, become susceptible to diseases and pests or perish.

Some plant stresses are unavoidable to the home gardener. Transplant shock is the most common. Some bedding plants go through a short phase of imposed stress before acclimating to a new environment and its conditions. To reduce this stress, it is recommended to harden-off plants before planting. To harden a plant, withhold water and fertilizer and gradually expose the plant to sun. This will allow for a smoother plant transition.

Summary

Horticulture is a dynamic and exciting field. It has branches in science, business and art. By understanding the structure, function, development and physiology of plants, a working knowledge of horticulture will be gained.

Terms To Know

Absorption
Adventitious
Aggregate fruit
Alternate leaf arrangement
Angiosperm arrangement
Annuals
Apical dominance
Axil
Axillary bud
Biennial
Binomial nomenclature
Bolt
Botany
Bracts
Branch
Bud
Bulb
Calyx
Cambium
Cane
Chlorophyll
Chloroplasts
Complete flower
Compound leaf
Conduction
Cone
Cool-season crop
Corm
Corolla
Cortex cells
Corymb
Cross-fertilization
Crown
Cultivation
Cuticle
Cutin
Cutting
Cyme
Day-neutral plants
Deciduous
Dicots
Dioecious
Dischasium cyme
Embryo
Endosperm
Epidermis
Etiolation
Evergreen
Fertilization
Fibrous root
Flowers
Foliage
Fruit
Test Your Knowledge

1. A dioecious species has either pistillate or staminate (male) flowers occurring on separate plants. Name an example of this type of plant:

2. A corn plant has both male and female parts on the same plant, but as separate distinct flowers. What best term describes this type of plant?

3. What is the difference between respiration and photosynthesis?

4. True or false? The rate of transpiration depends on environmental factors such as temperature, relative humidity, wind and available soil moisture.

5. True or False? Fertilization or seed development occurs after pollination (pollen transfer) has occurred to the female stigma parts of the flower.

Resources

American Society of Horticulture Science
ashs.org

The United States Department of Agriculture
usda.gov

The University of Tennessee Extension
utextension.tennessee.edu

The University of Tennessee Gardens
utgardens.tennessee.edu