CHAPTER **THREE**

BASIC BOTANY

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3 BASIC BOTANY

Learning Objectives

- Describe plant nomenclature, including common and scientific names
- Understand horticulture-related plant classification and define others, including line, landrace, open-pollinated, heirloom, and hybrid
- Describe plant life cycles
- Understand plant parts and their functions
- Describe leaf parts, structure, and arrangement
- Discuss the function of leaves
- Describe the parts and types of stems and root growth and function
- Discuss the function of the vascular system
- Define flower parts and their functions
- Discuss the role of fruit in seed development and dispersal
- Describe seed viability and how it is affected by seed storage conditions
- Understand the seed germination process, the vegetative growth stage, and the reproductive stage of plant development

Introduction

Botany is the study of plants. To become a knowledgeable plant person, it is essential to understand basic plant science. It is important to understand how plants grow, how their various parts function, how they are identified and named, and how they interact with their environment. Learning the language of botany means learning many new words. Making the effort to learn this material will prove extremely valuable and will create excitement as you learn to unravel the mysteries of the plant world.

Like all living organisms, plants are complex, and there is far more to know about them than can be learned in an introductory Master Gardener course. Nonetheless, this chapter is designed to provide the Master Gardener student with a brief, but broad, introduction to many aspects of botany.

Plant Nomenclature and Classification

Plant classification and the scientific naming of plants are important for correct and precise identification. Plant classification can be useful for Master Gardeners involved in identifying plants, germinating seeds, growing a garden, diagnosing plant problems, or controlling pests.

Plants generally have a common name and a scientific name. Common names are usually simple and easy to remember for the general public. They often are descriptive of the plant; for example, burning bush, bleeding heart, or paper birch.

There are problems, however, with using common names. The same species of plant may have two or more common names, with names varying from country to country, region to region, and sometimes even within a local area. This makes it difficult to communicate about a plant. For example, the state flower of Idaho is *Philadelphus lewisii*, commonly called syringa in Idaho. In other parts of the country, however, the same plant is known as mock orange. To add to the confusion, *Syringa* is the genus for lilac shrubs. Another example of confusing common names is *Malva parviflora*, which is called little mallow, round leaf mallow, cheeseweed, or sometimes buttonweed. The same common name may also be used for several plants. An example is the common name geranium, which can refer to plants in either the genus *Geranium* or the genus *Pelargonium*.

With scientific names, a plant has only one name. Scientific names use the Latin language and often are descriptive of some characteristic of the plant. A dictionary on plant names can help with pronunciation and clarify the meaning of Latin words.

Plants are named using a **binomial** (two-part) naming system. A binomial name includes the plant's genus name (capitalized and italicized) plus the specific epithet name (lowercased and italicized). The name may be followed by the initial of the person credited with originally describing and naming the plant. For example, *Solanum tuberosum* L. indicates that Carl von Linne (Linnaeus), a Swedish physician, described and named the white (Irish) potato.

Plant classification groups plants with similar characteristics, first in a broad sense, then through a series of subgroups, using progressively more specific flower and plant traits. This process continues until a single, unique plant form remains.

This plant is given a binomial species name. Ranked from general to specific, the plant classification groups are as follows: kingdom, division or phylum, class, order, family, genus, species, and variety or cultivar. Each species is assigned to a genus, each genus to a family, and so on. Refer to Table 1 for examples of plant classification.

Understanding plant classification is useful for maintaining a successful garden. For example, vegetable crops should be rotated each year, and rotation can be simplified by grouping plants from the same family. To do so, you need to know which

Table 1. Examples of plant classification.

Common name	Black chokecherry	Siskiyou blue Idaho fescue	Western white pine
Kingdom	Planta	Planta	Planta
Division or phylum	Magnoliophyta	Magnoliophyta	Pinophyta
Subdivision	Angiospermae	Angiospermae	Gymnospermae
Class	Magnoliopsida (dicots)	Liliopsida (monocots)	Pinopsida
Order	Rosales	Poales	Pinales
Family	Rosaceae	Poaceae	Pinaceae
Genus	*Prunus*	*Festuca*	*Pinus*
Species	*Prunus virginiana*	*Festuca idahoensis*	*Pinus monticola*
Variety or cultivar	var. *melanocarpa*	'Siskiyou Blue'	

plants belong in which family. A second example: when using the internet to research solutions to a plant problem, it is absolutely essential to enter the correct scientific name. The more you study plants, the more you likely will appreciate the usefulness of the scientific nomenclature system.

An important distinction among plants at the Division level is between those with seedlings having one seed leaf (**monocots**, such as grasses and lilies) and those with seedlings having two seed leaves (**dicots**, such as beans). Monocot and dicot seeds germinate differently. The distinction between monocots and dicots becomes very important when using herbicides. For example, common lawn herbicides for broadleaf weeds (for example, 2,4-D) will kill only dicot plants, leaving the grass plants (monocots) unharmed.

FAMILY

Master Gardeners usually work with the classification of plants at the family level and below. Plant families are important in gardening because members of the same family often have similar cultural requirements and similar insect and disease problems.

In a family of plants, similarities occur primarily with reproductive parts (flowers, fruit, and seed), although leaves and other plant parts may also be similar. Table 2 includes some common families and some of their characteristics.

GENUS

Genus is a subdivision of a plant family. Plants of the same genus share similarities mostly in flower characteristics and genetics. Plants in one genus usually cannot breed with plants in another, but species within a genus will often intercross. The first letter of the genus name is capitalized and the entire name is italicized or underlined.

SPECIES

Species is a group of individual plants that freely interbreed and have many (or all) characteristics in common. Species names use the binomial naming system of genus and specific epithet.

VARIETY AND CULTIVAR

Variety

Variety is a word commonly used to describe cultivated and hybridized plant types. This is a misnomer; used in its proper context, a variety is a botanical division of a species. It is a subgrouping of plants within a species that differs in some particular way from other members of that species. In the wild, variety may be used to describe a particular regional variant of a species with unique plant size, flower color, or other visible trait. In cultivated plants, variety may be used to designate a particular useful form of a species. For example, cauliflower (*Brassica oleracea* var. *botrytis*) and cabbage (*Brassica oleracea* var. *capitata*) are varieties of the same species. The variety name follows the abbreviation “var.” It is written in lower case and is italicized or underlined.

Cultivar

This word is a contraction of the term “cultivated variety.” A cultivar is a very specific, human-bred, cultivated form of a useful crop species. If propagated asexually (vegetatively), cultivars can be termed **clones**. When vegetatively propagated, cultivars maintain their characteristics from generation to generation, thus preserving desirable traits. However, seeds of clones will not produce plants with the same desirable characteristics as the cultivar. If propagated by seeds, cultivars can be termed **lines**.

Cultivar names are indicated by placing the term in single quotation marks or by preceding the cultivar name with the abbreviation cv. (do not use both). The first letter of the cultivar name is capitalized, but the name is not italicized or underlined. An example is the tomato cultivar Early Girl, expressed as *Solanum lycopersicum* ‘Early Girl’ or cv. Early Girl.

Both ancient practices of plant domestication and modern processes of plant breeding have contributed to the vast pool of plants we have available for food, industry, and beautification.

Understanding the titles used to describe these plants will help in making decisions as to which cultivars are suitable for specific uses.

Landrace. This term is used to describe a locally domesticated and utilized form of a plant species that was developed through a long process of selection without the use of modern genetics.

Landraces typically have ancient origins and their production was historically limited to a very small geographical area. They often are specifically adapted to production conditions typical of their point of origin. One example is Palomero Toluqueño,

Table 2. Common plant families.

Scientific family name	Common family name	Common plants in family	Family traits
Apiaceae	Carrot family	Carrot (*Daucus carota*) Parsnip (*Pastinaca sativa*) Dill (*Anethum graveolens*) Poison hemlock (*Conium maculatum*)	Flowers usually in simple or compound, flat-topped clusters called umbels; stems often hollow.
Asteraceae or Compositae	Sunflower family	Lettuce (*Lactuca sativa*) Sunflower (*Helianthus annuus*) Zinnia (*Zinnia elegans*) Spotted knapweed (*Centaurea stoebe*)	Flowers organized as heads with ray and disk flowers. One of the largest families: 20,000 species.
Brassicaceae or Cruciferae	Mustard family	Broccoli (*Brassica oleracea* var. *botrytis*) Kale (*Brassica oleracea* var. *acephala*) Cabbage (*Brassica oleracea* var. *capitata*) Radish (*Raphanus sativus*) Shepherd's-purse (*Capsella bursa-pastoris*)	Flowers have four petals that are not joined; there usually are six stamens (four long, two short).
Fabaceae or Leguminosae	Pea or bean family	Common pea (*Pisum sativum*) Common bean (*Phaseolus vulgaris*) Lupine (*Lupinus argenteus*) Hairy vetch (*Vicia villosa*)	Flowers with a distinct upper "flag" petal, arranged in heads or spikes.
Lamiaceae or Labiatae	Mint family	Peppermint (*Mentha* x *piperita*) Sweet basil (*Ocimum basilicum*) English lavender (*Lavendula angustifolia*) Henbit (*Lamium amplexicaule*)	Leaves usually opposite; flowers tubular; stems square.
Poaceae	Grass family	Corn (*Zea mays*) Kentucky bluegrass (*Poa pratensis*) Blue fescue (*Festuca glauca*) Quackgrass (*Elytrigia repens*)	Leaves simple and strap-like; inflorescence usually a long spike. Large family of between 7,500 and 10,000 species.
Ranunculaceae	Buttercup family	Columbine (*Aquilegia vulgaris*) Larkspur (*Delphinium elatum*) Lenten rose (*Helleborus orientalis*) Creeping buttercup (*Ranunculus repens*)	Large and variable family with variable flower form; most species have showy sepals rather than petals.
Rosaceae	Rose family	Apple (*Malus pumila*) Garden strawberry (*Fragaria* x *ananassa*) Rose (*Rosa* spp.) Sulfur cinquefoil (*Potentilla recta*)	Flowers with five (or multiples of five) petals and many stamens.
Solanaceae	Nightshade or potato family	Tomato (*Lycopersicon esculentum*) Pepper (*Capsicum annuum* var. *annuum*) Potato (*Solanum tuberosum*) Black henbane (*Hyoscyamus niger*)	Leaves alternate; flowers have five petals fused at the base; stamens attached to the petals and form a column around the pistil.

a type of popcorn that was historically grown in the highlands of Mexico.

Landraces typically have improved traits that make them valuable for human use in comparison with the original wild species. At the same time, individual plants within a landrace often vary in appearance, quality, and resistance traits.

Open-pollinated. These cultivars are developed through modern breeding practices, genetically stabilized to ensure uniformity, and then seed propagated using methods that allow uncontrolled distribution of pollen within the crop. They differ from hybrids, which are produced through a process that completely controls pollen transfer. Open-pollinated cultivars will grow true-to-type if seed is collected from parental plants that are isolated from other cultivars of the same species. Most lettuce, bean, and pea varieties for home gardeners are examples of open-pollinated plants.

Heirloom. No universally accepted definition of heirloom exists. Some people consider varieties to be heirlooms only if they are at least one hundred years old. Other people feel the proper cutoff date is 1951, the year recognized as the time when modern hybrid cultivars became available. Nonetheless, there are two fairly common characteristics attributed to heirloom cultivars: (1) they are relatively old and (2) they are not currently planted in large-scale production agriculture.

Cultivars designated as heirloom have recently become very popular in home garden and small agriculture production. They provide unique appearance and quality characteristics. However, they also tend to be narrowly adapted and lack the pest resistance that is common in modern cultivars.

The terms "open-pollinated" and "heirloom" are often used synonymously. By any standard used to define heirloom, this is incorrect. Open-pollinated refers to any cultivar developed through modern (traditional) breeding methods that is not a controlled-pollination hybrid. Every year, modern breeding programs release new open-pollinated cultivars of many crops and landscape species. Cultivars designated as heirloom, however, include many of the older, lesser known open-pollinated cultivars, clonal cultivars, and, in some cases, landraces.

Hybrid. Hybrid cultivars are often referred to as F1 hybrids. This means that the seed we purchase and the resulting plants grown are the first-generation offspring of two open-pollinated parents. (The abbreviation F1 stands for the term "first filial" generation.) Hybrid cultivars are limited almost exclusively to food plants, with a few exceptions. In production agriculture, hybrid cultivars can provide many important advantages, including higher yield, greater plant uniformity, more consistent quality, and the combination of the superior traits of two outstanding parents.

The main difference between hybrid and open-pollinated cultivars is that subsequent generations grown from the seed of a hybrid do not breed true to type. Thus, growers cannot collect and use their own seed, but must purchase new seed each year. For this reason, many people do not consider hybrid cultivars sustainable in small-scale agricultural production.

Clonal. Many plant cultivars are not propagated from seed. They are propagated using vegetative parts. Some familiar plants propagated in this manner include potatoes, rhubarb, asparagus, bulb flowers, and most types of fruit trees. Types of plant material used to establish a new generation include tubers, bulbs, root cuttings, stolons or runners, rhizome pieces, and stem cuttings. Many clonally produced cultivars can trace their origins to a single plant discovered many hundreds of years ago.

GMO. Short for "genetically modified organism," GMO cultivars are radically different from the cultivar types discussed previously, all of which have their basis in traditional breeding and/or selection. Biotechnologists have discovered ways to isolate and remove specific genes from one organism and attach them to the chromosomes of a different organism. This makes it possible to give plants traits that nature did not provide.

This technology is widely used in production agriculture to address critical production and nutrition issues. Examples include insect-resistant corn and cotton cultivars (greatly reducing the need for insecticide use), herbicide-resistant soybeans and sugar beets (minimizing the need for expensive hand weeding), and rice cultivars with high levels of vitamin A (reducing the incidence of blindness in many developing countries). Currently, there are no GMO cultivars available for home food production. Many people oppose the use of GMO cultivars, limiting their value for use in small-scale farming or home production of food crops.

Plant Life Cycles

A plant is classified by its life cycle, specifically how long it lives and how long it takes to complete reproductive processes and develop seed.

ANNUALS

Annuals grow, mature, flower, produce seed, and die in one season. An annual may be a summer annual or a winter annual. For summer annuals, the seed germinates in the spring, and a plant develops, matures, and produces seed by the end of the growing season. Summer annuals include zinnias, corn, and beans. Winter annual seed germinates in the fall, producing a plant that overwinters, matures, and produces seed the following growing season. Winter wheat and downy bromegrass (a weed) are winter annuals.

BIENNIALS

Biennials take two years or at least part of a second year to complete their life cycle. During the first season, they grow a hardy rosette of basal leaves that will overwinter. During the second season, the plant flowers, produces seeds, and then dies. Parsley and table beets are examples of biennial plants.

PERENNIALS

Perennials live for more than two years. **Herbaceous perennials** have soft, nonwoody stems. Herbaceous perennials die back each winter, and a new plant grows from the crown or roots the following spring. Herbaceous perennials may live for 3–25 years, or even longer under ideal growing conditions. Many herbaceous plants, such as tomatoes or lantana (a flowering shrub), are perennial in warmer climates, but are grown as annuals in temperate climates.

Woody perennials such as trees or shrubs have a woody stem or trunk. Those that lose their leaves every fall and grow new leaves in the spring are called **deciduous**.

Trees or shrubs that keep their leaves (needles or broad leaves) through the winter are called **evergreens**. Sometimes, the term evergreen may be somewhat of a misnomer because the older needles (those closer to the tree trunk) fall off. For example, a spruce tree will hold its needles for 7–10 years, while a pine tree will hold needles for about 3 years.

Woody perennials have a wide range of life spans, ranging from 10–12 years for aspens in a home landscape to more than 1,000 years for some conifers. Life expectancy is often linked to growth rates. (Slower growing plants such as bristlecone pines tend to live longer.)

Plant Parts and Their Function

VEGETATIVE PARTS: LEAVES, STEMS, AND ROOTS

Understanding plant part terminology (Figure 1) and the functions of plant parts will help you identify plants and diagnose plant problems.

Leaves

Leaves are the main structures produced on plant stems. Leaves come in many different shapes, sizes, and arrangements and are used for plant identification. They also serve many vital roles, the most important being the harvest of light energy. The leaf is the primary site of photosynthesis, respiration, and transpiration, all important growth processes for plants.

Leaf parts and structure. There are two main parts to a leaf: the **blade** (flat, thin portion) and the **petiole**. The petiole attaches the blade to the stem and contains conducting tissues between the leaf and the stem.

The outer cell layers on the top and bottom of the leaf blade are the **epidermis**; they serve to protect the inner leaf tissue. Specialized epidermal cells on the undersides, and sometimes upper sides, of leaves form openings called **stomata.** (The singular of stomata is **stomate**.) Open stomata keep water and nutrients moving through the plant and

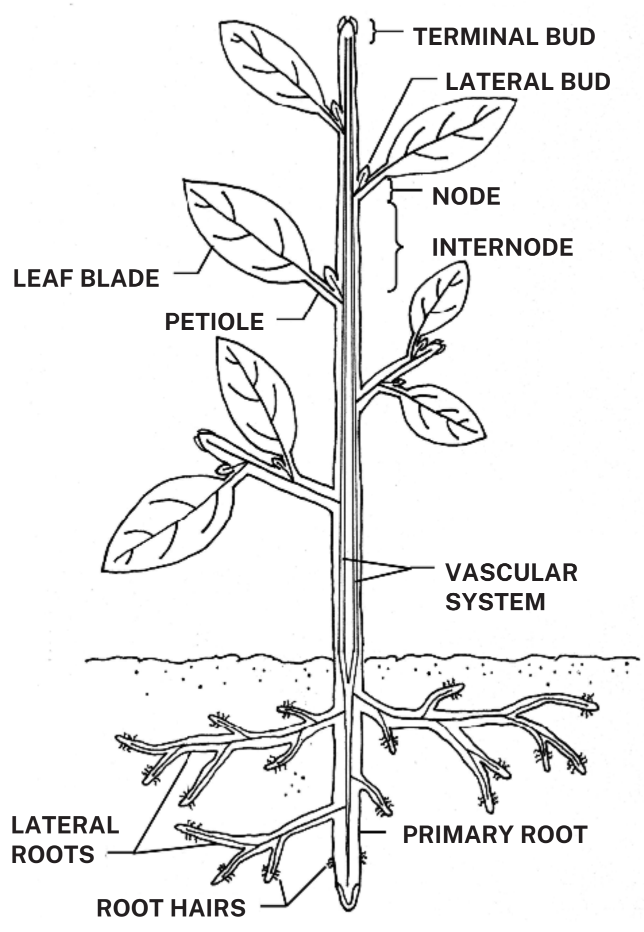

Figure 1. Parts of a vascular plant.

allow the exchange of carbon dioxide and oxygen between the air inside and outside the leaf, a process that is critical for photosynthesis. Conditions that cause plants to lose a lot of water (high temperature, wind, low humidity) cause the stomata to close. Consequently, it is important to keep plants adequately watered to allow air exchange for photosynthesis.

Some plant leaves have a waxy layer on the epidermis called the **cuticle**. The cuticle protects the leaf from dehydration and prevents penetration of some disease-causing organisms.

The leaf blade texture (smooth, hairy, waxy, etc.) is often important to consider when applying pesticides. For example, herbicides may not make good contact on hairy or waxy leaves; consequently they are less effective. Also, some pesticides may remove a desired waxy leaf texture. When this happens on Colorado spruce needles, for example, the color of the needles may change from blue to green.

Leaf arrangement and shape. Leaves are attached to a stem in one of three patterns: **opposite**, **alternate**, and **whorled**. Opposite arrangement means two leaves attach at the same point, but on opposite sides of the stem. With alternate arrangement, leaves are attached at alternating points from one side of the stem to the other. In a whorled arrangement, three or more leaves are attached at the same point. Leaf arrangement is often used for plant identification. For example, maple trees have opposite leaf arrangement, and birch and willow trees have alternate leaf arrangement.

Leaves are most often thought of as being flat blades of various shapes. Examples include the leaves of maple trees or green beans. However, a leaf blade may be needle-like, such as in conifers. Spruce trees have about 1-inch-long needles, and pine trees 2–3-inch-long needles. Leaves can also be scale-like, such as in red cedar and arborvitae, or flat and strap-shaped as in grass plants. Leaf shapes are also helpful for identification.

Photosynthesis in leaves. Plants are able to take solar energy and turn it into chemical energy through the process of photosynthesis. Without photosynthesis, life on earth would not exist. All other life forms depend on the oxygen and food that photosynthesis provides.

Inputs for photosynthesis include carbon dioxide, water, and light. Carbon dioxide enters the leaf through the stomata, water enters through the roots, and light energy comes from natural or artificial light. Outputs of photosynthesis are oxygen and carbohydrates.

Gardeners are basically managing a living plant factory. The goal is to maintain plant health and manage the environment so plants can produce the most carbohydrates possible. Anything that damages the leaves (diseases or insect feeding) or reduces their ability to absorb sunlight (too much shade) or take in carbon dioxide will limit the photosynthetic capability of a plant.

Respiration in leaves. Respiration is essentially the reverse of photosynthesis. It is the process by which carbohydrates are converted into energy. With the production of energy, sugars and oxygen are converted to carbon dioxide, water, and a small amount of heat. Respiration releases energy to build new tissues, maintain chemical processes, and produce growth within the plant. Respiration occurs in all cells at night as well as during the day, a key point that is discussed below.

Relationship between photosynthesis and respiration. The rates of photosynthesis and respiration depend on temperature. Plants have an optimum temperature range and a maximum temperature for photosynthesis. The rate of photosynthesis will increase with increasing temperature up to a certain point and then decrease at higher temperatures. Likewise, higher temperatures will increase respiration. Unlike photosynthesis, however, respiration continues to rise with increasing temperature.

Photosynthesis does not occur at night, but respiration does. If nighttime temperatures are too warm, the plant will use all of the energy produced by photosynthesis during the day for metabolic processes at night just to stay alive, rather than converting the carbohydrates into new plant cells. This can affect the portions that we eat, such as potato tubers and cucumbers. If days are hot and nights are warm, plant growth will be reduced and yields may decrease. Grasping this relationship between photosynthesis and respiration will help you understand plant growth and yield variability from year to year.

Transpiration in leaves. The loss of water through leaf stomata is called **transpiration**. Transpiration pulls water containing dissolved nutrients from the soil through the roots and the rest of the plant. It also provides evaporative cooling for leaf tissue. About 90% of the water entering roots is used in transpiration, and the remainder is used for photosynthesis.

The amount of water used depends on temperature. As temperatures rise, the amount of water needed increases. Consequently, it is critical to irrigate more frequently during warm weather. Also, plants growing in a dry climate need more water than those growing in a more humid environment.

Stems

The stem is the main aboveground support structure of a plant. It contains the vascular system that allows water, nutrients, and carbohydrates to move within a plant.

Parts of a stem. All stems have **nodes**, where leaf attachments occur. Nodes contain buds that may develop into leaves, flowers, or lateral branches. The areas between nodes are called **internodes**. Plants that grow in reduced light conditions may have very long internodes.

It is important to be able to recognize nodes when pruning. For example, it is often necessary to remove a tree branch back to a node that will produce a new stem. Also, when plants are propagated asexually via vegetative cuttings, new roots most often form at nodes.

Types of stems. Most stems grow aboveground and many grow erect (for example, trees, corn and sunflowers). Some aboveground stems can also grow along the ground, such as cucumbers and pumpkins. There are also several other types of stems that gardeners need to understand because plants with these modified stems may need to be managed differently.

Crowns are compressed, aboveground stems with very short internodes. Examples of plants with crowns include dandelions, strawberries, rhubarb, asparagus, and many grasses such as Kentucky bluegrass. Rhubarb and asparagus are propagated by planting crowns. Crown identification is especially important when planting strawberries, as covering the crown with soil is detrimental to their growth.

Spurs are short, stubby stems commonly found on fruit trees such as apple and pear. Spurs produce fruiting buds. If a severe pruning cut is made close to a spur, the spur may produce a stem rather than the intended fruit.

Stolons, also called runners, are horizontal stems, either fleshy or semiwoody, that grow on top of the soil surface. For example, stolons attach a strawberry plant to its plantlets. Some types of grass, such as creeping bentgrass, form stolons. This species often is planted on golf course putting greens.

Rhizomes are stems that grow belowground. A very popular lawn grass, Kentucky bluegrass, spreads by rhizomes. Another grass that spreads by rhizomes is quackgrass, which is considered a difficult-to-control weed.

There are several other types of modified stems, such as tubers (the edible part of potatoes) and bulbs (tulips and onions). These topics are covered in more detail in the chapter titled "Herbaceous Ornamentals."

VASCULAR SYSTEM

Plants need a system to transport water and nutrients from the roots to the leaves and to move photosynthetic sugars to stems, roots, and other plant parts. You could think of this vascular system as being similar to the vessels and veins in vertebrate animals. There are two types of vessels in plants. **Xylem vessels** conduct water and minerals up from the roots, while **phloem tubes** carry sugars and other compounds from the leaves to the rest of the plant.

The xylem and phloem are grouped in vascular bundles. In dicots, the vascular bundles are arranged in a continuous ring in the outer perimeter of the stem. In woody plants (trees and shrubs), these vascular bundles are located just under the bark. Thus, they can be easily damaged by lawn mowers, string trimmers, or stems rubbing against each other. In monocots, the vascular bundles are scattered throughout the stem and are not as easily damaged.

Buds

A **bud** is a fully formed but undeveloped shoot or flower. If a bud is at the tip of a shoot, it is called a **terminal bud**. Regardless of location, buds that form shoots or leaves are **vegetative buds**. **Flower buds** produce one or more flowers. Mixed buds produce both shoots and flowers.

Buds may grow immediately after they are formed or stop growing and remain **dormant** until the following spring. Buds on many plants, such as fruit trees, require a specified duration of cold temperature below a critical level before they will grow in the spring. This cold period is easily accomplished in Idaho, but may not be achieved in warmer states such as Florida or California.

During dormancy, buds can tolerate very low temperatures without damage. However, once the plant has had enough cold temperature to satisfy the requirement for growth, a new bud can easily be damaged by subsequent cold temperatures.

Roots

Roots are often neglected or forgotten while caring for plants because they are not visible. However, roots are a critical plant part that gardeners need to understand to properly care for plants. Roots make up a large proportion of the total plant — about 20%–30% of the total volume. Small feeder roots are so numerous that the total amount of roots can account for up to 90% of the surface area of a plant!

Establishing a healthy root system is one key to growing attractive and productive plants. The importance of roots is evident when transplanting trees. Transplanted trees often suffer from "transplant shock" and do not seem to grow well the first two or three years. The problem is the amount of root system that was removed during the transplanting process. Bare-root or balled and burlapped trees have less than about 5% of their original root system and cannot grow normally until a complete new root system has developed.

Root functions. Roots absorb nutrients and moisture from the soil or growth medium (potting soil), anchor the plant, physically support the stem, and move water and minerals to the stem. In some cases, roots serve as food storage organs. Roots profoundly affect the size and vigor of the plant, the method of propagation, adaptation to soil types, and responses to cultural practices and irrigation.

Types of root systems. After the primary root emerges from the seed, it may continue to grow straight down and become a **taproot** or it may branch and form a **fibrous** root system with many side (lateral) roots.

Root growth. There is a common misconception that tree roots penetrate the soil to several feet. In fact, most of the functional feeder roots of woody plants — those that absorb water and nutrients — are located in the upper 18 inches of soil. Many plants have even more shallow root systems. The depth to which roots penetrate depends on the plant type, soil texture and structure, and water status. A dense, compacted soil layer or a high water table will restrict or terminate root growth.

Another misunderstanding about roots is that they will grow to "find" water. Roots will not grow into dry soil, so unless soil is moist, roots will not grow to their maximum length.

The roots of most plants are far more extensive than the aboveground area beneath the plant. Tree roots extend several feet beyond the drip-line of the tree. Disturbing the soil by, for example, digging a trench or compacting the soil via vehicular or foot traffic will have an adverse effect on the tree's health.

REPRODUCTIVE PARTS: FLOWERS, FRUITS, AND SEEDS

Flowers

Flowers are the sexual reproductive organs of seed-bearing plants, designed to produce and distribute pollen, accept pollen, provide a way to fertilize the ovary, and nourish and protect the developing seed (Figure 2). This makes flowers critical to the survival, adaptation, evolution, and distribution of plant species.

Angiosperms produce the reproductive structures we recognize as flowers and are the group of plants discussed in this section. **Gymnosperms** (conifers) produce pollen and seeds, but don't have structures recognizable as flowers. Some plants, such as ferns, do not produce flowers or seeds and instead reproduce using spores.

Parts of the flower. A typical flower has four major parts: **sepals**, **petals**, **stamens**, and **pistils**. However, not all flowers have all four parts. Flowers lacking one or more of these basic parts are called **incomplete** flowers. In nature, any combination of flower parts can occur. The shape and visibility of flower parts also vary widely among plant species.

Sepals are the outer covering of the flower when it is in the bud stage. They are usually green and leaf-like in appearance. In some plants, they have the form and color of petals (for example, in tulips). Collectively, all of the sepals form the **calyx**.

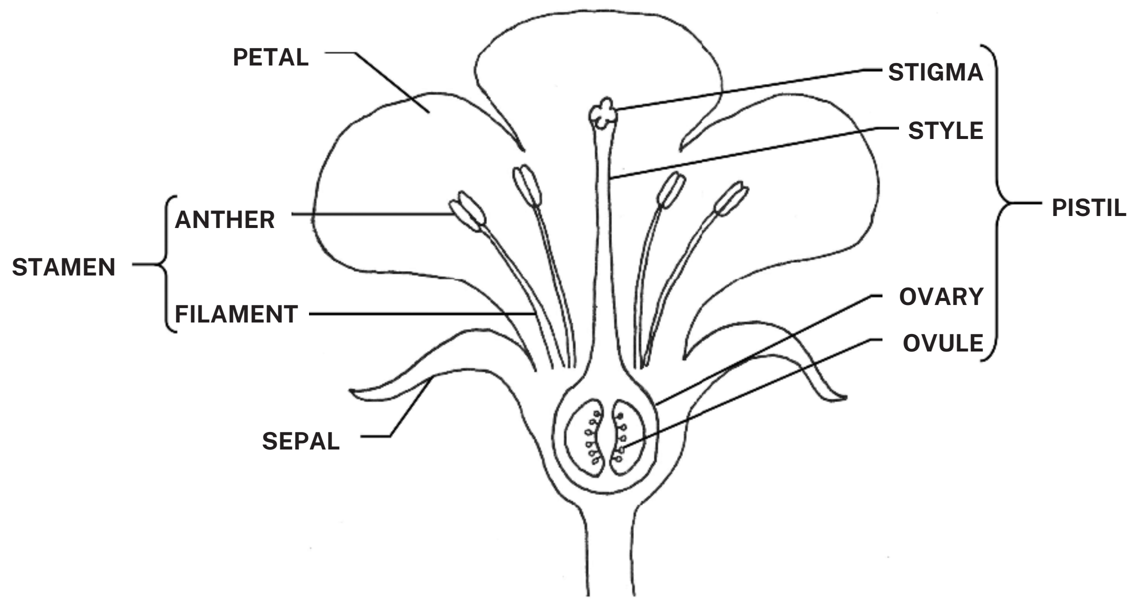

Figure 2. Parts of a flower.

Petals are usually the largest and most visible feature of a flower and are commonly brightly colored. The color helps attract insects to pollinate the flower. As a group, the petals form the **corolla**.

Stamens are the male parts of the flower and are usually found near the center of the flower. Each flower contains multiple stamens — in some cases very large numbers. At the top of each stamen is an anther sac in which pollen is produced.

The **pistil** is the female component of the flower. The upper part of the pistil, called the **stigma**, usually has some type of sticky surface designed to trap and accept pollen. The base of the pistil contains one or more **ovules** (eggs) that develop into seeds after pollination and fertilization.

Arrangement of male and female flowers. Many species of plants produce flowers lacking one or more of the sexual parts and are referred to as **imperfect**. Flowers with no pistils are male flowers (**staminate**). Flowers with no stamens are female flowers (**pistillate**).

Depending on species, imperfect flowers may be arranged within and among plants in a number of ways. Individual plants may produce separate male and female flowers on the same plant. The term for this arrangement is **monoecious** (a Latin term meaning "one house"). Cucumbers are an example of this type of plant; the male flowers (the ones lacking tiny fruit under the corolla) and female flowers (the ones with a tiny cucumber under the corolla) alternate along the vines (see Table 3 for additional examples of common monoecious species).

Other species may have separate male and female plants, with flowers of only one sex on any single plant. The term for this arrangement is **dioecious** (a Latin term meaning "two houses"). Holly is an example of a dioecious plant. Only the female plants produce berries, and only if a male plant is nearby to supply pollen (see Table 3 for additional examples of dioecious plants).

Pollination of flowers. For seed to develop, pollen must be transferred from the anthers to the pistil, where it can fertilize the ovules. Some plants require a pollinator to transfer pollen from flower to flower. Pollinators can include many types of animals, most commonly insects or birds. Honeybees are an example of common pollinating insects.

Plants that require a pollinator (such as an apple tree) produce sticky pollen that adheres to animal visitors. Other plants, such as corn, utilize the wind for pollination. They release large amounts of small, light, nonsticky pollen grains into the air and rely on chance to carry them to the pistil of a nearby plant. As a rule, plants that require pollinators have large and/or showy flowers. Wind-pollinated plants tend to have inconspicuous flowers.

Table 3. Examples of plants with a monoecious or dioecious flower arrangement.

	Scientific name	Common name
Monoecious species	*Betula alba* *Curcurbita pepo* *Juglans nigra* *Musa acuminata* *Quercus macrocarpa* *Salix matsudana* *Zea mays*	European white birch Pumpkin Black walnut Banana Bur oak Globe willow Corn
Dioecious species	*Acer negundo* *Asparagus officinalis* *Fraxinus pennsylvanica* *Juniperus horizontalis* *Populus alba* *Spinacia oleracea* *Taxus cuspidate*	Box elder Asparagus Green ash Carpet juniper White poplar Spinach Japanese yew

Fruits

After pollination, the embryo starts to develop, fruit forms, and seeds enlarge within the fruit. Fruits come in many sizes and forms. They may be fleshy (peach) or dry (elm). They can be single (avocado) or aggregated (raspberry; the crumbles of a raspberry are actually individual fruits). They can have a hard coat (a nut) or soft, fragile skin (tomato). They can hold one seed (plum) or many (cantaloupe).

The fruit serves to protect the developing seed. Once the seed is mature, the fruit can be important in seed dissemination. Sweet, edible fruits, such as serviceberries, are often consumed by animals, and the seed is then deposited elsewhere in their droppings. Other types of fruit may dry and break open violently (dehiscence), flinging the seed some distance from the mother plant. An example of a plant using this dissemination mechanism is chickpea. Still other fruits may have “wings” (**samaras** in maples) or “umbrellas” (the parachute-like **pappus** of dandelions) that allow them to “ride the wind” to a new location. Cockleburs have a barbed fruit that attaches itself to clothing or animal fur, providing the seed with transportation. Small animals gather, transport, and bury nuts, not only moving the seeds but planting them as well.

Fruits are also important for human nutrition, and many garden plants are produced for their edible fruits. Some fruits, such as cucumbers and peas, are picked and eaten at a botanically immature stage. Others reach full maturity before being picked, meaning growth is complete and the seed is capable of germination. Examples are apples and pumpkins.

Seeds

Seeds form when ovules are fertilized after pollination. Thus, they contain genes from both the female and male parents. Each seed is an encapsulated embryo, in essence a miniature but fully formed plant within a protective coat. Once the embryo is formed, it usually goes into a state of arrested development until the seed is separated from the mother plant and is exposed to proper growing conditions.

Seeds, in addition to fruits, are important sources of food for humans. We grow many plants for their edible seeds, including nuts, legumes, and grain.

Seed viability. In order for seeds to grow, the embryo must be **viable**, or alive. Factors such as improper pollination, less-than-ideal growing conditions during seed development, or competition within a plant for resources can lead to **nonviable** seed. Nonviable seeds may look normal, but will not grow, even when planted in optimal conditions. In nature, nonviable seeds affect the ability of plants to propagate themselves. In the garden, nonviable seeds have a negative impact on plant stands and productivity. Nonviable seeds should not be confused with dormant seeds, which are discussed below.

Seeds enable plants to bridge periods of time when growing conditions are not favorable (winter, dry periods, etc.). Consequently, if conditions are appropriate, seeds of most plant species can remain viable for extended periods of time. Germination and growth may be delayed until suitable growing conditions occur. Having seeds of desirable plants remain viable for many years is beneficial, but when weed seeds remain viable for many years, it creates a need for ongoing weed management.

There are exceptions to the rule of extended seed viability. The seeds of some plant species are capable of growth for only a few days and then only if kept constantly moist. Species of plants with short periods of viability usually live in warm, or at least moist, conditions and often produce seeds that develop within wet, pulpy fruits.

Recently purchased seed has usually gone through a certification process, meaning the germination percentage has been tested in a laboratory and acceptable levels of seed viability ensured. Older seed or seed that has not been certified can be tested at home to make sure it is viable. Before testing germination, make sure the seed is not dormant (see a discussion of dormancy below).

A quick, simple way to test the viability of most seeds is to float the seed in a container of water. Seeds that float are usually not viable; live seeds sink. However, the most reliable method for assessing viability is a germination test. Place a known quantity of seeds on a moist paper towel and seal it in a plastic bag. After a week to 10 days, inspect the seed to determine the percentage that has sprouted.

Seed storage. Due to the tendency of seed to remain viable over extended periods of time, seed can often be stored for one to several years, depending on species and storage conditions (Table 4). Even under ideal conditions, however, seeds of some plants (such as onions, leeks, and parsnips) may remain viable for only one year. Seeds of other plant species (such as radishes, tomatoes, grains, and many grass species) may remain viable at least six and sometimes more than twenty years.

Successful seed storage requires proper conditions. The keys to long storage are temperature and humidity, with cool, dry conditions being best. The "rule of 90" can help you determine a suitable storage site. Measure the temperature and relative humidity of the intended storage location and add the two values together. If the sum is less than 90, extended seed storage should be successful. Low humidity is the most critical factor for seed storage, but generally, lowering either humidity or temperature will extend the storage period. Long-term viability of seeds can be ensured by placing the seed in a sealed container with a desiccation gel packet and placing the container in a freezer.

Seed dormancy. Some seeds, although viable and planted under correct conditions, fail to grow. These seeds are exhibiting a natural survival characteristic termed **dormancy**. Dormancy is an adaptation of some plants to keep seeds from germinating until conditions favor seedling survival. Most of our common food crops and annual flowers lack dormancy, meaning the seed will grow as soon as it is planted

Table 4. Examples of longevity and minimum germination (percentage of live seed required to ensure successful production).

Kind of seed	Longevity (years)	Minimum germination (percent)
Bean	3	70
Beet	4	65
Carrot	3	55
Corn, sweet	2	75
Cucumber	5	80
Lettuce	1	80
Muskmelon	5	75
Pea	3	80
Pumpkin	4	75
Radish	4	75
Spinach	3	60
Squash	4	75
Watermelon	4	70

*Source: J.E. Ells, L.N. Bass, and D. Whiting. 2020 (revision). *Storing Vegetable and Flower Seeds*. Colorado State University Extension, 7.221. **https://extension.colostate.edu/topic-areas/yard-garden/storing-vegetable-and-flower-seeds-7-221/**.

into warm, moist soil. However, many perennial flower species (such as monkshood, alliums, columbines, and penstemons) and most hardy shrubs and trees produce seed with some form of dormancy. In these cases, dormancy must be broken before seedling establishment can be successful.

The most common mechanisms of dormancy are **seed coat impermeability** and **embryo dormancy**. Seed coat dormancy is caused by the presence of a thick, hard seed coat that is impermeable to water. In nature, weathering, soil abrasion, the action of microorganisms, or passage through the digestive tract of an animal can soften the seed covering, thus allowing the seed to take up water and begin growing.

For garden production, an artificial method known as **scarification** can be used to break or soften the seed coat. The simplest scarification method is mechanical; simply scratch the seed coat with sandpaper or nick it with a knife. Heat treatments using boiling water can also disrupt the seed coat enough to allow germination. With this method, it is important to use caution to avoid personal injury. Also, be sure you know the proper length of treatment to avoid damaging or killing the seed.

Embryo dormancy is a chemical/physiological condition that prevents growth, usually associated with the balance of growth hormones in the seed. In nature, this type of dormancy ensures that seedlings will emerge in the spring, rather than in the fall. The hormonal balance of the seed changes toward a status favoring growth during exposure to cold, moist soil conditions. This type of dormancy can be overcome by **stratification**, a process of artificially chilling seeds under moist conditions. Place the seed in moist potting soil in a small plastic bag and place the bag in a refrigerator for 1–3 months.

Seed dormancy attributes and the methods required to overcome dormancy vary widely among plant species. Success with many plants depends on understanding dormancy characteristics and finding the best ways to satisfy dormancy requirements. Good reference materials are available to determine the necessary conditions for germinating seed of difficult species.

Plant Development

Plants go through definable stages of life, beginning with germination (sprouting) and ending with senescence and death. Some annuals complete this entire process within a few months, while some tree species live for thousands of years.

SEED GERMINATION

Plant development begins with the germination of a seed. First, the seed swells as it absorbs water. The first root (**radicle**) emerges from the seed coat and grows downward. In proper soil moisture conditions, the new roots and root hairs grow down into the soil to anchor the plant and acquire water and minerals. Meanwhile, the shoot portion of the stem emerges from the seed and begins extending toward the soil surface.

During germination and seedling establishment, young plants are vulnerable to damage from conditions that may not damage an established plant. Lack of moisture, excessive heat or cold, pests, and diseases can all kill or seriously damage an emerging seedling. For example, an established plant may be hardy to −25°F, while a tender young plant of the same species may be hardy to only 32°F. As the fragile new shoot moves up through the soil, it may also be damaged by the inability to penetrate heavy or compacted soil.

Because of this extreme vulnerability, germinating seedlings require that we pay careful attention to cultural details. We must adequately prepare the soil, plant seed to the proper depth, maintain proper moisture conditions, minimize exposure to pests, and control temperature as much as possible.

VEGETATIVE GROWTH STAGE

Once a seedling is established, the size and complexity of the plant increases as the first true leaves are formed. Stems elongate and produce additional leaves. The leaf surface increases, thereby enhancing the plant's ability to capture and utilize light. During this stage of development, growth is rapid and plant parts tend to be large and succulent. Also, the growing plant begins to display characteristic branching and rooting patterns. For example, carrots will produce fern-like leaves and a long taproot, while blue fescue will develop long, narrow leaves from a crown and a dense, fibrous root system.

New growth on all plants develops from localized **meristems** — specific regions of rapidly dividing cells. Meristematic tissues within any plant include those providing both **apical** and **lateral** growth. The apical meristems are found at the tips of stems and roots and produce cells resulting in longer stems and branches. Lateral meristems are located along the interior of the stem and roots and serve to increase the diameter of stems, trunks, branches, and roots. Lateral meristems are especially important in the expansion (increase in diameter) of woody tissues in trees and shrubs.

Grass plants have a unique form of apical meristem called the **intercalary meristem**, located at the base of the leaves. Intercalary meristem cells divide and produce new growth from the leaf base, giving grasses the unique ability to regrow after mowing or grazing. Scalping grass with a mower (cutting to a very short length) or overgrazing may damage or remove this meristem and cause a bald spot (no grass) in the lawn or pasture.

REPRODUCTIVE GROWTH STAGE

Upon achieving adequate size and storing sufficient energy, flowering plants go through a process of physiological change that favors the development of reproductive organs at the expense of vegetative growth. Among angiosperms, this means producing flowers and fruits. Once flowering is induced, particularly with annuals and herbaceous perennials, leaf growth usually slows and the plants become more fibrous and stout. For annuals, the reproductive process occurs only once before the plant senesces and dies. For long-lived perennial and woody species, the reproductive cycle may be repeated many times during the life span of a single plant.

Flowering is influenced by many external and internal factors, including genetics, plant mass, plant health, hormone balance, temperature, and day length. Cold or warm temperatures at a specific stage of growth can trigger the flowering process. For example, consistent cold weather will cause young broccoli plants to bloom early instead of growing large heads. Another important trigger for some plants is the length of the light period. Onions, for example, require increasingly long early summer days to trigger bulb growth. These triggering mechanisms ensure that the plants produce flowers during the optimal time of the year so that flowering and fruit development can be unhindered.

During fruit set — the next phase of reproductive growth — the ovary develops into a fruit with seed. Fruit and seed development take a great deal of energy. For this reason, it may be beneficial to prevent fruit from developing when plants are just getting established. Deadheading is another example of preventing fruit development, in this case to promote more flowering. Any stress that reduces photosynthesis — drought, nutrient deficiencies, insects, or diseases — will negatively affect fruit development.

SENESCENCE

For annuals and biennials, death is the next and final stage following fruit development. **Senescence** is a series of steps that lead to the death of a plant. The plant ceases to metabolize and nutrients are moved from the vegetative structures to the fruits.

Perennial plants do not die after fruit production. On herbaceous perennials, however, fruiting may signal an annual dieback of foliage. In woody species, fruiting may or may not be associated with fall leaf drop and annual dormancy.

For all plants, the stages of development associated with maturation and senescence are accompanied by a lack of response to outside influences. In other words, the plants are programmed to naturally decline and no inputs of nutrients, moisture, or any form of tender loving care will extend their life. During this stage of development, plants also become more prone to diseases and insect feeding. Luckily, pests do little lasting damage to plants at this stage of their lives and efforts to control pest issues during senescence are usually unwarranted.

Further Reading and Resources

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