CMG GardenNotes #120-145

Botany

Trifolium pratense, Red Clover
Artwork by Melissa Schreiner © 2023

This Botany curriculum was developed by David Whiting, CSU Extension, retired; Joanne Jones, CSU Extension, retired; Linda McMulkin, CSU Extension, retired; Alison O'Connor, PhD, CSU Extension; and Laurel Potts, CSU Extension, retired. Cover art by Melissa Schreiner. Used with permission.

Updated 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #120

Botany

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #121, *Horticulture Classification Terms.*
- #122, *Taxonomic Classification.*
- #131, *Plant Structures: Cells, Tissues, and Structures.*
- #132, *Plant Structures: Roots.*
- #133, *Plant Structures: Stems.*
- #134, *Plant Structures: Leaves.*
- #135, *Plant Structures: Flowers.*
- #136, *Plant Structures: Fruit.*
- #137, *Plant Structures: Seeds.*
- #141, *Plant Physiology: Photosynthesis, Transpiration, and Respiration.*
- #142, *Plant Growth Factors: Light.*
- #143, *Plant Growth Factors: Temperature.*
- #144, *Plant Growth Factors: Water.*
- #145, *Plant Growth Factors: Hormones.*

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.

Plant*talk* Colorado™

- http://planttalk.org.
- #2004, *Additional Information: Plant Societies*.
- #2008, *Commonly Used Plant Terms.*

Other

- International Plant Name Index at www.ipni.org.
- U.S. Department of Agriculture Plant Data Base at http://plants.usda.gov.
- *Botany for Gardeners, Fourth Edition: An Introduction to the Science of Plants*, Brian Capon. Timber Press, 2022. ISBN: 978-1643261430.
- *Gardener's Latin: A Lexicon*, Bill Neal. Algonquin Books, 2003. ISBN: 9781565123847.
- *The Science of Plants.* Tom Michaels. 2022 University of Minnesota Libraries https://open.umn.edu/opentextbooks/textbooks/1196.

- *Manual of Woody Landscape Plants,* Sixth edition, Michael A. Dirr. Stipes, 2009.
- *Flora of Colorado*, Jennifer Ackerfield. Second edition. BRIT press, 2022.
- *How Plants Work*, Linda Chalker-Scott. 2015.
- *Alice in the Land of Plants,* Yiannis Manetas. 2012.
- *The Why and How of Home Horticulture*, D.R. Bienz. Freeman, 1993. ISBN: 9780716723530.
- *Plant Form: An Illustrated Guide to Flowering Plant Morphology*, Adrian D. Bell, 2008, Timber Press.

Learning Objectives

At the end of this training, the student will be able to:

- Understand the importance of using correct terminology to enhance communications about plants.
- Practice skills needed in diagnosis by carefully examining plants and plant parts for plant identification.
- Correlate plant structure and growth processes with common plant disorders.

Review Questions

Note: Class time does not permit the instructor to cover all the topics. Please take time to read and review study materials. This unit covers many horticultural and botanical terms. The objective is to understand that terms are used to communicate and using terms correctly improves communications.

It is not the purpose of this training to memorize terms or definitions. When you come across a term that you do not understand, you can use the glossary in most botany or horticulture textbooks to look up the meaning.

Classifying Plants

1. Why is it important to understand the concepts of plant taxonomy and classification as a gardener?
2. What is meant by:
    - Warm season and cool season plants.
    - Tender and hardy plants.
    - Alpine, prairie, woodland, wetland, xeric and native plants.
    - Herbaceous and woody.
    - Trees, shrubs, and vines.
    - Deciduous, evergreen, and semi-evergreen.
    - Broadleaf, narrowleaf and needleleaf.
    - Annual, summer annual and winter annual.
    - Biennial.
    - Perennial, herbaceous perennial, spring ephemerals and woody perennials.
3. Why is it important to know the difference between monocots and dicots, especially when it comes to applying herbicides?
4. How can you identify monocots and dicots based on leaf venation, flower parts, and seed cotyledons?
5. Give the protocol for writing out scientific names.

Plant Structures

6. Describe the relationships of cells to tissues to structures to plants.
7. List the three primary functions of roots.

8. Define and identify the following root terms:
    - Meristematic zone.
    - Primary roots.
    - Lateral roots.
    - Root tip.
    - Epidermis.
    - Root hairs.
    - Tap root system.
    - Fibrous root system.
    - Adventitious roots.
9. List the three primary functions of stems.
10. Identify the following parts of a stem:
    - Nodes.
    - Internodes.
    - Terminal bud.
    - Lateral bud.
    - Terminal bud scar.
    - Leaf scar.
    - Bundle scar.
11. Describe how stem characteristics are used in plant identification.
12. Define the following stem terms:
    - Shoot.
    - Twig.
    - Branch.
    - Trunk.
    - Cane.
    - Bulb.
    - Corm.
    - Crown.
    - Stolon.
    - Rhizome.
    - Tuber.
13. List the two primary functions of leaves.
14. Define and identify the following leaf terms:
    - Leaf blade.
    - Leaf tip.
    - Leaf base.
    - Mid-vein or midrib.
    - Lateral veins.
    - Leaf stalk or petiole.
    - Stipules.
    - Bud.
    - Pinnate venation.
    - Palmate venation.
    - Parallel venation.
    - Simple leaf.
    - Pinnately compound.
    - Palmately compound.
    - Doubly (bipinnately) compound.
    - Alternate leaf arrangement.
    - Opposite leaf arrangement.
    - Whorled leaf arrangement.
15. What is the primary function of flowers?
16. Identify the following parts of a flower:
    - Sepals.
    - Calyx.
    - Petals.
    - Anthers.
    - Filament.
    - Stamen.
    - Stigma.
    - Style.
    - Ovary.
    - Ovules.
    - Pistil.
    - Floret.
17. Define the following flower and plant terms:
    - Complete flower.
    - Incomplete flower.
    - Perfect flower.
    - Monoecious plant.
    - Dioecious plant.
18. Describe how flowers are used in plant identification.
19. What is the primary function of fruit?
20. Identify the following parts of a seed:
    - Seed coat.
    - Endosperm.
    - Cotyledon.
    - Plumule.
    - Radicle.

Plant Growth

21. Define:
    - Photosynthesis.
    - Respiration.
    - Chloroplasts.
    - Chlorophyll.
    - Transpiration.
    - Stomate.
22. Define what is meant by:
    - Full sun.
    - Filtered shade.
23. Define photoperiod.
24. List three factors that influence plant hardiness.
25. What does a hardiness zone map indicate?
26. Define the following terms related to winter injury:
    - Sunscald.
    - Frost crack.
    - Winter drought.
27. How do temperate-zone plants know when to start growing in the spring?
28. List the roles of water in plant growth.
29. Explain how a plant balances shoot growth with root growth.
30. Explain how a plant grows toward the sun.

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #121

Horticultural Classification Terms

Outline:

Horticulture and Related Fields

Horticulture – The science and art of cultivating flowers, fruits, vegetables, turf, and ornamental plants in an orchard, garden, nursery, or greenhouse, on a large or small scale.

Horticulturist – A specialist in horticulture.

The terms **ornamental horticulture**, **landscape horticulture**, and **environmental horticulture** are commonly used to identify the sub-fields of horticulture dealing with designed landscape settings.

Agriculture – The theory and practice of growing crops.

Agronomy – A branch of agriculture dealing with field crop production and soil management.

Botany – A branch of biology dealing with plant life, (i.e., anatomy, taxonomy, genetics, physiology, and ecology). The science of applied botany deals with plants grown in uncultivated settings.

Forestry – The science of developing, caring for, or cultivating forests; the management of growing timber.

Urban forestry – A branch of forestry dealing specifically with the unique growth limitations and needs of trees in the landscape setting.

Horticultural Classifications of Plants

With hundreds of thousands of plant species and varieties on the planet, horticulturists look for practical ways to group them together. Plants are grouped by various common characteristics to help us communicate similar cultural requirements, garden uses, morphology, or taxonomy among other things. The following are examples of common classifications used in horticulture.

Classification by Use

1. **Edibles**
   A. Fruits*
      1. Tree fruits.
      2. Small fruits.
   B. Vegetables
      1. Warm-season vegetables.
      2. Cool-season vegetables.
   C. Herbs
      1. Culinary.
      2. Medicinal.
   D. Nuts

2. **Ornamentals/Landscape Plants**
   A. Woody plants
      1. Trees.
      2. Shrubs.
      3. Vines and ground covers.
   B. Herbaceous plants
      1. Flowers and foliage plants.
      2. Vines and ground covers (that do not develop woody stems).
   C. Grass/Turf

3. **Potted Plants, Houseplants, Gift Plants**
   A. Flowering Plants (grown primarily for flowers).
   B. Foliage plants (plants that may produce flowers, but which are grown for their foliar characteristics).

*Note: Do not confuse the multiple uses of the word ***fruit***. In reference to cookery (fruits and vegetables), "fruit" refers to crops primarily used in some European cuisines as a dessert (e.g. peaches, apples, strawberries, and raspberries) whereas "vegetables" refers to crops served as part of savory dishes (potatoes, carrots, spinach, etc.). In this frame of reference, tomatoes are vegetables. In taxonomic or anatomical classification, "fruit" refers to a seed-bearing structure – in this sense, tomatoes and squash are fruit. Potatoes are rhizomes (modified stems), carrots are roots, spinach is leaves, etc.

Classification by Climatic Requirements

Tropical plants originate in tropical climates with a year-round summer-like growing season without freezing temperatures (but possibly with wet and dry seasons). Examples include cacao, cashew and macadamia nuts, banana, mango, papaya, and pineapple.

Sub-tropical plants cannot tolerate severe winter temperatures but often need winter chilling to grow and produce correctly. Examples include citrus, dates, figs, and olives.

Temperate plants require a cold winter season as well as a summer growing season and are adapted to survive temperatures below freezing. Examples include apples, cherries, peaches, maples, cottonwoods, and aspen. In temperate-zones, tropical and sub-tropical plants can be grown as annuals and houseplants.

Cool Season plants thrive in cool temperatures (40°F to 70°F daytime temperatures) and are tolerant of light frosts. Examples include Kentucky bluegrass, peas, lettuce, and pansies.

Warm Season plants thrive in warm temperatures (65°F to 90°F daytime temperatures) and are intolerant of cool temperatures. Examples include corn, tomatoes, and squash.

Tender plants are intolerant of cool temperatures, frost, and cold winds. Examples include most summer annuals, including impatiens, squash, and tomatoes.

Hardy plants are tolerant of cool temperatures, light frost, and cold winds. Examples include spring-flowering bulbs, spring-flowering perennials, peas, lettuce, and cole crops.

Hardiness refers to a plant's tolerance to winter climatic conditions. Factors that influence hardiness include minimum temperature, recent temperature patterns, water supply, wind and sun exposure, genetic makeup, and carbohydrate reserves.

Cold hardiness zones are determined by the USDA and refer to the average annual minimum temperature for a geographic area, and thus the average minimum temperature that a plant can tolerate. Temperature is only one factor that influences a plant's winter hardiness.

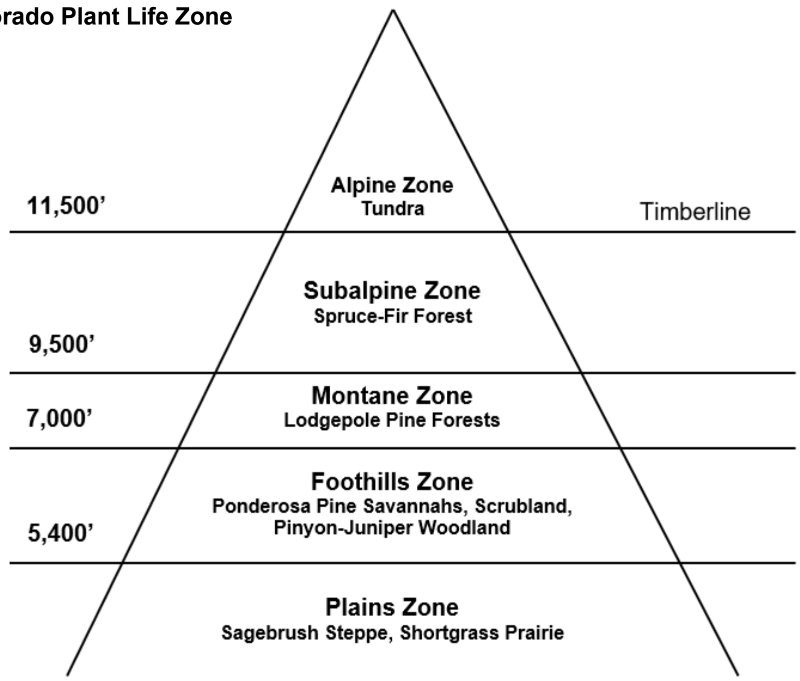
Classification by Elevation and Plant Life Zones

Plants can be classified by the plant communities in which they usually occur. Environmental characteristics determined by elevation create "zones" dominated by distinguishable plant communities. Examples of these communities include pinyon-juniper woodlands, sagebrush steppes, high plains grasslands, montane and subalpine forests, and the alpine tundra. Matching plants' life zones to garden conditions can be a great way to pair the "right plant" with the "right place." Plants grown outside of their life zones may require mitigations like extra water, more (or less) shade than they might tolerate in their natural habitat, special soil modifications, etc.

The elevation of life zones shifts downward as latitude increases. A climb of 1,000 feet is equal to a trip around 600 miles northward. Plant life zones will remain in the same relative position regardless of latitude, but the absolute elevation of each zone decreases as you move northward, for example the alpine tundra above 11,500 feet in Colorado is similar to the artic tundra near sea level on the north coast of Alaska and Canada. Higher elevations have increasingly shorter growing seasons due to colder temperatures. High elevations tend to have poorly developed soils, stronger light, persistent winds, and greater temperature fluctuations than lower elevations of the same region. Due to this harsh environment, plants of the alpine tundra tend to be compact in form. [**Figure 1**]

Figure 1 on next page.

Figure 1. Colorado Plant Life Zone



Classification by Ecological Adaptations

Related to life zones are ***ecological adaptations*** of plants. For example, characteristics of the Colorado high plains include low humidity, limited rainfall, and alkaline soils low in organic matter. Plants from environments with similar growing conditions will do well on the high plains, in general.

In higher mountain communities, the short frost-free season and low summer growing temperatures significantly change what plants can be grown well there compared to on the plains.

The following are a few examples of terms used to describe classifications based on ecological adaptation.

Alpine plants tolerate the short growing season, cold, and wind of higher mountain elevations. They are typically low-growing, small leaf perennials. Growing alpines at lower elevations takes special gardening techniques and care and has led to the development of Rock Alpine gardening as a horticultural movement.

Prairie plants are adapted to the open sun and winds of the plains. These plants are further classified into dry, mesic, and wet categories, or as tallgrass or shortgrass prairie plants. Many prairie plants, particularly tallgrass prairie plants, are very competitive in deep, nutrient-rich soil that you would find in the American Midwest.

Woodland plants are adapted to low light conditions either by shade avoidance (spring and winter growth and summer dormancy) or by shade tolerance. They tend to do best in soils rich in organic matter.

Wetland plants tolerate continually moist soil conditions of a bog or a pond. Some will tolerate drier soils, but most make poor choices for standard garden conditions. Some wetland species, like cattails, will spring up in overwatered, compacted soils in landscapes, and can serve as an indicator of irrigation issues.

Xeric plants tolerate dry conditions. They are often also tolerant of bright light and warm temperatures due to a variety of adaptations such as succulent, waxy, hairy, or small leaves, taproots, and succulent stems. Growing xeric plants in too wet conditions can result in poor plant performance.

Native and Adapted Plants for the Urban Environment

Native (indigenous) plants refer to plants growing in a given area during a defined time period. In The United States, the term often refers to plants growing in a region prior to the time of settlement by people of European descent. Many gardeners mistakenly consider *native* plants as *xeric* plants, and *xeric* plants as *native* plants. The two terms are **not** interchangeable – many native plants in our region are xeric, for example, but many others are not.

In gardening, the concept of native should not refer to political boundaries, such as state or country, but to an ecological habitat during a defined chronological period. For example, Colorado blue spruce and quaking aspen are native to the ecological habitat referred to as the montane zone. They are not native to the Colorado high plains, or elevations below 8,000 feet. Between 500 million and 300 million years ago, what is now Eastern Colorado was once an inland sea. Therefore, aquatic plants such as kelp would have been native at one time. Over time, the ecological habitat changed, changing the native plants along with it. Environmental change is an ongoing process, based both on global climatic events and on the activity of all organisms, including humankind.

Adapted plants are those that reliably grow well in a particular habitat without specific attention from humans in the form of winter protection, soil amendments, pest protection, water, etc. Adapted plants are considered to be ***low maintenance*** plants. In the context of gardening, **Adapted Plants** usually refers to non-native plants from similar ecological contexts. Some adapted plants have become noxious weeds.

The urban environment, for gardening purposes, needs to be recognized as a unique ecosystem, with challenges beyond what could be expected in the native natural environment. Characteristics of the urban environment include:

- Soil compaction.
- Reduced rooting areas.
- Increased surface runoff creates significant water quality problems.
- Higher temperatures and lower humidity.
- Air pollution.

Characteristics of an urban environment cultivated by humans (a garden) may include:

- Reduced wind.
- Increased availability of water due to irrigation.
- Increased organic matter and soil fertility.
- Different insect communities, both pests and beneficials.
- Increased soil stability.
- Slower temperature fluctuations.

The unique challenges of the urban environment and site-specific features should be considered when planning gardens with native or adapted plants.

Classification by Stem and Leaf Texture

- **Herbaceous** plants have non-woody stems.
- **Woody** plants have woody stems that usually live for several years, adding new growth each year.
  - **Deciduous** trees and shrubs shed all leaves at approximately the same time annually. Deciduous plants can be conifers (e.g. larch or bald cypress) or flowering plants (most shade trees), broadleaf or narrowleaf.
  - **Evergreen** trees and shrubs retain some leaves longer than one growing season so that leaves are present throughout the year. Seasonal drop of some of the oldest interior leaves are a natural part of the life cycle. Evergreens can be broadleaf or narrowleaf.
  - **Semi-evergreen** plants may retain their leaves year-round, depending on the winter temperature and moisture, losing them only in harsh winters.
- **Broadleaf** plants have a broad leaf blade, such as ash, maple, lilac, and beans.
- **Narrowleaf** plants have needle-like leaves such as pine and spruce, or awl-like leaves such as junipers.
- **Grass-like** plants or **graminoids** have narrow leaves, usually arising from the base of the plant. Grasses, rushes, and sedges are all graminoids.

Classification of Woody Plants by Growth Habit

Growth Habit refers to the genetic tendency of a plant to grow in a certain shape and to attain a certain mature height and spread. [**Figure 2**]

- **Trees** typically have a single trunk and mature height over twelve feet.
- **Shrubs** typically have multiple branches from the ground and a mature height less than twelve feet.
- **Vines** have a climbing, clasping, or self-clinging growth habit.

Many landscape plants can be considered small trees or large shrubs. The terms tree or shrub is applied based on the general appearance of the plant – some say, “you walk under a tree, and around a shrub.” Trees can be further classified by canopy shape.

A thorough understanding of growth habits is important to make knowledgeable decisions regarding plant placement, selection, pruning, and maintenance.

The species, cultivar, and/or marketing names of plants sometimes indicate a particular characteristic of growth habit – for example, *Pinus ponderosa* roughly translates to “big [heavy/significant] pine,” and Mini-Man™ Viburnum is a dwarf variety.

Figure 2. Tree Forms

Classification by Life Span

From a horticultural perspective, life span is a function of inherent plant characteristics, climate, and usage. Garden plants including tomatoes and geraniums that are grown as annuals in Colorado, are perennials in climates without freezing winter temperatures.

Annuals complete their life cycle (from seedling to setting seed) within a single growing season. However, the growing season may be from fall to summer, not just from spring to fall. These plants come back in subsequent growing seasons only from seeds.

> **Summer annuals** germinate from seed in the spring and complete flowering and seed production by fall, followed by plant death. Their growing season ranges from spring to fall. Examples include marigolds, squash, and crabgrass.
>
> **Winter annuals** germinate from seed in the fall, with flowering and seed development the following spring, followed by plant death in summer. Their growing season is from fall to summer. Examples include winter wheat, cheatgrass, redstem filaree (*Erodium cicutarium*) and annual bluegrass.

Biennials complete their life cycle within two growing seasons. Biennials germinate from seed during the first growing season and produce foliage and storage organs the first summer. Quite often, they maintain a rosette growth habit the first season, meaning that all the leaves are basal, or close to the base of the plant. They flower and develop seeds the second season, followed by death.

In the garden setting, we grow certain biennials as annuals - carrots, onions, and beets, for example, because we are more interested in the root than the bloom. Some biennial flowers, such as hollyhocks, may persist as short-lived perennials.

Perennials live through several growing seasons and can survive a period of dormancy between growing seasons. These plants regenerate from root systems or protected buds, in addition to seeds.

Authors: David Whiting, CSU Extension, retired. Artwork by Scott Johnson and David Whiting. Used with permission.
Reviewed September 2022 by John Murgel, CSU Extension.

Reviewed September 2022

CMG GardenNotes #122

Taxonomic Classification

Outline:

The most universal classification system of plants is plant taxonomy, or systematics. Taxonomy is the science of systematically naming and classifying organisms into groups that reflect their relatedness to other organisms. Plant systematics is an old science that uses the gross morphology (physical characteristics, [i.e., flower form, leaf shape, fruit form, etc.]) and, more recently, genetic information to understand their relationships and heritage. The science of classifying organisms to understand their relationships and evolutionary history is also known as *Phylogenetics*. Characteristics that distinguish organisms sometimes become a part of their name, though not always unambiguously. For example, *Quercus alba* means “white oak”, and is so named because the underside of the leaf is white, and *Pinus contorta*, lodgepole pine, translates to “twisted pine”, named for twisted seeds rather than its characteristically straight trunks.

Plant taxonomic classification changes with continuing research, so inconsistencies in nomenclature will be found among references. Knowing the currently accepted names is important, but do not get caught-up in which is “correct”, as it can be a moving target. Rather focus on “are you communicating?”

An overview of plant taxonomy helps the gardener understand the basis of many cultural practices. For example, fire blight is a disease of the rose family; therefore, it is helpful to recognize members of the rose family to diagnose this disease.

Common Taxonomic Divisions

The scientific system of classification divides all living things into groups called **taxa** (singular, **taxon**). Taxa are arranged in hierarchy, ranging from Kingdom to Subspecies, with each taxonomic division “nested” into the group above. A phylogenetic Kingdom is usually the largest recognized taxonomic group. Every living thing can be classified into taxonomic groups according to this system.

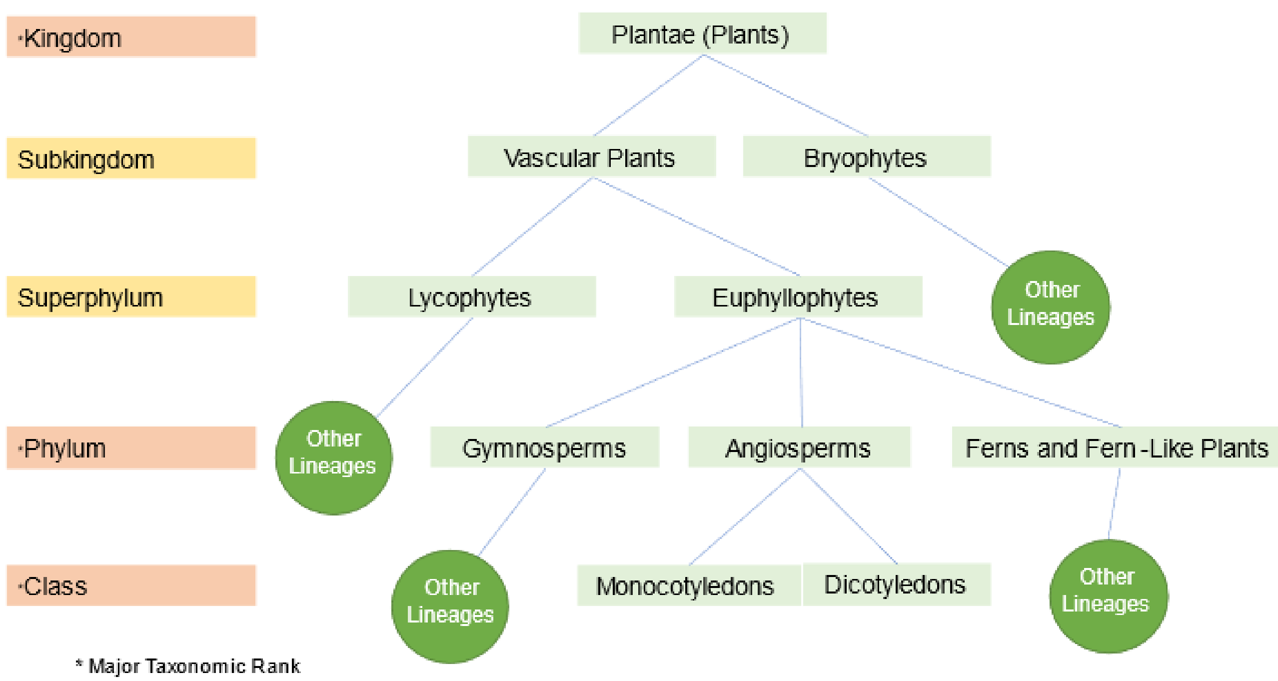
The seven major taxonomic groupings are, in order:

Kingdom
Phylum
Class
Order
Family
Genus
Species

Plants are in the kingdom of ***Plantae***. Other kingdoms include ***Fungi***, ***Protista*** (one-celled organisms including yeasts, bacteria, and protozoans), and ***Animalia*** (animals). [**Figure 1**]

The plant kingdom is divided between **bryophytes**, or **non-vascular plants**, (including true mosses and liverworts) and ***tracheophytes*** or **vascular plants** (plants with a vascular system that includes *tracheids*, a type of xylem cell).

Figure 1. The Upper Portion of the Plant "Family Tree"

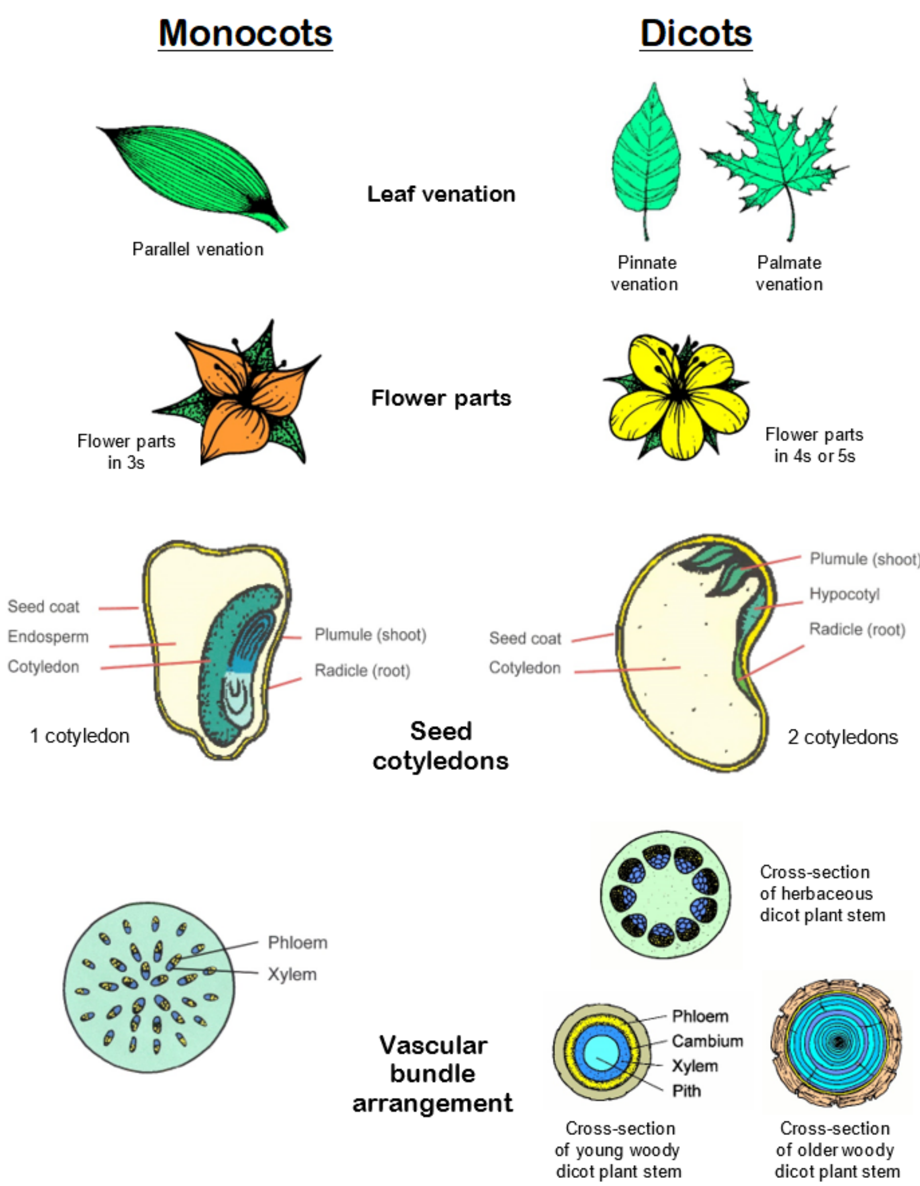


Vascular plants are further divided into two subgroups: lycophytes (plants with very simple vascular systems, like *Selaginella* and club-mosses) and *euphyllophytes* (plants with complex vascular systems and overtopping branches, like ferns, conifers, and flowering plants). One sub-group of the Euphyllophytes is the ***spermatophyta***, or **seed plants**, so named because they produce seeds rather than spores or free-swimming gametes. The seed plants include five phyla, Cycads, Gingkos, Conifers, and Gnetophytes (commonly referred to as a group as **Gymnospermae** or Gymnosperms) and flowering, **Magnoliaphyta** (Angiosperms). Plants from these groups make up most of the plants in the landscape (the most notable exception being ferns, which reproduce from spores rather than from seeds).

Gymnosperms do not produce flowers, but rather "naked seeds" (the translation of Gymnosperm) on or in specialized structures, such as pinecones. Cycads are common landscape plants in tropical and sub-tropical areas and may be grown as houseplants in Colorado. *Ginkgo biloba* is the only existing species in the Ginkgoales, but the fossil record includes many other members. Arborvitae, junipers, Douglas-fir, fir, pine, and spruce are examples of conifers (or literally, “cone-bearers”). The Gnetophytes are another small group, with only a few dozen species, the most well known in our area being *Ephedra*.

Angiosperms or phylum Magnoliaphyta, are flowering plants, and with nearly 260,000 existing species make up most of the diversity of plants. Angiosperms have more complicated vascular systems than other plant groups and a highly modified reproductive system compared to older lineages. Angiosperm seeds are enclosed in a fruit (i.e., not naked). The angiosperm phylum is divided into several classes: two important groups for landscape maintenance are ***monocotyledons*** (**monocots**) and ***dicotyledons*** (**dicots**). (Note that “dicots” are not themselves an individual taxonomic “class,” but rather the term refers to several variously related classes of flowering plants that are distinct from monocots). Distinguishing between monocots and dicots is a common practice in landscape management. For example, some of our common herbicides are selective against one group or another. Lawn weed sprays (such as 2,4-D and dicamba) kill dicots (broadleaf plants like dandelions) but not monocots (the grass). Other herbicides will kill monocots but not dicots, allowing the gardener to kill grass (a monocot) in the shrub or flowerbed (dicots). [**Figure 2**]

Figure 2. Monocots versus Dicots



Orders and Families

Plant Orders and Families are separated from one another by characteristics inherent in their reproductive structures (flowers, fruit, and seed). Many family members have obvious morphological similarities, but the resemblances can be less plain too. As with higher taxonomic groups, orders and families share common traits that reflect a shared heritage.

Family names end in '*aceae'*. Examples of common families include the following:

- ***Caprifoliaceae*** – Honeysuckle family, including elders, honeysuckle, snowberry, and viburnum.
- ***Fabaceae*** – Pea family, including Pagoda tree, locust and Siberian peashrub.
- ***Oleaceae*** – Olive family, including ash, forsythia, lilac, and privet.
- ***Rosaceae*** – Rose family, including apple, cotoneaster, crabapple, potentilla, peach, plum, mountain ash and 250 common landscape plants.

Genus and Species

The taxonomic divisions beneath the family level are genus and species. Plant species are named using a binomial system that was standardized by Carolus Linnaeus (1707-1778), a Swedish biologist who is known as the father of modern taxonomy thanks to his efforts. The binomial system assigns each living thing two names: a genus and specific epithet, which together make up the species name. The genus name comes first and is analogous to a person's last name (like Smith). The specific epithet names follow as a more specific identifier. It would be analogous to a person's first name (like John). Plant names are regulated internationally by the International Code of Botanical Nomenclature (ICBN), https://www.iapt-taxon.org/nomen/main.php. The goal of the ICBN is to provide only one, internationally recognized, correct name for each taxonomic group within a stable system of names (i.e., a "classification"), and is officially updated every six years by the International Botanical Congress.

Genus	Specific Epithet
Smith	John
Catalpa	*speciosa*

The common names of plants typically apply to a genus (plural ***genera***). For example, *Acer* is the genus of maples, *Fraxinus* of the ash, and *Juniperus* of the junipers. Many genus names have become 'generic' common names. For example: anemone, rhododendron, crocus, and viburnum, are all common names that are identical to the genus name. Genus names are always nouns in the singular.

The specific epithet classifies a member of a genus as a unique species. The specific epithet is always used in conjunction with the genus, never alone, and is an adjective, noun in apposition, or possessive noun that modifies the generic name. The specific epithet must grammatically agree with the genus (according to the rules of Latin).

When genus name and specific epithet are written, they are italicized. The genus name is always capitalized, but the specific epithet is not.

In writing, the abbreviation "sp." following the genus indicates a single unidentified species and "spp." indicates multiple species. For example, "Acer sp." would indicate an unidentified species of maple, and "Acer spp.*"* refers to multiple species in the maple genus. The "sp." or "spp." is not italicized.

In technical papers, the person who first described the species, called the **Authority**, follows the specific epithet. For example, Japanese maple would be written *Acer palmatum* Thunberg or *Acer palmatum* T. The potato would be written *Solanum tuberosum* Linnaeus or *Solanum tuberosum* L.

Variety and Cultivar

The taxonomic divisions beyond the genus and species level include subspecies, variety, and form (forma).

Variety, form, or **subspecies** is a sub-grouping of species assigned to individuals displaying unique differences in natural populations. The differences are inheritable and reproduce true-to-type in each generation. For example, cauliflower and cabbage are varieties of the same species, *Brassica oleracea*, and our local native maple, *Acer saccharum* subsp. *grandidentatum* is a subspecies of sugar maple, *Acer saccharum*.

In technical writing, variety and subspecies names must be denoted with 'var.' or 'ssp/subsp.' when following a species name. The names themselves are italicized, while var. or ssp. is not. For example, the thornless variety of honeylocust would be written *Gleditsia triacanthos* var. *inermis*. The bigfruit evening primrose would be written *Oenothera macrocarpa* ssp. *incana*.

A cultivar ("cultivated variety") is a man-made variety of plant that displays unique characteristics, typically of gardening importance. Some cultivars can be reproduced by seed; others need to be propagated vegetatively because they derive from a single plant. Vegetatively propagated cultivars are genetic clones. Cultivar names are not italicized, rather they are placed in 'single quotes'. Often, a grower will introduce a trademarked marketing name for plants that is different from the recognized cultivar name - a marketing name has no taxonomic value. For example, October Glory Red Maple is *Acer rubrum* 'October Glory', whereas the real name of Autumn Blaze® Maple is *Acer* 'Jeffersred'.

It is possible to have a cultivar of a variety. For example, *Cornus florida* var. *rubra* 'Cherokee Chief'. Cultivars of native plants are sometimes called "Nativars".

Examples of Taxonomic Classification chart on next page.

Examples of Taxonomic Classification:

Examples of Taxonomic Classification

- Vascular plants
  - Seedless
    - *Pteridophyta (Pterophyta)* – ferns
  - Seeded
    - *Gymnospermae* – **Gymnosperms** (naked seed plants)
      - *Cycadophyta* – Cycads
      - *Pinophyta (Coniferophyta)* – **Conifers** (cone bearing plants)
        - *Cupressaceae* (cypress family)
          - *Juniperus* spp. – **junipers**
            - *Juniperus horizontalis* (creeping Juniper)
              - *Juniperus horizontalis* 'Blue Chip' (blue chip juniper)
          - *Thuja* spp. – **arborvitae**
        - *Pinaceae* (pine family)
          - *Abies* spp. – **fir**
          - *Larix* spp. – **larch**
          - *Picea* spp. – **spruce**
            - *Picea pungens* – Colorado spruce
              - *Picea pungens* 'Bakeri' – Bakeri Colorado spruce
          - *Pinus* spp. – **pines**
            - *Pinus ponderosa* – ponderosa pine
          - *Pseudotsuga menziesii* – **Douglas-fir**
    - *Angiospermae* – **Angiosperms** (flowering plants) / ***Magnoliophyta (Anthophyta)***
      - *Aceraceae* – Maple family
        - *Acer* spp. – **maples**
          - *Acer platanoides* – Norway maple
            - *Acer platanoides* 'Crimson King' – Crimson King Norway maple
      - *Salicaceae* – Willow family
        - *Populus* spp. – **cottonwood, poplar, and aspen**
          - *Populus deltoides* – eastern cottonwood
            - *Populus deltoides* 'Siouxland' – Siouxland eastern cottonwood
          - *Populus tremuloides* – quaking aspen
      - *Rosaceae* – rose family
        - *Rosa* spp. – **roses**
          - *Rosa rugosa* – Rugosa rose
            - *Rosa rugosa* 'Hansa' – Hansa rugosa rose
        - *Cotoneaster* spp. – **cotoneasters**
          - *Cotoneaster apiculatus* – cranberry cotoneaster

Why Are Scientific Names "in Latin"?

When Linnaeus published *Species Plantarum* in 1753, he consistently used and established modern binomial classification. Because Latin was used in Western Europe at that time as the language of state and science, scientific names of plants are Latinized - that is, they take the form of Latin words, while they themselves are not necessarily Latin. (Even Linnaeus' own name is Latinized, from the Swedish Karl von Linne). Today, Linnaeus' system continues to provide consistent naming across the globe, allowing scientists from anywhere, speaking any language, to communicate with one another with confidence.

Pronouncing Scientific Names

Botanic names are universal **in spelling** (that is, each plant has a single genus and specific epithet, **spelled the same** worldwide). By using botanic names, plants can be positively identified from over 380,000 known plant species.

However, pronunciation of scientific names is not universal and will vary based on the local language. (You say 'toe-may-toe' and I say 'toe-mah-toe'.) Based on the native language and local dialect of the user, scientific names sound rather different in various countries.

Here are a few basic guidelines for American English:

- Botanic names, like Latin, are entirely phonetic. Silent letters are rare and occur only in names derived from languages other than Latin (e.g. Greek) or when a botanic name is based on a person's name. In general, what you see is what you say.
- Consonants are pronounced as in English. The letters 'c' and 'g' are normally hard in front of the vowels 'a', 'o' and 'u'. When in front of 'i' and 'e', the sound can be soft in American parlance (think "circle" and "gentle").
- The letters "ch" are usually pronounced like "k" because they are usually derived from the Greek letter χ ("chi") in botanic names.
- Vowels are usually long in an accent syllable. For example, *Acer* becomes AY-ser and *Pinus* become PIE-nus.
- Adjacent vowels may be marked with a dieresis or double dot, to indicate that they are to be pronounced separately. For example, the cycad genus *Dioön* is pronounced in three syllables: "dye-oh-on", not in two syllables: "dye-oon". The vowel pair "ae" is pronounced as a diphthong (i.e., not separately) as in "Julius Caesar". When in doubt, pronounce vowels separately.
- Examples:
  - *Quercus macrocarpa* (bur oak) – KWER-kus MAC-row-CAR-pah.
  - *Elaeagnus angustifolia* (Russian olive) – Ell-ee-AG-nus an-GUS-tih-FOL-ee-auh.
  - *Ptelea trifoliata* (hoptree/wafer ash) – TEA-lee-ah.
  - try-FOAL-ee-AH-tah (note the Greek-derived "pt").
  - *Kalanchoe pinnata* – KAL-an-COE-ee pin-NAH-ta (note the Greek-derived "ch" and separately pronounced vowels "oe").

Botanic Names Add Meaning

Botanic names often reflect something about the plant's description since the specific epithet is an adjective or noun modifying the genus name. For example:

- ***americana*** = of America – *Fraxinus americana* (white ash).
- **-ensis** = from a particular area (e.g. *texensis* for "from Texas") – *Clematis texensis* (scarlet leatherflower)
- ***baccata*** = berry bearing – *Taxus baccata* (common yew).
- ***micro*** = little, small – *Antennaria microphylla* (littleleaf pussytoes).
- ***officinalis*** = medicinal – *Rosmarinus officinalis* (rosemary).
- ***repens*** = creeping, crawling – *Berberis repens* (creeping Oregon grape).
- ***undulata*** = wavy – *Quercus undulata* (wavyleaf oak).
- ***variegatus*** = variegated – *Miscanthus sinensis* 'Variegatus' (variegated maiden grass).
- ***vulgaris*** = common – *Syringa vulgaris* (common purple lilac).
- ***alba*** = white – *Quercus alba* (white oak).
- ***niger*** = black – *Pinus nigra* (black pine).
- ***rubra*** = red – *Acer rubrum* (red maple), *Quercus rubra* (red oak).

- ***sanguineus*** = blood-red – *Geranium sanguineum*.

Common Names

In contrast to scientific names, common names are local in use rather than global. For example, *Liriodendron tulipifera* is known as the tulip tree in the northern USA and as yellow poplar in the south. *Carpinus caroliniana* goes by American hornbeam, blue beech, musclewood, water beech and ironwood. The European white lily, *Nymphaea alba*, has fifteen English common names, forty-four French common names, one-hundred-five German common names, and eighty-one Dutch common names. More problematic still, the same common name can often refer to more than one plant, for example, “bluebell” refers to several dozen plants across different genera and families. Common names can lead to confusion about taxonomy, (“poison oak” is not an oak at all), and huge numbers of plants do not have common names. **The use of scientific names is absolutely essential to ensure efficient, accurate communication about plants, particularly on a worldwide basis.**

References on Plant Taxonomy

Some suggested sources of scientific names and taxonomic information include the following:

- World Flora Online http://www.worldfloraonline.org/.
- Missouri Botanical Garden Angiosperm Phylogeny http://www.mobot.org/MOBOT/research/APweb/.
- USDA Plant Data Base at http://plants.usda.gov/.
- Published *Florae* of Geographic Areas, for example, *Flora of Colorado* by J. Ackerfield (Brit Press, 2015).

Authors: David Whiting, CSU Extension, retired; Alison O’Connor, CSU Extension; Joanne Jones CSU Extension, retired; Linda McMulkin, CSU Extension, retired; and Laurel Potts, CSU Extension, retired. Line drawings by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O’Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed October 2022 by John Murgel, CSU Extension.

Reviewed October 2022

CMG GardenNotes #131

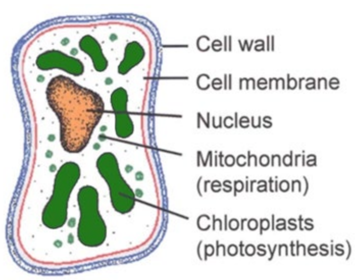
Plant Structures: Cells, Tissues, and Structures

Outline:

Plant bodies are structurally and functionally specialized. This specialization is effected by differentiation among types of cells and tissues. Plant **cells** are grouped into **tissues** based on function (e.g., protecting the plant, conducting water, etc.). Cells and tissues comprise distinct **organs**, or externally recognizable plant parts.

Cells are individual building blocks for life processes and growth. Common cells contain genetic matter (**deoxyribonucleic acid**, or **DNA**) and metabolic and storage organelles. Cells are the site of **photosynthesis** (sugar production). Photosynthesis, the process of converting light energy into stored carbohydrates, is conducted in organelles called **chloroplasts**. [**Figure 1**]

Figure 1. Plant Cell



Tissues are groups of cells that are similar in function. Categorizing plant cells in this way is in some sense artificial because structural features in plants not only vary and intermix with one another, but because they are capable of changing into one another. Tissues are typically divided by functional properties that are related to position within the plant body. Plant tissues are organized into three systems, the **dermal**, **ground** (or fundamental) and **vascular** systems.

The dermal system separates the plant from the outside world, the ground system forms the bulk of the plant body and carries out essential metabolic functions, and the vascular system conducts water and nutrients through the plant.

Some Plant Cell and Tissue Types:

Epidermis is the continuous surface layer of cells that protects the plant body. The outside surface of the epidermis tissue is usually covered with a waxy substance called cutin, which reduces water loss and mechanically protects the plant. In addition to epidermal cells proper, stomatal guard cells, trichomes, root hairs, and secretory cells are all part of the epidermis.

Periderm is present in plants with secondary growth (wood) in stems and roots. When present, it replaces the epidermis and generates, among other things, bark.

Parenchyma cells form continuous tissues within the body of the plant. In stems and roots, for example, the parenchyma cells make up the cortex (storage tissues) and pith. In leaves, a layer of parenchyma cells called **mesophyll** under the epidermis is the primary site of photosynthesis. Parenchyma cells are active in wound healing and the production of secondary plant structures like adventitious roots.

Meristems are “immortal” cells that continuously divide to produce new cells at the growing points of plants.

Sclerenchyma tissue is made up of thick-walled support cells found throughout the plant, occurring both as continuous tissue, and as small, isolated groups.

Xylem is a structurally complex tissue that conducts water and nutrients throughout the plant, provides storage, and support. Several cell types are present in xylem. In woody plants, the xylem tissue becomes the wood.

Phloem tissue conducts food and metabolites from photosynthesis throughout the plant, including down to the roots, and like xylem, includes several different cell types.

Organs (structures) are externally recognizable plant parts (e.g., roots, stems, leaves). Flowers are typically viewed as an assemblage of organs (stamens, carpels, petal, and sepals).

Plants are made up of coordinated, highly specialized cells and tissues that form a single integrated organism.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O’Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #132

Plant Structures: Roots

Roots are the beginning of the vascular system pipeline that moves water and minerals from the soil up through the plant body.

To function, roots must have adequate levels of soil oxygen. Soil compaction or waterlogged soil situations, which reduce soil oxygen levels, will kill roots and lead to a shallow root system.

The structure and growth habits of roots have a pronounced effect on:

- Size and vigor of the plants.
- Adaptation to certain soils.
- Response to cultural practices.

Because they are out of sight, roots are often out of mind. They are widely overlooked as to their significance in plant health. The majority of all plant problems start with soil/root problems.

Functions of Roots

- Anchor and support plants.
- Absorb and conduct water and minerals.
- Store products of photosynthesis (carbohydrates, sugars, proteins).
    - Winter survival of perennials.
- Horticultural uses.
    - Food and feed.
    - Propagation.
    - Soil erosion control.

Structure

Primary (young) root in cross section. [**Figure 1**]

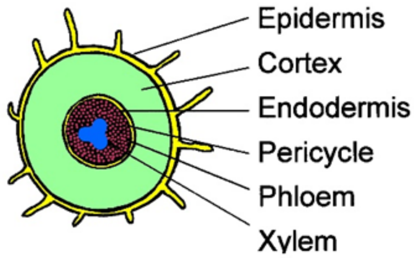


Figure 1. Cross section of a root.

Epidermis – The outer layer of cells.

Root hairs – Absorptive unicellular extensions of epidermal cells of a root. These tiny, hair-like structures function as the major site of water and mineral uptake. Root hairs are very delicate and subject to desiccation. Root hairs are easily destroyed in transplanting.
[**Figure 2**]

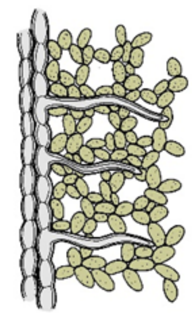


Figure 2. Root hairs are an extension of the epidermis.

Cortex – Primary tissues of a root bordered on the outside by the epidermis and on the inside by the endodermis. When roots begin thickening (secondary growth), the cortex and epidermis are gradually shed and replaced by the periderm.

Endodermis – A single layer of cells in a root that separates the cortex tissues from the pericycle. The endodermis includes the **Casparian Strip**, an impermeable layer that allows plants to control which substances can move from the cortex into the vascular system for transport to the rest of the plant.

Pericycle – A layer of parenchyma cells immediately inside the endodermis. Branch roots arise from the pericycle.

Vascular system

Phloem tissue conducts products of photosynthesis from leaves throughout the plant including down to the roots.

Xylem tissue conducts water and minerals from the roots up through the plant.

Root Meristems

[**Figure 3**]

Root Tip Meristem – Region of cell division that supports root elongation, found at the root tips just behind the root cap.

Root Cap – A thimble-shaped group of thick-walled cells at the root tip serves as a “hard hat” to push through soil. The root cap protects the tender meristem tissues.

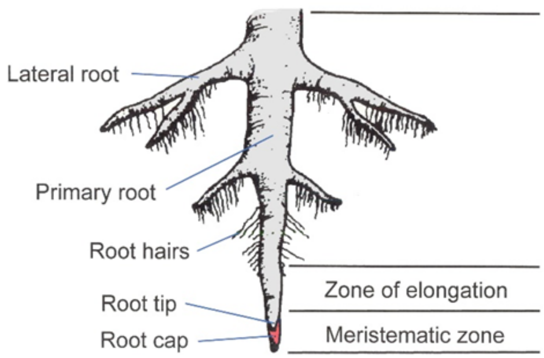


Figure 3. Lateral view of a root.

Vascular Cambium – The site of secondary root growth (root thickening). Vascular cambium develops in association with primary xylem and phloem and annually generates new vascular tissue in a ring shape, increasing the root girth and gradually crushing and sloughing off the pericycle, endodermis, cortex, and epidermis, replacing it with periderm.

Fibrous – Profusely branched roots that occupy a large volume of shallow soil around a plant's base (petunias, beans, peas). [**Figure 4**]

Taproot – Main, downward-growing root with limited branching, where soils permit (carrots, beets, radishes). [**Figure 4**]

Adventitious Roots – Generated in the ground system and arise at an “unexpected” place. For example, the buttress roots on corn and the short whitish bumps along a tomato stem are adventitious roots.

Aerial Roots – Arise from above-ground stem tissues. Aerial roots are common on ficus, philodendrons, pothos, and Christmas cactus.

Lateral Roots – The building blocks of the root system; branching roots that grow horizontally from the pericycle of the primary root.

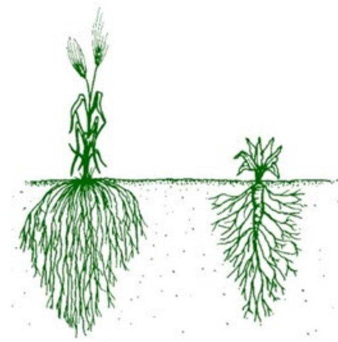


Figure 4. Root types.
Left: Fibrous root system of corn.
Right: Taproot system of carrot.

Sinker Roots – Make a sharp dive into deeper soils, wherever oxygen is available. Sinker roots are common on some tree species.

Storage or Tuberous Root – Enlarged roots that serve as storage organs (Canada thistle, morning glory, sweet potato, dahlia).

Depth and Spread

The depth and spread of roots are dependent on the inherent growth characteristics of the plant and the soil’s texture and structure. Roots require adequate levels of soil oxygen, so growth habit will be determined by where oxygen is available in addition to inherent plant characteristics. [**Figure 5**]

In compacted soils, roots will be shallow, remaining near the surface where oxygen is available.

In droughty soils, the root system will often spread farther, mining a larger soil area for moisture and minerals.

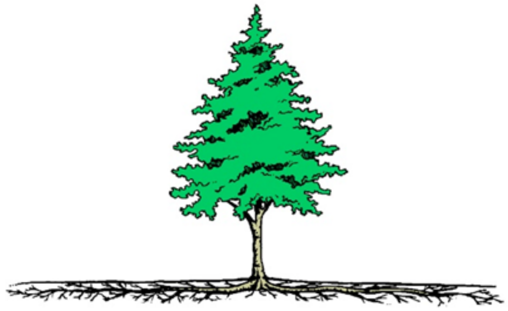


Figure 5. Typical rooting pattern of trees. Shallow and spreading.

It is difficult to predict root spread and depth. Under favorable growing conditions, the typical rooting of a tree includes:

- 90-95% of roots in the top thirty-six inches.
- 50% of roots in the top twelve inches.
- Extends two to three times tree's height or canopy (dripline) spread.

In compacted clayey soils, the typical root spread of trees includes:

- 90-95% of roots in the top twelve inches or less.
- 50% of roots in the top four inches.
- Potentially extends five or more times the tree's height or canopy (dripline) spread.

Some plants are genetically programmed to have very deep, spreading root systems (i.e., they are more tolerant of low soil oxygen levels). This growth habit is an environmental adaptation. Examples include bindweed and prairie grasses.

Soil type is a key factor in water penetration and root uptake. Where soil allows, the primary water extraction depth extends to:

- Flowers – eighteen to twenty-four inches.
- Turf – twenty-four inches.
- Vegetables – twenty-four inches.
- Shade trees – twenty-four to sixty inches.

Root Associations

Mycorrhizae are beneficial soil fungi that form mutualistic (mutually beneficial) associations with plants via roots. While the role of mycorrhizae is not fully understood, they function to expand the root's contact with the soil profile, enhancing water, and nutrient uptake. The same mycorrhizal partner can be associated with multiple trees, connecting multiple individuals. For additional information, refer to CMG GardenNotes #212, The Living Soil.

Rhizobium is a beneficial soil bacterium that forms a mutualistic relationship with plants, primarily those in the bean/pea family. These bacteria make atmospheric nitrogen available to plants. Rhizobium typically forms nodules on the roots of plants. These may be mistaken for insect injury or deformity. When alfalfa, a member of the bean/pea family, is left to mature then tilled into a field, it is considered "green manure" because the plant is rich in nitrogen due to the Rhizobium in the roots.

Natural Root Grafts are formed between roots of different trees, usually of the same species. Roots that come into contact with one another fuse at root hairs and can subsequently grow together by secondary growth, establishing a vascular connection between individuals. Large numbers of plants can become connected in this way; providing a mechanism for not only resources but pathogens and poisons to be shared widely.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #133

Plant Structures: Stems

Outline:

Stems are the part of a plant that bears leaves and flowers, and they are the continuation of the vascular system pipeline that starts in the roots. Stems can grow in *length* at the tips and in *girth* in older stems that have developed a vascular cambium.

Functions

- Framework for leaves, flowers, and seeds.
- Continuation of vascular system carrying water and minerals from the soil, and sugars manufactured in leaves throughout the plant.
- Green stems also manufacture food.
- Food storage.
- Horticultural uses.
  - Aesthetic (winter interest in the landscape, appealing bark, etc.).
  - Feed and food.
  - Fuel.
  - Plant identification.
  - Propagation (cuttings and layering).
  - Wildlife habitat.
  - Wood industry and construction.

Stems in Common Parlance

Shoot – Young, typically pliable stem.

Twig – Slender woody stems growing from a branch or trunk.

Branch – A woody stem growing from a trunk or bough. Branches are usually considered to be larger than twigs but smaller than boughs.

Bough – Larger or main limbs of a tree, though sometimes applied to smaller branches.

Trunk – Main support stem(s) of woody plants.

Water Sprouts – Adventitious shoots arising on a branch vertically, generally growing very rapidly. Because they are adventitious, they are poorly attached to the main limb. Also called **epicormic shoots**.

Suckers – Adventitious shoots arising from the roots, generally rapidly growing.

Canes – Stems with relatively large pith and that usually live (or are allowed to grow) for only one to two years (roses, grapes, blackberries, and raspberries).

Structure

Internal Features

Shoot Apical Meristem – "Immortal" cells at the tips of stems that generate new cells for differentiation and growth in stem length.

Epidermis – Outer layer of wax-coated cells that provides protection and covering.

Cortex – Primary structural and storage tissues of a stem.

Vascular Tissues

Vascular Bundle – grouped phloem, xylem, and associated cells in primary stems. Vascular bundles give rise to the Vascular Cambium in plants that are capable of secondary growth (stem thickening).

Vascular Cambium – the layer of meristematic (dividing) tissues that forms in some plants to generate **secondary growth** (growth in girth). The cambium divides to form phloem tissues toward the outside of the stem and xylem tissues toward the inside. Cell division of the cambium tissues adds width to the stem. [**Figure 1**]

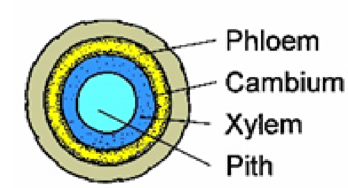


Figure 1. Cross section of stem in secondary growth.

Secondary Phloem (inner bark) – In plants with secondary growth (woody plants), the phloem is located to the outside of the vascular cambium and just beneath the bark. If the stem is damaged or girdled so as to disrupt or block the phloem, it can enlarge just above the blockage due to the sugars moving down from the leaves for distribution throughout the plant. Tissues below the blockage slowly starve. Roots die back, eventually leading to death of the plant.

Secondary Xylem (wood) – distributes water and minerals from the roots up through the plant. Typically only the xylem tissue nearest the vascular cambium (the youngest xylem) functions for water transmission; older xylem provides structural support.

Pith – the soft center of dicot plant stems, consisting of parenchyma cells. In some plants the pith breaks down forming a hollow stem. [**Figure 2**]

Woody stems are used in tree and shrub identification. Features to look at include the cross-section shape of the pith (rounded, star-shaped, or triangulate) and whether the pith is solid, hollow, or chambered.

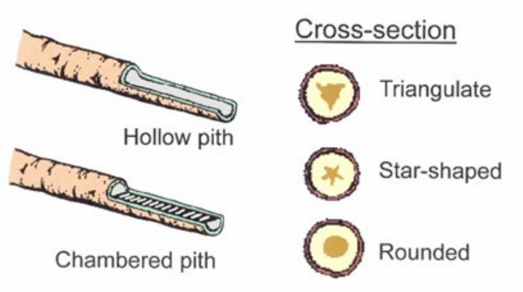


Figure 2. Stem pith is used in plant identification. It may be solid, hollow, or chambered. In a cross section, the pith may be rounded, triangulate, or star-shaped.

Tree Rings

In trees and shrubs, xylem growth makes the “annual rings” used to tell a tree’s age (phloem, being to the outside the vascular cambium, is continually sloughed off and renewed and does not accumulate in rings). Water and mineral movement occur in the more recent years of xylem rings, that is, those closest to the outside of the tree. Because water is critical in supporting cell growth and expansion, drought reduces both the width of the annual rings and the size of xylem vessels in the rings, and thus the potential for water and nutrient movement. Multi-year droughts, with their corresponding reduction in xylem size, have long-term impacts on plant growth potential. [**Figure 3**]

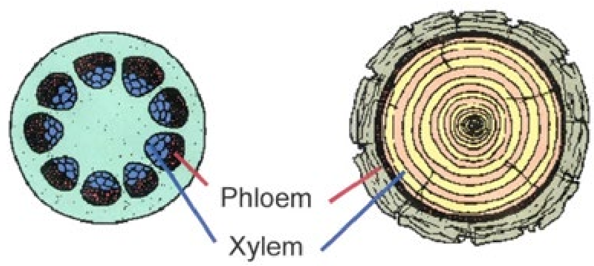


Figure 3. Cross section of dicot stems in primary growth (left) and secondary growth (right).

External Features

Bud – A stem's primary growing point. Buds can be either leaf buds (vegetative) or flower buds (reproductive). These buds can be remarkably similar in appearance, but flower buds tend to be plumper than leaf buds.

Terminal bud – Bud at the tip of a stem. In many plants, auxin (a plant hormone) released from the terminal bud suppresses development of lateral buds, thereby focusing the growth of the plant upward rather than outward. If the terminal bud is removed during pruning (or natural events) the lateral buds will develop and the stem becomes bushy. [**Figure 4**]

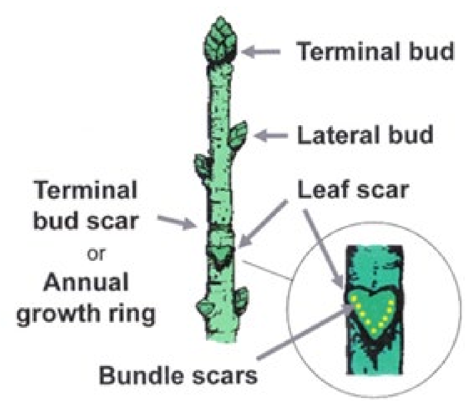


Figure 4. External features of a stem.

Lateral Buds – They grow from the leaf axils on the side of a stem.

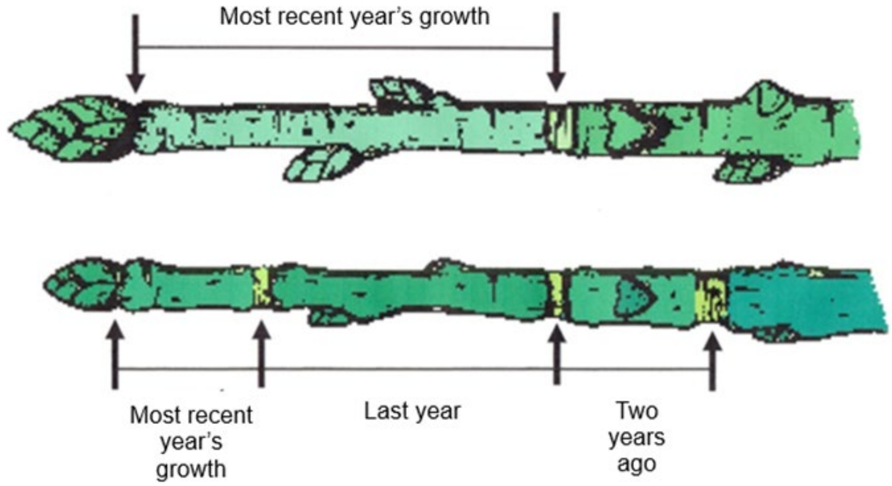
Leaf Scar – Mark left on stem where leaf was attached. Often used in woody plant identification.

Bundle Scar – Marks left in the leaf scar from the vascular tissue attachment. Used in woody plant identification.

Lenticel – Pores that allow for gas exchange.

Terminal Bud Scale Scars or **Annual Growth Rings** – Marks left on stem from the terminal bud scales in previous years. Terminal bud scale scars can be used to measure annual growth. Therefore, they are important in assessing plant vigor. [**Figure 5**]

Figure 5. Terminal Bud Scars and Annual Growth Increments



Node – Segment of stem where leaves and lateral buds are attached. [**Figure 6**] Note: Roots do not have nodes.

Internode – Section of a stem between two nodes.

Bark – Protective outer tissue that develops with age. Used in woody plant identification.

Close examination of stems can tell you a great deal about a plant pertinent to its identification and health.

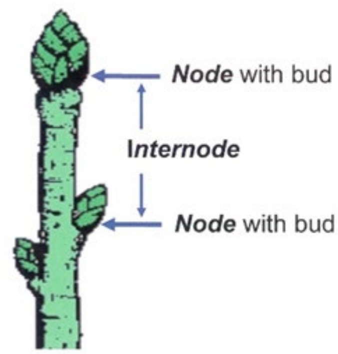


Figure 6. **Node and Internode**

Modified Stems

Corm – Short, thickened, underground monocot stem. [**Figure 7**]

Crown – Compressed stem having leaves and flowers growing above and roots beneath (strawberry plant, dandelion, African violet). [**Figure 8**]

Rhizome – Horizontal, underground stem, typically forms roots and plantlets at tips or nodes (iris, bentgrass, cannas). [**Figure 9**]

Spur – Very compressed (shortened), fruiting twig found on some apples, pears, cherries, and ginkgo. [**Figure 10**]

Stolon (or runner) – Horizontal, above-ground stems often forming roots and/or plantlets at their tips or nodes (strawberry runners, spider plants). [**Figure 11**]

Figure 7. Corm

Figure 8. Crown

Figure 9. Rhizome

Figure 10. Spur

Figure 11. Stolon

Thorn – A stem modified for plant defense. Thorns maintain cell types and morphology of stems, whereas prickles are superficial outgrowths of the epidermis. Hawthorns have thorns, roses have prickles.

Twining stems – Modified stems used for climbing. Some twist clockwise (hops, honeysuckle); others twist counterclockwise (pole beans, Dutchman's pipe).

Tuber – A solid thickened portion or outgrowth of an underground stem containing stored food (e.g., potato, the eyes of the potato are axillary buds). [**Figure 12**]

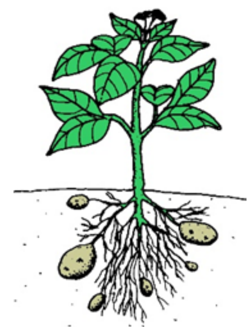


Figure 12. Tuber

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised June 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #134

Plant Structures: Leaves

Outline:

Leaves, produced on stems, are the principle structure where photosynthesis takes place.

Functions

- Capture light for photosynthesis (the manufacture of sugars).
- Transpiration from the leaves moves water and nutrients up from the roots.
- Water, gas exchange for photosynthesis and respiration, and temperature are regulated through small openings on the leaf, known as **stomata**.
- Horticultural uses:
  - Aesthetic qualities.
  - Feed and food.
  - Mulch and compost.
  - Plant identification.
  - Propagation from cuttings.
  - Summer cooling. (Evaporative cooling accounts for 70-80% of the shading impact of a tree.)
  - Wildlife habitat.
  - Wind, dust, and noise reduction.

External Structure Features

[**Figure 1**]

Leaf Blade – Flattened part of the leaf.

Petiole – Leaf stalk.

Stipules – Appendages at the base of the leaf, which may be leaf-like, spines, or reduced/absent.

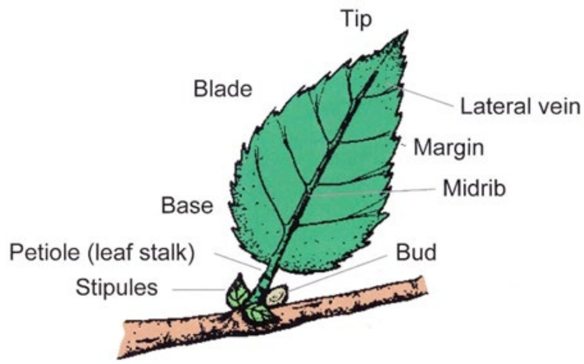


Figure 1.
External features of a leaf.

For plant identification purposes, the shape of the leaf margin, leaf tip, and leaf base are key features to note. Remember, a leaf begins at the lateral or auxiliary bud.

Leaf Arrangement on Stems [**Figure 2**]

Alternate – Arranged in staggered fashion along stem (willow).

Opposite – Pair of leaves arranged across from each other on stem (maple).

Whorled – Arranged in a ring (catalpa).

Rosette – Leaves arranged tightly at the plant crown (dandelion).

Figure 2.
Leaf arrangement on stem.

Leaf Types [**Figure 3**]

Simple – Leaf blade is one continuous unit (cherry, maple, and elm).

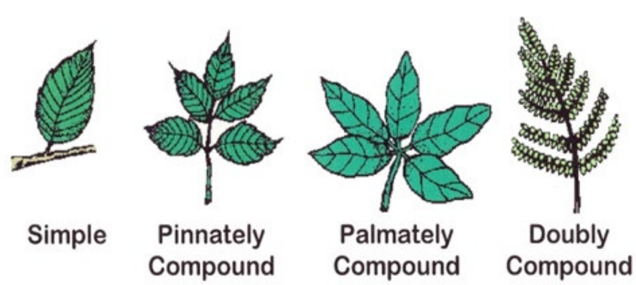
Compound – Several **leaflets** arise from the same petiole.

Palmately Compound – Leaflets radiate from one central point, like fingers from a palm. (Ohio buckeye and horse chestnut).

Pinnately Compound – Leaflets arranged on both sides of a common rachis (leaf petiole), like a feather (mountain ash).

Bi-pinnately (Doubly) Compound – Leaflets are themselves compound, with smaller leaflets on a secondary rachis.

Figure 3.
Leaf Types



Note: Sometimes identifying a "leaf" or "leaflet" can be confusing. Look at the petiole attachment. A leaf petiole attaches to the stem at a bud node. There is no bud node where leaflets attach to the petiole.

Overall Leaf Shape

Leaf shape is a primary tool in plant identification. Descriptions often go into minute detail about leaf shapes and margins. **Figure 4** illustrates common overall leaf shapes.

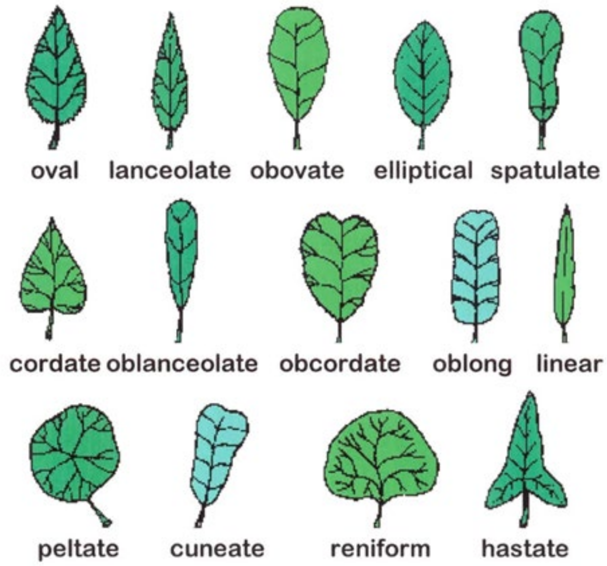


Figure 4. Leaf Shapes

Leaf Shape Descriptions

Cordate – Heart-shaped.

Cuneate – Leaves with small width at base, widening near the top (think wedge).

Elliptical – Leaves widest in the middle, tapering on both ends.

Hastate – Arrowhead shaped leaves.

Lanceolate – Leaf is three times or longer than width and broadest below the middle.

Linear – Leaves narrow, four times longer than width and have the same width.

Obcordate – Reverse appearance of cordate leaves. (The heart shape is upside down).

Oblanceolate – Leaf is three times longer than wide and broadest above the middle.

Oblong – Leaf is two to three times as long as it is wide and has parallel sides.

Obovate – Leaf is broadest above the middle and about two times as long as the width.

Ovate – Leaf is broadest below the middle and about two times as long as the width, also called oval (egg shaped).

Peltate – Leaves rounded with petiole attached under the leaf base.

Reniform – Leaves wider than they are high.

Spatulate – Generally narrow leaves widening to a rounded shape at the tip.

Shape of Leaf or Leaflet Apex

The shape of the leaf apex (tip) and base is another tool in plant identification. **Figures 4** and **5** illustrate common tip and base styles.

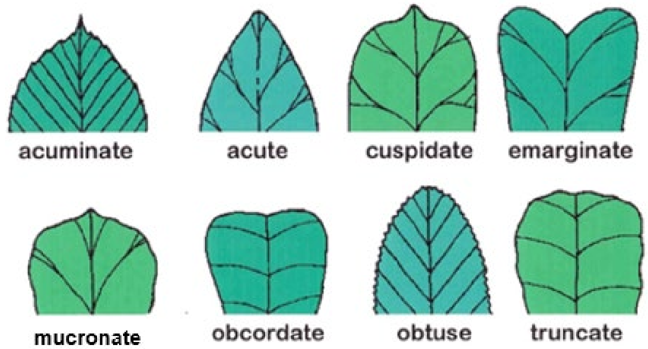


Figure 5.
Common leaf tips shapes.

Leaf Apex Descriptions

Acuminate – Leaf margins forming a terminal angle of less than 45 degrees.

Acute – Leaf margins forming a terminal angle of 45 to 90 degrees.

Cuspidate – Tip is sharp; looks like two curves meeting at the tip.

Emarginate – Tip is slightly indented.

Mucronate – Tip ends in a small sharp point that is actually continuation of leaf midrib.

Obcordate – Upside down heart shape.

Obtuse – Leaf tip is blunt with an angle greater than 90 degrees.

Truncate – Leaf tip appears to be squared off, as though cut, or truncated.

Shape of Leaf Base [Figure 6]

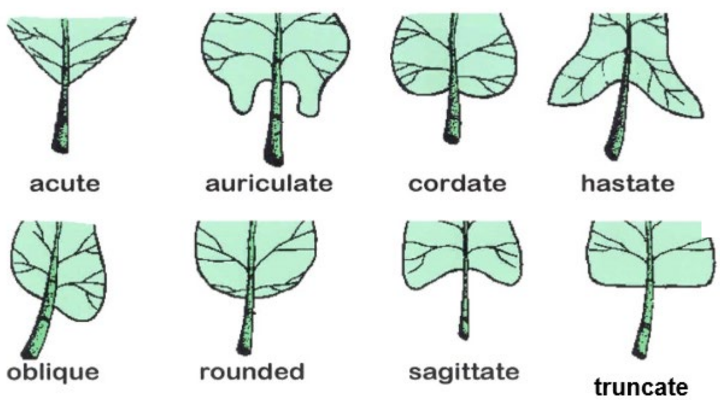


Figure 6.
Common leaf base shapes.

Leaf Base Descriptions

Acute – Base is pointed toward the stem, with leaf edges forming an angle of less than 90 degrees to one another.

Auriculate – Base has ear-shaped appendages near the petiole.

Cordate – Base is heart-shaped.

Hastate – Base has pointed, flaring lobes, making a triangular leaf that resembles a spearhead.

Oblique – Base has one side lower than the other.

Rounded – Circular with no point.

Sagittate – Lower lobes of leaf are folded or pointed down, like an arrowhead.

Truncate – Leaf base is roughly squared, perpendicular to the petiole.

Leaf Margins

The leaf margin is another tool in plant identification. **Figure 7** illustrates common margin types.

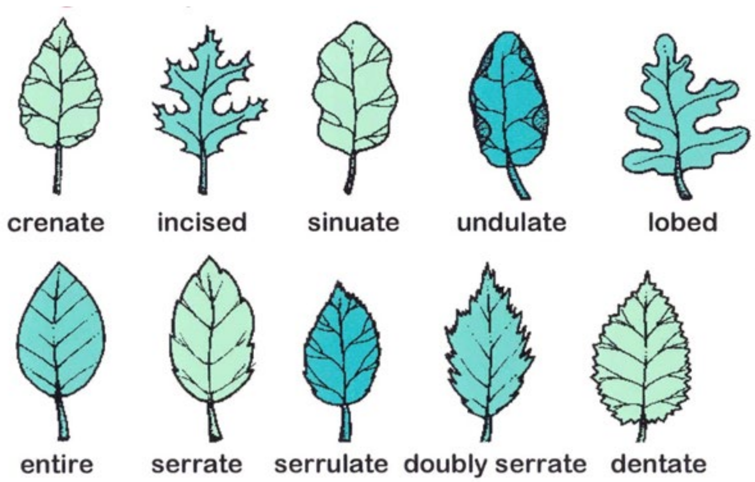


Figure 7.
Common leaf margins.

Leaf Margin Descriptions

Crenate – Leaf edge has blunt, rounded teeth.

Dentate – Leaf has triangular or tooth-like edges.

Doubly Serrate – Edges with saw like teeth that have even smaller teeth within the larger ones.

Entire – Leaf edge is smooth.

Incised – Leaf margins have deep, irregular teeth.

Lobed – Leaf edges are deep and rounded.

Serrate – Leaf edges are sharp and saw-like (think serrated knife).

Serrulate – Leaf edges with smaller, more evenly spaced serrations than a serrated leaf.

Sinuate – Margins are slightly wavy.

Undulate – Very wavy margins.

Leaf Venation

Monocots

Parallel Venation – Veins run in parallel lines (common in monocots, e.g., grasses, lilies, tulips). [**Figure 8**]

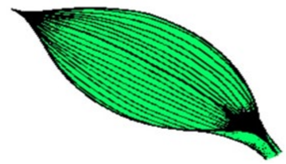


Figure 8.
Parallel veined monocot leaf.

Dicots [**Figure 9**]

Pinnate Venation – Veins extend from a midrib toward the edge, resembling a feather. (elm, peach, apple, cherry).

Palmate Venation – Veins radiate from a central point in a fan-shape from the petiole, like fingers on a palm (maple, grapes).

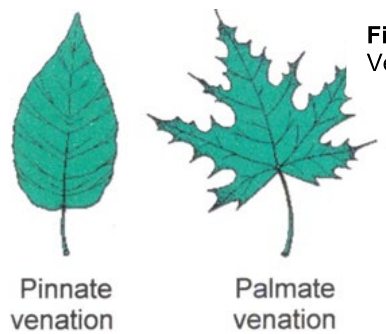


Figure 9.
Venation of dicot leaves.

Modified Leaves

Adhesive Disc – Modified leaf used as an attachment mechanism. Sometimes referred to as a holdfast (Boston ivy).

Bract – Specialized, often highly colored leaf below flower that often serves to lure pollinators (poinsettia, dogwood).

Tendril – Modified leaf, stipule, or other plant part used for climbing or as an attachment mechanism (Virginia creeper, peas, grapes). Distinguished from twining stems by the absence of leaves along their length (since they are themselves leaves).

Internal Structural Features

The leaf blade is composed of several layers. [**Figure 10**]

Epidermis – Outer layer of cells

Cuticle – Waxy protective outer layer of epidermis that prevents water loss from leaves, green stems, and fruits. The amount of cutin or wax increases with light intensity.

Leaf Hairs/Trichomes – Uni- or multicellular projections that can provide physical defense or excrete chemical compounds.

Stomates (**Stomata**) – Natural openings in leaves and herbaceous stems that allow for gas exchange (water vapor, carbon dioxide and oxygen) and plant cooling. Most stomates are found on the underside of leaves.

Guard Cells – Specialized kidney-shaped cells that open and close the stomata.

Vascular bundle – Xylem and phloem tissues comprising the leaf veins.

Mesophyll – Cells within the leaf directly involved with photosynthesis, storage, and other metabolic processes. Mesophyll organization is variable within the leaves of different plant species.

Palisade Layer – Closely ranked cells directly beneath the epidermis, very photosynthetically active. Not all plants have a well differentiated palisade layer.

Spongy Mesophyll – Loosely organized ground tissue (mostly parenchyma cells) that are involved with photosynthesis, water and nutrient exchange, and metabolism.

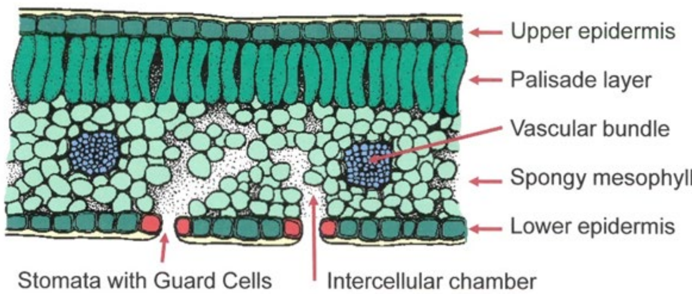


Figure 10.
Cross sectional view of a leaf.

Figures 4, 5, and 7, drawn after by D. Whiting, inspired from the book Manual of Woody Landscape Plants, Michael A. Dirr. Stipes Pub LLC, fifth edition,1998. ISBN: 0-87563-795-7.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised October 2017 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #135

Plant Structures: Flowers

Flowers are the reproductive structures of a flowering plant. Flowers are the primary structures used in identifying plant families.

Function

Reproduction.

Horticultural uses:

- Aesthetic qualities.
- Cut flowers and potted blooming plants.
- Edible flowers and herbs.
- Plant identification.

Structure

Pistil – Collective term for female floral parts. [**Figure 1**]

Stigma – Receives pollen, typically flattened and sticky.

Style – Connective tissues between stigma and ovary, elevates stigma to be within reach of pollination.

Ovary – Contains and protects developing ovules which are underutilized, immature seeds. Ovarian tissue develops into fruits. Ovaries can be separated into ***carpels***, divisions, or sections that each contain ovules. Ovaries can be superior (attached to the receptacle above the point where other floral parts are attached), or inferior (attached to the receptacle below the point where other floral parts are attached).

Stamen – Male floral organ. [**Figure 1**]

Anther – Pollen-producing organ.

Filament – Stalk supporting anther.

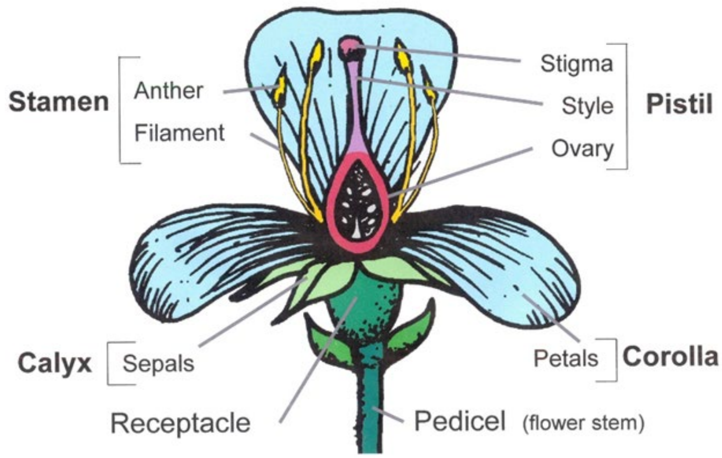
Petals – Usually colorful display organs of the flower, collectively called the ***corolla***. [**Figure 1**]

Sepals – Protective leaf-like enclosures for the flower buds, usually green, collectively called ***calyx***. Sometimes highly colored like the petal as in iris. [**Figure 1**]

Receptacle – Base of the flower where the parts of the flower are attached. [**Figure 1**]

Pedicel – Flower stalk of an individual flower in an inflorescence. [**Figure 1**]

Figure 1. Parts of a Flower



Terms Defining Flower Types

Complete – Flower containing sepals, petals, stamens, and pistil.

Incomplete – Flower lacking sepals, petals, stamens, and/or pistils.

Perfect – Flowers containing male and female parts.

Imperfect – Flowers that lack either male or female parts.

Pistillate (**Gynoecious**) – Flowers containing only female parts.

Staminate (**Androecious**) – Flowers containing only male parts.

Radially Symmetrical – Able to be cut into a mirror image along many axes (e.g., daisy, lily, rose).

Zygomorphically Symmetrical – Flowers symmetrical along a single plane only; divisible into a mirror image in only one way (e.g., orchids, penstemon, snapdragon).

Terms Defining Plant Types

Monoecious – (from the Greek for "one house") Plants with separate male flowers and female flowers on the same plant.

Dioecious – (from the Greek for "two houses") Plants with male flowers and female flowers on separate plants, functionally resulting in "male" and "female" plants.

Inflorescence (Flower Arrangement on a Stem)

Catkin – A unisexual inflorescence, with flowers arranged along a central stalk; forming a roughly cylindrical and generally dangling structure which falls off in a single piece (e.g., willow, birch, alder, ash).

Composite or Head – A daisy-type "flower" composed of several ray florets (usually sterile with an attractive colored petal) around the edge and fertile disc florets in the center of the flat head (e.g., sunflower and aster). Some inflorescences may be composed entirely of ray florets, entirely of disc florets, or of various combinations of the two (e.g., chrysanthemum, rudbeckia, dandelion). [**Figure 2**]

Corymb – A modified raceme, with flowers attached by stemlets (pedicels) arranged along the main stem proportionally so that outer, older flowers are level with inner, giving the display a flat top (e.g., yarrow, crabapple). [**Figure 2**]

Cyme – Clustered inflorescence with the single flower along the central stem opening first and bloom continuing in branches outwards, with subsequent flowers borne at the tips of lateral branches. May be flat-topped or helicoid (e.g., elderberry, borage). [**Figure 2**]

Panicle – An indeterminate inflorescence with repeated loose branching, creating "airy" clusters of flowers (e.g., oats, panicum grass, pagoda tree, begonia). [**Figure 2**]

Raceme – A loose spike, with flowers attached to a single main stem (peduncle) by stemlets (pedicels) of roughly equal length and with the terminal flower blooming last (e.g., snapdragon, lupine). [**Figure 2**]

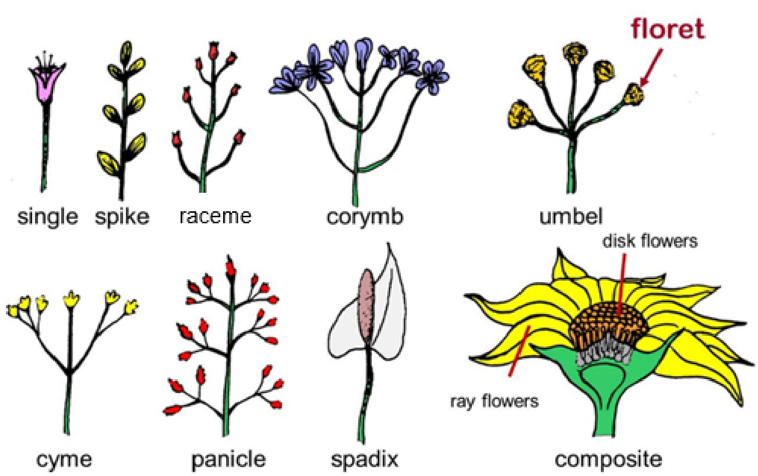
Solitary or Single – One flower per stem (e.g., tulip, crocus). [**Figure 2**]

Spadix – A thick, fleshy spike, often surrounded by a ***spathe*** (ornamental bract) (e.g., calla, caladium). [**Figure 2**]

Spike – Flowers attached quite closely to main stem, without or with very short stemlets, with bottom florets opening first (e.g., gladiolus, ajuga, and gayfeather). [**Figure 2**]

Umbel – Flowers attached to main stem at one central point, forming a flat or rounded top. Outer flowers open first (e.g., dill, Queen Anne's lace). [**Figure 2**]

Figure 2. Inflorescences



Pollination and Nectar Guides

To produce fruit and seed and ensure their survival, plants need to be pollinated. Some flowers are wind pollinated (anemophilous), but most are not. They must attract an animal to assist with the process of moving pollen from the anthers to the stigma. Nectar, an energy rich fluid produced by flowers, along with protein rich pollen, is the prize.

Figure 3. Nectar guides on penstemon (lines on the flower).

When pollinators collect nectar, the hairs on their bodies brush against the pollen and hold it tightly. As the pollinator moves to other flowers of the same species, the pollen can brush off onto the stigma and thus, pollination occurs.

To help bees and other pollinators find their way to their nectar, many plants have “nectar guides” on their flower petals.

These may or may not be visible to humans. Often, they are not, as many are only visible in the ultraviolet range. Fortunately, most insect pollinators can see in this light range and quickly find their way to the nectar. It is an example of mutualism, which ensures efficient pollination for the plant and fast nectar and pollen collection for the insects.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised June 2016 by Patti O’Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #136

Plant Structures: Fruit

Fruit develops from the maturing ovary following pollination and fertilization. Fruits can be either fleshy or dry. They contain one or more seeds.

Function

- Seed protection and distribution.
- Horticulture uses:
  - Feed, food, and oils.
  - Aesthetic qualities.
  - Plant identification.

Structure

Fruit consists of tissue derived from the plant pistil; the carpels house the developing seeds, and the ovary wall, or **pericarp**, develops into structures to help protect and/or distribute the seeds. Most fruits have seeds enclosed within the ovary, see **Figure 1**, (apples, peaches, oranges, squash, and cucumbers); but some plants have fruits with seeds that are situated on the periphery of the pericarp (strawberry). The peel of an orange, the pea pod, the sunflower shell, and the skin flesh and pit of a peach are all derived from the pericarp.

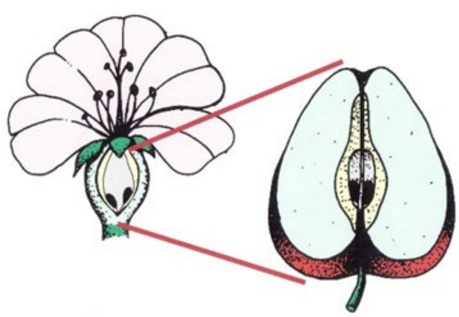


Figure 1. In apples, the ovary wall becomes the fleshy part of the fruit. Notice the small fruit structure in the blossom.

Fruit Types

Dehiscent Fruit – Fruit splits open at maturity, releasing (usually multiple) seeds (beans, flax, penstemon).

Indehiscent Fruit – Fruit formed from an ovary in which usually only one seed develops, and within which the seed remains during distribution (sunflowers, grasses).

Fleshy Fruit – Fruit developed from unicarpellate (one-seeded) or multicarpellate (many-seeded) ovaries. The ovary wall develops rapidly proliferating cells that take on diverse roles in the resulting fruit.

Hesperidium – Citrus fruit, with a rind and easily divisible segments.

Pome – A fleshy enlarged fruit derived from non-ovarian "accessory tissue" (like the receptacle) surrounding a leathery or papery core (the true "fruit"). Typical of the rose family, including apples, pears, and rosehips. [**Figure 2**]

Berry – A pulpy fruit with many seeds scattered throughout (tomato, blueberry).

Pepo – A type of berry usually with a hard outer rind, specifically characteristic of the family Cucurbitaceae (zucchini, pumpkin, cucumber).

Drupe – A fleshy fruit with a single seed originating from a single carpel, the pit (peaches, plums). [**Figure 3**]

Drupelet – A single-seeded fruit making up part of a larger composite fruit, as in blackberries and raspberries.

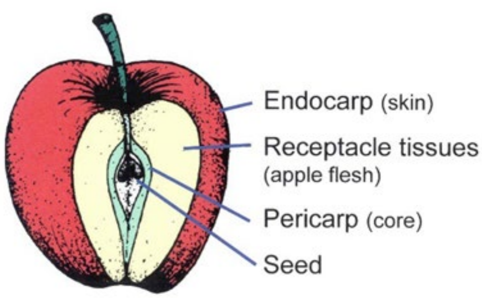


Figure 2. Pome fruit (apple).

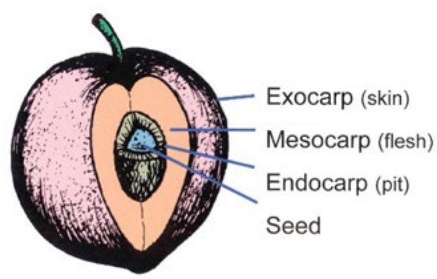


Figure 3. Stone fruit (peach).

Fruit Growth Terms

Pollination – Transfer of pollen from the anthers of the male flower to the stigma of the female flower.

Fertilization – Union of the sperm from the pollen grain with the egg cell in the female flower.

Abscission – The natural separation of the fruit from the plant.

Drop – Early abscission when not fertilized, when too much fruit sets on a tree, or caused by environmental factors.

Climacteric Fruit – Fruit that will continue to ripen if removed from a plant, for example, peaches, apples, bananas, pumpkins.

Seed Dispersal in Conifers

Conifers technically do not have fruit (remember that “gymnosperm” refers to the “naked seeds” of these plants). They do have analogous structures, though, in cones. Cones can be dry (pinecones) or fleshy (juniper berries). [**Figure 4**]

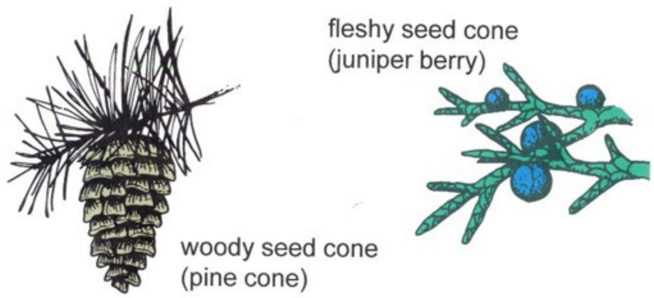


Figure 4. Fruit of conifers.
Left: Woody seed cone (pinecone).
Right: Fleshy seed cone (juniper berry).

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O’Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

CMG GardenNotes #137

Plant Structures: Seeds

A seed contains the plant embryo, nutrient tissue, and a protective cover. Most seeds contain a built-in food supply called endosperm, which is the result of a separate fertilization event within the ovule (the process of creating an embryo with its endosperm is known as *double fertilization*). The endosperm contains high amounts of carbohydrates/starch, along with proteins and lipids.

Function

- Propagation.
- Horticultural uses.
    - Feed.
    - Food, beverages (coffee, cocoa, beer), medicine, fiber (cotton) and industrial oils and biofuels.

Structure and Emergence

The seed of angiosperms develops as a consequence of double fertilization – development of both embryo and endosperm is required for successful seed growth. Seeds provide protection and resources for developing embryos, making them more versatile than spores for the continuation of plant species. The nutrients are primarily contained initially in endosperm; though during seed maturation the embryo itself can absorb and store the nutrients in its seed leaves, the cotyledons, before the seed becomes dormant. Still other seeds, notably those of orchids, contain very little nutritive tissue.

Externally, seeds can be differentiated and characterized by their shape, size, surface texture, placement of the *hilum* (attachment point to the mother plant, akin to a belly button), and the presence or absence of structures such as *arils* or *elaiosomes*, appendages that aid in seed dispersal.

Internally, seeds are often divided into groups based on the position of the embryo within. Growth and development of all seeds follow a standard sequence and proceed in stages including cell differentiation of the various structures, growth of the endosperm, and finally, development and growth of the embryo in preparation for germination. During germination, the embryo mobilizes its stored food reserves to quickly develop and expand the photosynthetic apparatus that will allow it to feed itself as a young plant.

After maturation and before germination, most seeds enter dormancy, a state of very low metabolic activity that allows the embryo to survive until conditions are right for germination. Some seeds can survive only a short time before needing to germinate, others, particularly of plants from stressful and unpredictable habitats, can wait decades before sprouting. Plants use many different mechanisms (and combinations of mechanisms) to prevent seeds from germinating at unpropitious times, summarized in **Table 1**.

Exogenous Factors ("Imposed" on the Embryo From the Outside)		
Type	**Mechanism**	**Broken By**
Physical	Seed coat impermeable to water.	Opening of specialized structure or scarification.
Chemical	Germination inhibitors contained in the seed coat.	Leaching with water.
Mechanical	Woody or hard structures physically impede embryo growth.	Warm and/or cold stratification.
Endogenous Factors (Inherent in the Embryo Itself)		
Physiological	"Physiological Inhibiting Mechanism" (PIM) – Biochemical restriction.	Warm and/or cold stratification.
Morphological	Underdeveloped embryo.	Appropriate conditions for embryo growth.
Morphophysiological	PIM directly influencing embryo development.	Warm and/or cold stratification.

(After from Nikolaeva, M.G. (1977) Factors controlling the seed dormancy pattern. pp. 51–74 in Khan, A.A. (Ed.) The physiology and biochemistry of seed dormancy and germination. Amsterdam, North-Holland.)

Seed Growth and Development Terms

Cotyledon – Also known as the seed leaves, these are the first leaves that develop within the seed and allow the seedling to feed itself immediately following germination while it grows "true leaves."

Dormancy – State of suspended growth to survive adverse conditions.

Germination – Sprouting of seed following exposure to correct environmental conditions for the species.

Hypocotyl – From the Greek, "below the cotyledon," this is the embryonic plant stem.

Radicle – Embryonic plant root, often pushing through the seed coat at the beginning of germination.

Seed Coat – Hardened exterior protective layer of seeds, often involved in enforcing dormancy.

Stratification – Exposing seeds to variable temperatures in order to promote germination and growth. Cold, moist stratification is most common for plants of temperate habitats. Etymological note: "stratification" refers to the placement of the seeds in layers of growing medium in order to provide the needed germination conditions.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Revised May 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

CMG GardenNotes #141

Plant Physiology: Photosynthesis, Transpiration, and Respiration

The three major functions that are basic to plant growth and development are:

- **Photosynthesis** – The process of using chlorophyll to capture light energy and convert it to energy stored in sugars. Photosynthesis uses light energy, carbon dioxide (CO2), and water (H2O) to generate glucose with a byproduct of oxygen.
- **Transpiration** – The loss of water vapor through the stomates of leaves.
- **Respiration** – The process of metabolizing (burning) sugars to yield energy for growth, reproduction, and other life processes. Respiration uses glucose and oxygen to generate kinetic energy, with a byproduct of carbon dioxide and water.

Photosynthesis

A primary difference between plants and animals is the plant's ability to manufacture its own food. In photosynthesis, plants use carbon dioxide from air and water in the soil with the sun's energy to generate photosynthates (sugar) releasing oxygen as a byproduct. [**Figure 1**]

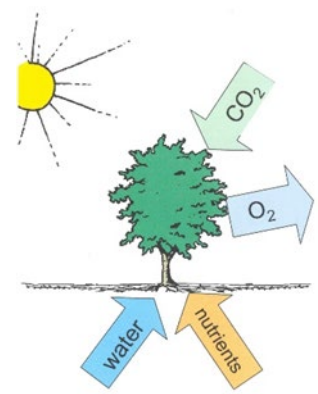


Figure 1. Photosynthesis

Photosynthesis literally means to put together with light. It occurs only in the **chloroplasts**, organelles contained in the cells of leaves and green stems. The chemical equation for photosynthesis is

carbon dioxide + water + light energy = glucose + oxygen

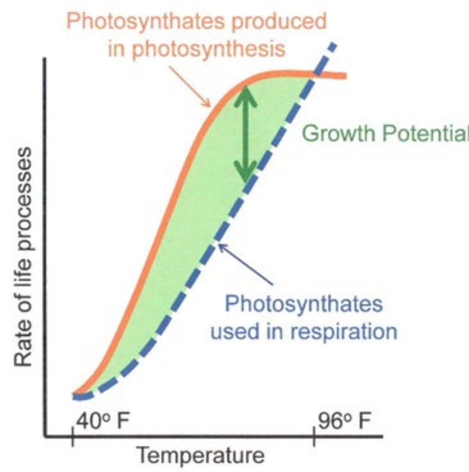
$$6CO_2 + 6H_2O + \text{light energy} = C_6H_{12}O_6 + 6O_2$$

This process is directly dependent on the supply of water, light, and carbon dioxide. Limiting any one of the factors on the left side of the equation (carbon dioxide, water, or light) can limit photosynthesis regardless of the availability of the other factors. An implication of drought or severe landscape irrigation restrictions result in reduction of photosynthesis and thus a decrease in plant vigor and growth.

In a tightly closed greenhouse, there may be very little fresh air infiltration and carbon dioxide levels can become limiting during the day while photosynthesis is actively occurring, thus limiting plant growth. Large commercial greenhouses may provide supplemental carbon dioxide to stimulate plant growth.

The rate of photosynthesis is temperature dependent. In general, warmer temperatures increase the rates of photosynthesis, but only up to a point. At high temperatures, enzymes used in photosynthesis become less efficient. Furthermore, respiration increases with temperature as well. For example, when temperatures rise above 96 degrees Fahrenheit in tomatoes, the rate of food used by respiration rises above the rate of food manufacture through photosynthesis. Plant growth comes to a stop. Most other plants react similarly. [**Figure 2**]

Figure 2. In the tomato plant, rates of photosynthesis and respiration both increase with increasing temperatures. As the temperature approaches 96°F, the rate of photosynthesis levels off, while the rate of respiration continues to rise.



Transpiration

Water in the roots is pulled through the plant by **transpiration** (loss of water vapor through the stomates of the leaves). Transpiration uses about 90% of the water that enters the plant. The other 10% is used as an ingredient in photosynthesis and cell growth.

Transpiration serves three essential roles:

- **Movement of dissolved nutrients and minerals** up from the roots (via xylem) and sugars (products of photosynthesis) throughout the plant (via phloem). Water serves as both the solvent and the avenue of transport.
- **Cooling**. 80% of the cooling effect of a shade tree is from the evaporative cooling effects of transpiration. This benefits both plants and humans.
- **Turgor Pressure**. Water maintains the turgor pressure in cells much like air inflates a balloon, giving form to the non-woody plant parts. Turgidity is important so the plant can remain stiff, upright, and have a competitive advantage when it comes to light. Turgidity is also important for the functioning of the guard cells that surround the stomates, regulates water loss, and carbon dioxide uptake. Turgidity also is the force that pushes roots through the soil.

Water movement in plants is also mediated by osmotic pressure and capillary action.

Osmotic pressure is defined as water flowing through a permeable membrane in the direction of higher salt concentrations. Water will continue to flow in the direction of the highest salt concentration until the salts have been diluted to the point that the concentrations on both sides of the membrane are equal.

A classic example is pouring salt on a slug. Because the salt concentration outside the slug is highest, the water from inside the slug's body crosses the membrane that is its skin. The slug dehydrates and dies. Envision this same scenario the next time you gargle with salt water to kill the bacteria that are causing your sore throat.

Fertilizer burn and dog urine spots in a lawn are examples of salt problems. In moderately salty soil, the plant can draw water into its roots less efficiently than from soils not affected by salts. In severe cases, the salt level is higher outside the plant than within it, and water is drawn from the plant.

Capillary action relies on the property of water that causes it to form droplets (hydrogen bonding). Water molecules in the soil and in the plant cling to one another and are reluctant to let go. You have observed this as water forms a meniscus on a coin or the lip of a glass. Thus when one molecule is drawn up the plant stem, it pulls another one along with it. These forces that link water molecules together can be overcome by gravity and are more effective in small diameter tubes ("capillaries"), in which water can move opposite gravity to considerable height.

Respiration

In **respiration**, plants (and animals) convert sugars (photosynthates) back into energy for growth and other life processes. The chemical equation for respiration shows that the photosynthates are oxidized, releasing energy, carbon dioxide, and water. Notice that the equation for respiration is the opposite of that for photosynthesis.

$$\text{glucose} + \text{oxygen} = \text{energy} + \text{carbon dioxide} + \text{water}$$
$$C_6H_{12}O_6 + 6O_2 = \text{energy} + 6CO_2 + 6H_2O$$

Chemically speaking, the process is similar to the **oxidation** that occurs as wood is burned, producing heat. When compounds are oxidized, the process is often referred to as "burning." For example, athletes burn energy (sugars) as they exercise; the harder they exercise, the more sugars they burn so they need more oxygen. This is why at full speed they are breathing very fast. Athletes take in oxygen through their lungs.

Plants take up oxygen through the stomates in their leaves and through their roots. Like animals and microorganisms, plants respire to generate the energy they need to live, thus requiring both oxygen and carbon dioxide in order to survive. This is why waterlogged or compacted soils are detrimental to root growth and function, as well as the decomposition processes carried out by microorganisms in the soil, oxygen is not available.

Comparison of Photosynthesis and Respiration

Photosynthesis	←→	**Respiration**
Produces sugars from energy.		Burns sugars for energy.
Energy is stored.		Energy is released.
Occurs only in cells with chloroplasts.		Occurs in all living cells.
Oxygen is produced.		Oxygen is used.
Water is used.		Water is produced.
Carbon dioxide is used.		Carbon dioxide is produced.
Requires light.		Occurs in dark and light.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Revised June 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #142

Plant Growth Factors: Light

The quality, intensity, and duration of light directly impacts plant growth.

Light Quality

Light quality refers to the particular colors or wavelengths of light reaching the plant's surface. Visible light ("white" light) can be separated into the spectrum of colors familiar in the rainbow; each color of light is associated with particular wavelengths. [**Figure 1**]

Red and blue light have the greatest impact on plant growth – the particular energy of these wavelengths is what chlorophyll is able to capture best. Green light is least effective (plants appear green because the other wavelengths are more absorbed/used by the plants, leaving green to bounce back to our eyes).

Light quality is a major consideration for indoor growing.

LED lights are the most common lights available for indoor growing. For general use, bulbs that generate light in the 400-700nm wavelength range (blue to red) are effective for plant growth. Specialist and commercial growers can enhance the photosynthetically active spectra, but this is rarely needed in homes.

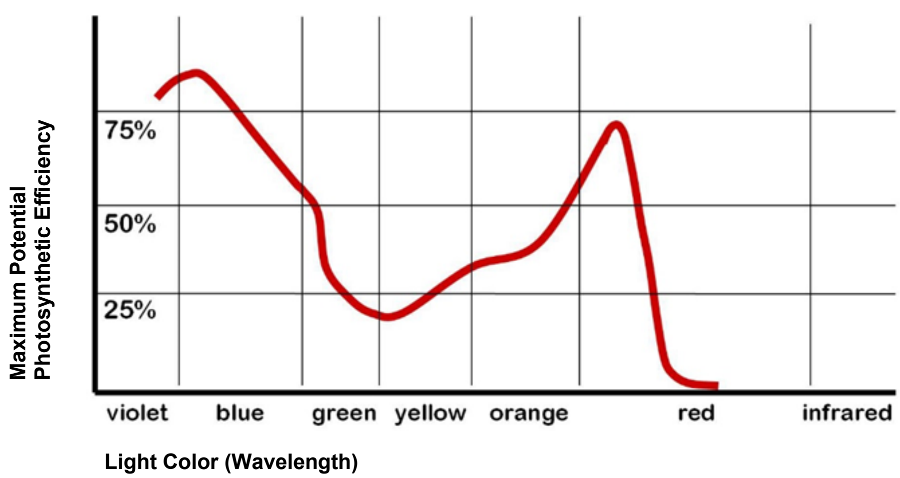


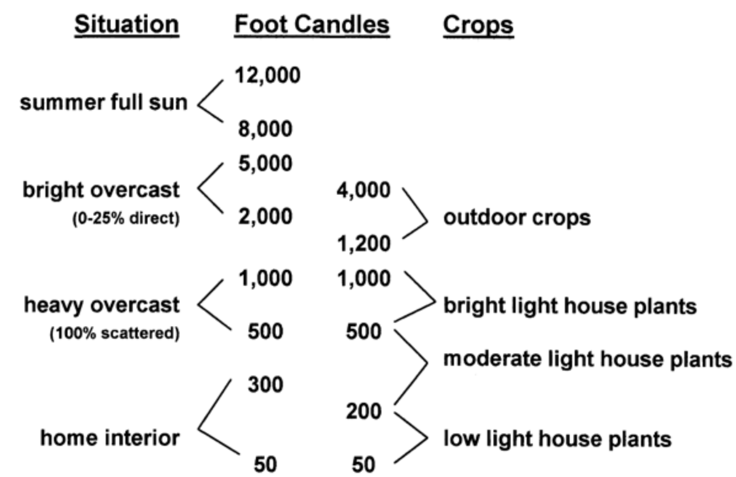
Figure 1. Relative efficiency of various light colors in photosynthesis.

Light Intensity

The more sunlight a plant receives, to a degree, the higher the photosynthetic rate will be. However, leaves of plants growing in low light readily sunburn when moved to a bright location. Over time, as the plant acclimates, it will become more sun tolerant.

As illustrated in **Figure 2**, light levels in most homes are below that required for all but low light house plants. Except for rather bright sunny rooms, most house plants can only be grown directly in front of bright windows. Inexpensive light meters are available in many garden supply stores to help the indoor gardener evaluate light levels (though importantly, do not distinguish among wavelengths, so cannot guarantee satisfactory plant growth).

Figure 2. Light Intensity for Various Situations
Light intensity is measured in *lux* or *foot-candles*.



Landscape plants vary in their adaptation to light intensity. Many gardening texts divide plants into sun, partial sun, and shade. However, the experienced gardener understands the various degrees of sun and shade:

Full sun – Direct sun for at least eight hours a day, including from 9 a.m. to 4 p.m.

Full sun with reflected heat – Where plants receive reflected heat from a building or other structure, temperatures can be extremely hot. This situation significantly limits the choice of plants for the site.

Morning shade with afternoon sun – This southwest and west reflected heat can be extremely hot and limiting to plant growth.

Morning sun with afternoon shade – This is an ideal site for many plants. The afternoon shade protects plants from extreme heat.

Filtered shade – Dappled shade filtered through trees can be bright shade to dark shade depending on the tree's canopy. The constantly moving shade pattern protects under-story plants from heat. In darker dappled shade, only the more shade-tolerant plants will thrive.

Open shade – Plants may be in the situation where they have open sky above, but direct sunlight is blocked during the day by buildings, fences, and other structures. Only more shade-tolerant plants will thrive here.

Closed shade – The situation where plants are under a canopy blocking sunlight, like under a deck or covered patio, is most limiting. Only the most shade-tolerant plants will survive this situation.

In hot climates, temperature is often a limiting factor related to shade. Some plants, like impatiens and begonias, may require shade as an escape from heat. These plants will tolerate full sun in cooler summer climates.

Light penetration is a primary influence on correct pruning. [**Figure 3**]. For example, dwarf apple trees are pruned to a Christmas tree shape. This gives better light penetration for the best quality fruit. Mature fruit trees are thinned each spring for better light penetration. A hedge should be pruned with a wider base and narrow top. Otherwise the bottom thins out due to the shade from above. A common mistake in pruning flowering shrubs is to shear off the top. The resulting regrowth gives a thick upper canopy that shades out the bottom foliage.

Figure 3. Light penetration is a primary influence in pruning.
Left: Dwarf apple trees pruned to a Christmas tree shape allow better light penetration for best quality fruit.
Right: Regrowth on flowering shrubs that are sheared on top creates/promotes heavy upper canopy growth. This shades out the bottom creating an unattractive “naked” base.

Light Duration

Light duration refers to the amount of time that a plant is exposed to sunlight. Travelers to Alaska often marvel at the giant vegetables and flowers that grow under the long days of the arctic sun even with cool temperatures.

Even so, plants are generally intolerant of continuous light for twenty-four hours. Many important physiological processes occur at night, including repair of photosynthetic mechanisms.

Photoperiod

The flowering response of many plants is controlled by the **photoperiod** (the length of the light period in twenty-four hours). Photoperiod response can be divided into three types. [**Figure 4**]

Short-day plants flower in response to long periods of night darkness. Examples include poinsettias, Christmas cactus, chrysanthemums, and single-crop strawberries.

Long-day plants flower in response to shorter periods of night darkness than daylight. Examples include asters, California poppies, and spinach.

Day-neutral plants flower without regard to the length of the night, but typically flower earlier and more profusely under long daylight regimes. Day neutral strawberries provide summer long harvesting (except during heat extremes).

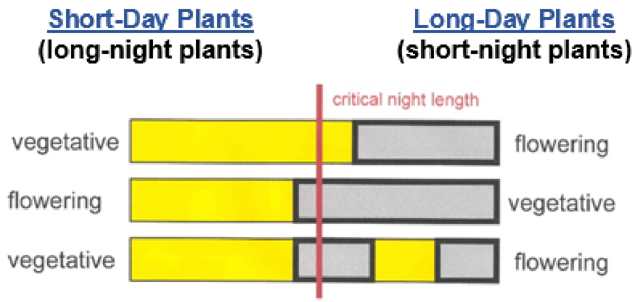


Figure 4. Photoperiod and flowering.
Left side: Short day plants flower with uninterrupted long nights.
Right side: Long-day plants flower with short nights or interrupted long nights.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson, David Whiting, and USDA. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

CMG GardenNotes #143

Plant Growth Factors: Temperature

Temperature Considerations

Temperature factors that figure into plant growth potentials include the following:

- Maximum daily temperature.
- Minimum daily temperature.
- Difference between day and night temperatures.
- Average daytime temperature.
- Average nighttime temperature.

Microclimates

Microclimates are small areas where environmental conditions may be different than the general surrounding area. The microclimate of a garden plays a primary role in actual garden temperatures. In mountain communities, changes in elevation, air drainage, exposure, and thermal heat mass (surrounding rocks) will make some gardens significantly warmer or cooler than the temperatures recorded for the area. In mountain communities, it is important to know where the local weather station is located so gardeners can factor in the difference in their specific location to forecast temperatures more accurately.

Examples of factors to consider include the following:

Elevation – A 300-foot rise in elevation accounts for approximately 1°F drop in temperature.

Drainage – At night, cool air drains to low spots. Valley floors may be more than 10°F cooler than surrounding gardens on hillsides above the valley floor. That is why fruit orchards are typically located on higher ground rather than on the valley floor. [**Figure 1**]

Figure 1. This garden on a hillside above Steamboat Springs, Colorado (a mountain community with a short frost-free season) has good drainage giving it a growing season that is several weeks longer than down in town.

Exposure – Southern exposures absorb more solar radiation than northern exposures. In mountain communities, northern exposures will have shorter growing seasons. In mountain communities, gardeners often place warm season plants, like tomatoes, on the south side of buildings to capture more heat. [**Figure 2**]

Based on local topography, buildings, fences, and plantings, garden areas may be protected from or exposed to cold and drying winds.

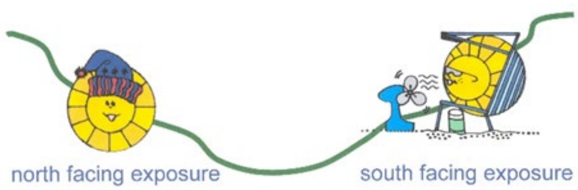


Figure 2. Temperatures and growing season vary greatly based on exposure. A north facing exposure will typically be cooler and moist. A south facing exposure will typically be hot and dry.

Thermal Heat Mass (Surrounding Rocks) – In many Colorado communities, the surrounding rock formations can form heat sinks creating wonderful gardening spots for local gardeners. Nestled in among the mountains, some gardeners have growing seasons several weeks longer than neighbors only a half mile away.

In cooler locations, rock mulch may give some frost protection and increase temperatures (particularly spring and fall soil temperatures) for enhanced plant growth. In lower elevations and latitudes, rock mulch can significantly increase summer temperatures and water requirements of landscape plants. [**Figure 3**]

In Phoenix, Arizona, the urban heat island effect created by impermeable surfaces and rock mulch has significantly raised day and night temperatures.

Figure 3. The sidewalks and stone walls of this intercity plaza creates a heat pocket with a frost-free period three months longer than the surrounding neighborhood.

Influence of Heat on Crop Growth

Temperature affects the growth and productivity of plants. The effect on individual plants depends on physiology, for example vegetables being a warm season or cool season crop dictate their performance at hot or cold temperatures.

Photosynthesis – Within limits, rates of photosynthesis and respiration both rise with increasing temperatures. As temperatures reach the upper growing limits for a plant, the rate of food used by respiration may exceed the rate at which food is manufactured by photosynthesis. Furthermore, photosynthesis becomes less efficient at higher temperatures. Some plants (many grasses and succulents, for example) have specialized photosynthetic pathways in order to allow them to grow at higher temperatures.

Temperature Influence on Germination

Seeds of cool season crops germinate at 40 degrees to 90 degrees. Warm season crop seeds germinate at 50°F to 105°F. In the spring, cool soil temperatures can be a limiting factor for plant growth. In mid-summer, hot soil temperatures may prohibit seed germination.

Examples of temperature influence on flowering:

Tomatoes

- Pollen does not develop if night temperatures are below 55°F.
- Blossoms drop when daytime temperatures are consistently above 85°F or nighttime temperatures are consistently above 70°F.
- Tomatoes grown in cool climates will have softer fruit with bland flavors.

Spinach (a cool season, short day crop) flowers in warm weather with long days.

Christmas cacti and poinsettias flower in response to cool temperatures and short days.

Examples of temperature influence on crop quality:

- High temperatures increase respiration rates, reducing sugar content of produce. Fruits and vegetables grown in heat will be less sweet.
- In heat, crop yields reduce while water demand goes up.
- In hot weather, flower colors fade and flowers have a shorter life.

Table 1 illustrates temperature differences in warm season and cool season crops.

Table 1. Temperature Comparison of Cool Season and Warm Season Crops

Temperature for:	Cool Season: broccoli, cabbage, carrots, etc.	Warm Season: tomatoes, peppers, squash, melons, etc.
Germination	40°F to 90°F, 65°- 85°F optimum range.	50°F to 105°F, 70°- 95° F optimum range.
Growth	**Daytime** • 65°F to 80°F preferred. • 40°F minimum. **Nighttime** • >32°F, tender transplants • > mid-20s°F, established plants.	**Daytime** • 75°- 85°F optimum. • 55°F minimum. • A week below 55°F will stunt plant, reducing yields. **Nighttime** • >52°F.
Flowering	Temperature extremes lead to bolting and buttoning.	• Nighttime <55°F, non-viable pollen (use blossom set hormones) • Daytime >95°F early in day; blossoms abort.
Soil	**Cool** • Use organic mulch to keep soil cool. • Since seeds germinate best in warm soils, use transplants for spring planting, and direct seeding for mid-summer plantings (fall harvest).	**Warm** • Use black plastic or rock mulch to warm soil, increasing yields and earliness of crop.

Influence of Cold Temperatures

Plant Hardiness Zone Maps indicate the **average annual minimum temperature** expected for geographic areas. While this is a factor in plant selection, it is only one of many factors influencing plant hardiness.

In 2012, the U.S. Department of Agriculture released a new USDA Hardiness Zone Map. It can be found at https://planthardiness.ars.usda.gov/. It documents a climate zone creep, that is, zones moving northwards in recent years. Zones are based on a 10°F difference in **average annual minimum temperature.**

Average Annual Minimum Temperature
Zone 4, -20° F to –30° F.
Zone 5, -10° F to –20° F.
Zone 6, 0° F to –10° F.
Zone 7, 0° F to –10° F.

Much of the Colorado Front Range area falls into Zone 5, with higher mountain areas in Zone 4. Warmer locations in the Denver Metro area, the upper Arkansas valley, and southeast Colorado fall into Zone 6. Warmer areas of western and southwestern Colorado are in Zone 7.

Plant Hardiness

Hardiness refers to a plant's tolerance to cold temperatures. Low temperature is only one of many factors influencing plant hardiness. Other hardiness factors include:
- Photoperiod.
- Genetics (source of plant material).
- Acclimation.
- Recent temperature pattern.
- Rapid temperature changes.
- Moisture.
- Wind exposure.
- Sun exposure.
- Carbohydrate reserve.

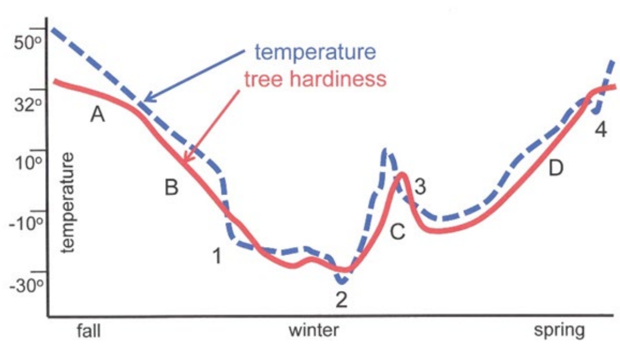


Figure 4. Influence of temperature change on winter hardiness of trees.

Figure 4. The solid line represents a tree's hardiness. Regions A-D represent various stages of hardiness through the winter season. The dotted line represents temperature. When the dotted (temperature) line drops below the solid (hardiness) line, damage occurs. Points 1-4 represent damage situations.

A. Increased cold hardiness induced by shorter daylength of fall.
B. Increased cold hardiness induced by lowering temperatures.

C. Dehardening due to abnormally warm mid-winter temperatures.
D. Normal spring dehardening as temperatures warm.

1. Injury due to rapid drop in temperatures with inadequate fall hardening.
2. Injury at temperatures lower than hardening capability.
3. Injury due to rise and fall of midwinter temperatures.
4. Injury due to spring frosts.

Examples of Winter Injury

Bud Kill and Dieback – From spring and fall frosts.

Root Temperature Injury – Roots have limited tolerance to sub-freezing temperatures. Roots receive limited protection from soil, mulch, and snow. Under extreme cold, roots may be killed by the lack of snow cover or mulch. Street trees are at high risk for root kill in extreme, long-term cold.

Soil Heaving – Pushes out plants, breaking roots. Protect with snow cover or mulch.

Trunk Injury – Drought predisposes trunks to winter injury.

Sunscald – Caused by heating of bark on sunny winter days followed by a rapid temperature drop, rupturing membranes as cells freeze. Winter drought predisposes tree trunks to sunscald. [**Figure 5**]

Frost Shake – Separation of wood along one or more growth rings, typically between phloem (inner bark) and xylem (wood), caused by sudden rise in bark temperature.

Frost Crack – Vertical split on tree trunk caused by rapid drop in bark temperature. [**Figure 6**]

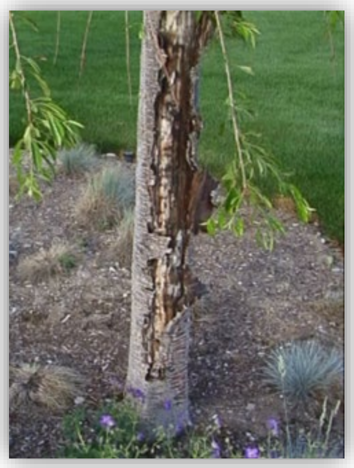


Figure 5. Southwest bark injury is common on trees that are drought stressed or that have thin, smooth bark.

Figure 6. Vertical frost crack is common on trees when the temperature drops rapidly. In Colorado it is common to go from a nice spring day back to cold with a 40 to 60 degree temperature drop in an hour!

Winter Injury on Evergreens

Winter drought – Water transpires from needles and cannot be replaced from frozen soils. It is more severe on growing tips and on the windy side of trees. [**Figure 7**]

Sunscald – Winter sun warms the needles, followed by rapid temperature drop rupturing cell membranes. It occurs typically on the southwest side, side of reflected heat, or with sudden shade.

Photo-Oxidization of Chlorophyll – Foliage bleaches during cold sunny days. Needles may green-up again in spring.

Tissue Kill – Tissues killed when temperatures drop below hardiness levels.

Figure 7. Winter drought, sunscald, and photo-oxidization of chlorophyll are common on arborvitae. It's a poor plant choice for this windy site with little winter moisture.

Rest Period

An accumulation of cool units controls the flowering period of temperate-zone woody plants. The winter rest period (hours above freezing and below 45°F) required to break bud dormancy includes:

- Apples at 250-1700 hours.
- Apricots at 350-900 hours.
- Cherry, sour, at 600-1400 hours.
- Cherry, sweet, at 500-1300 hours.
- Peaches at 800-1200 hours.
- Pears at 200-1500 hours.
- Plums, European, at 900-1700 hours.
- Plums, Japanese, at 300-1200 hours.

Authors: David Whiting, CSU Extension, retired. Artwork by Scott Johnson and David Whiting. Used with permission.
Revised July 2016. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #144

Plant Growth Factors: Water

In Colorado, both water availability and water quality can be limiting factors for plant growth. Quality issues are generally related to excessive sodium or other soluble salts.

Available water limits the potential for many crops and garden plants in many areas of the West. In western cities, the cost of the infrastructure to supply water, overallocation of limited water resources, and increasing population drive the need for water conservation.

Water management is a topic of other Colorado Master Gardener training classes. For additional information refer to CMG GardenNotes:
#260, *Irrigation Management References and Study Questions*.
#261, *Colorado's Water Situation*.
#262, *Water Movement Through the Landscape*.
#263, *Understanding Irrigation Management Factors*.
#264, *Irrigation Equipment*.
#265, *Methods to Schedule Home Lawn Irrigation*.
#266, *Converting Inches to Minutes*.
#267, *Watering Efficiently*.
#268, *Irrigation Management Worksheet: Lawn In-Ground Sprinkler System Check-Up*.
#410, *Water-Wise Landscape Design References and Study Questions*.
#411, *Water-Wise Landscape Design: Steps*.
#412, *Water-Wise Landscape Design: Selecting Turf Options*.
#413, *Water-Wise Landscape Design: Principles of Landscape Design*.

Role of Water

Table 1. Role of Water in Plant Growth	
Role of Water in Plants	**Impact of Water Shortage**
• Required component of photosynthesis and transpiration.	• Reduced plant growth and vigor.
• Turgor pressure (pressure to inflate cells and hold plant erect).	• Wilting.
• Solvent to move minerals from the soil up to the plant. ○ NO_3^-, NH_4^+, $H_2PO_4^-$, HPO_4^{-2}, K^+, Ca^{+2}, Mg^{+2}, SO_4^{-2}, $H_2BO_3^-$, Cl^-, Co^{+2}, Cu^{+2}, Fe^{+2}, Fe^{+3}, Mn^{+2}, MoO_4^{-2}, and Zn^{+2}	• Reduced plant growth and vigor. • Nutrient deficiencies.
• Solvent to move products of photosynthesis throughout the plant, including down to the root system.	• Reduced health of roots which leads (over time) to reduced health of plant.
• Regulation of stomatal opening and closure, thus regulating transpiration and photosynthesis.	• Reduced plant growth and vigor. • Reduced cooling effect = warmer micro-climate temperatures and warmer plant tissue temperatures.
• Source of pressure to move roots through the soil.	• Reduced root growth = reduced plant growth and vigor.
• Medium for biochemical reactions.	• Reduced plant growth and vigor.

One of the most common visible symptoms of long-term drought stress is leaf scorch. Street trees are especially vulnerable to leaf scorch in the hot parts of the year. **Leaf scorch** is characterized by:

- Marginal browning (necrosis).
- Often from the top down, on southwest side, or from the side with root injury or root restrictions.

Contributing factors to leaf scorch:

- Dry or overly wet soils.
- Compacted soils.
- Limited root spread.
- Root injury.
- Structural damage to xylem tissues.
- Trunk and branch injury.
- Excessive wind and heat (hot microclimates).
- Excessive canopy growth (from heavy fertilization).

Common Causes of Water Stress

Drought

- Decreased growth.
- Small, off-colored leaves.
- Decline from top down.
- Early fall color.
- Reduced xylem growth = long-term growth reduction.
- Stress may show up five or more years later.

Waterlogged Soils

- Root activity slows or shuts down, and plants show symptoms of drought.
- Decline in root growth slows plant growth processes.
- Leaves may wilt from lack of water uptake.
- Root rots are common in some species, plants vary in their ability to tolerate "wet feet."
- Lower, interior leaves may yellow first.

Bacterial and Fungal Infections

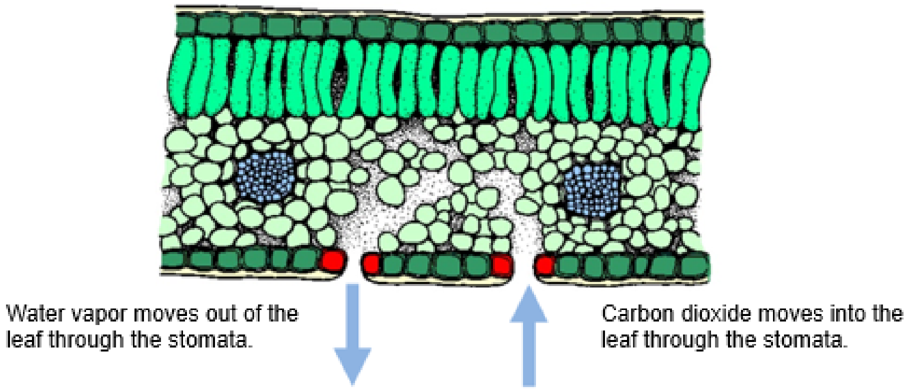
- Bacteria or fungi infect and proliferate in xylem tissue.
- Obstructed vascular system results in symptoms of drought stress.

Relative Humidity

You have already learned about osmosis and water movement. Another way to think of this is that water moves from areas of high relative humidity to areas of lower relative humidity. Inside a leaf, the relative humidity between cells approaches 100%. When the stomata open, water vapors inside the leaf rush out, forming a "bubble" of higher humidity around the stomata on the outside of the leaf.

The difference in relative humidity around the stomata and adjacent air regulates transpiration rates and pulls water up through the xylem tissues. Transpiration peaks under hot dry and/or windy conditions. When the supply of water from the roots is inadequate, the stomata close, photosynthesis shuts down, and plants can wilt. [**Figure 1**]

Figure 1. Leaf Cross Section



Colorado's typically low relative humidity means that, in general, plants not adapted to dry air are always experiencing or at the brink of experiencing stress. This is one of the reasons that it can be challenging to grow many classic garden plants without significant investment in supplemental watering and wind protection.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #145

Plant Growth Factors: Plant Hormones

Outline:

Plant Hormones and Plant Growth Regulators

Another factor in plant growth is the influence of plant hormones. **Hormones** are chemicals produced by plants that regulate their growth processes.

Plant growth regulators are chemicals applied to regulate plant growth; they are synthetic plant hormones. In plant propagation, cuttings are dipped in a rooting hormone to stimulate root development. In greenhouse production, many potted flowering plants (like poinsettias and Easter lilies) may be treated with plant growth regulators to keep them short. Seedless grapes are treated with plant growth regulators to increase the size of the fruit. In certain situations, turf may be treated to slow growth and mitigate the need for mowing. Some plant growth regulators are expensive, labor-intensive, and have little application in home gardening. Others are commonly used, including many herbicides.

Plant Hormones

Different hormones affect different plant processes. Understanding how hormones work allows horticulturists to manipulate plants for specific purposes.

Auxins produced in the terminal buds suppress the growth of side buds. This focuses the growth of the plant upward rather than outward. If the terminal bud is removed during pruning (or natural events) the lateral buds will develop and the stem becomes bushy. Auxins also stimulate root growth and affect cell elongation (tropism), apical dominance, and fruit drop or retention. [**Figure 1**]

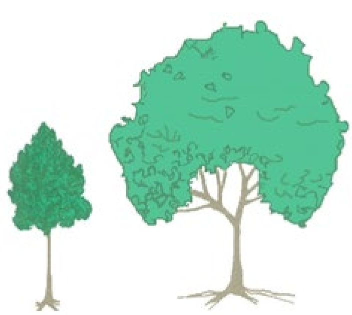


Figure 1. Auxins produced in the rapidly growing terminal buds suppress growth of side buds, giving a young tree a more upright form. As growth rates slow with age, reduction in apical dominance gives the maturing tree a more rounded crown.

Gibberellins affect:

- The rate of cell division.
- Flowering.
- Increase in size of leaves and fruits.
- Seed and bud dormancy.
- Induction of growth at lower temperatures (used to green up lawns two to three weeks earlier).

Cytokinins promote cell division, and influence cell differentiation and aging of leaves.

Abscisic acid inhibits the effects of other hormones to reduce growth during times of plant stress and plays a role in the development of stress tolerance and seed maturation. Despite its name, it plays a limited role in leaf abscission.

Ethylene is another hormone associated with maturation and/or stress. It plays an important role in promoting fruit ripening and leaf drop.

Hormone Influence on Pruning

Understanding hormones is key to proper pruning. **Auxin** produced in the terminal buds suppresses growth of side buds and stimulates root growth. **Gibberellins** produced in the root growing tips stimulate shoot growth. Pruning a newly planted tree removes the auxin-generating tissues, slowing root regeneration. [**Figure 2**]

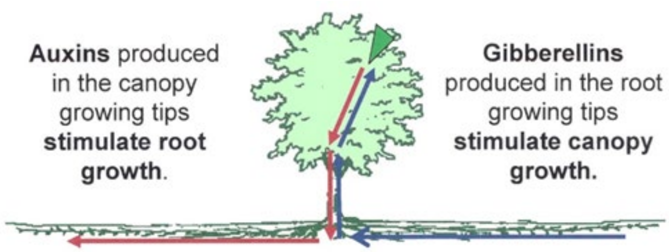


Figure 2. Trees balance canopy growth with root growth by concentrations of auxins and gibberellins.

Heading cuts remove a branch tip to eliminate the apical dominance maintained by auxins from the terminal bud. This allows side shoots to develop, and the branch becomes bushier. On the other hand, **thinning cuts** remove a side branch back to the branch union (crotch). This type of cut opens the plant to more light and does not have the same structural effect as removing growing tips from leaders; for this reason, most pruning should be limited to thinning cuts. [**Figure 3**]

Figure 3. Left: A heading cut releases apical dominance and the branch becomes denser as the lateral buds begin to grow. **Right:** A thinning cut removes a branch back at a branch union (crotch), opening the plant for better light penetration. Thinning cuts promote an open growth habit by redirecting sugars to the terminal shoots.

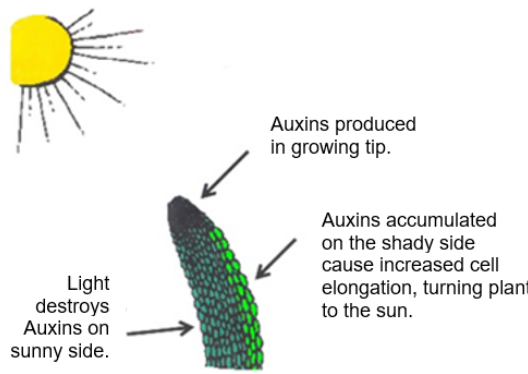
For details on pruning, refer to Fact Sheet 7.003, Training and Pruning Fruit Trees as well as CMG GardenNotes #610-617 on The Science of Pruning.

Tropisms

Auxins also play a key role in some **tropisms** (controlling the direction of plant growth). [**Figures 4** and **5**]

Figure 4. **Geotropism**
Under the influence of gravity, auxins accumulate in the lower side of a horizontal stem, causing cells to enlarge faster, turning the stem upright.

Figure 5. Phototropism
Auxin concentrations on the shaded side stimulates cell elongation, turning the stem to the sun.



Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023