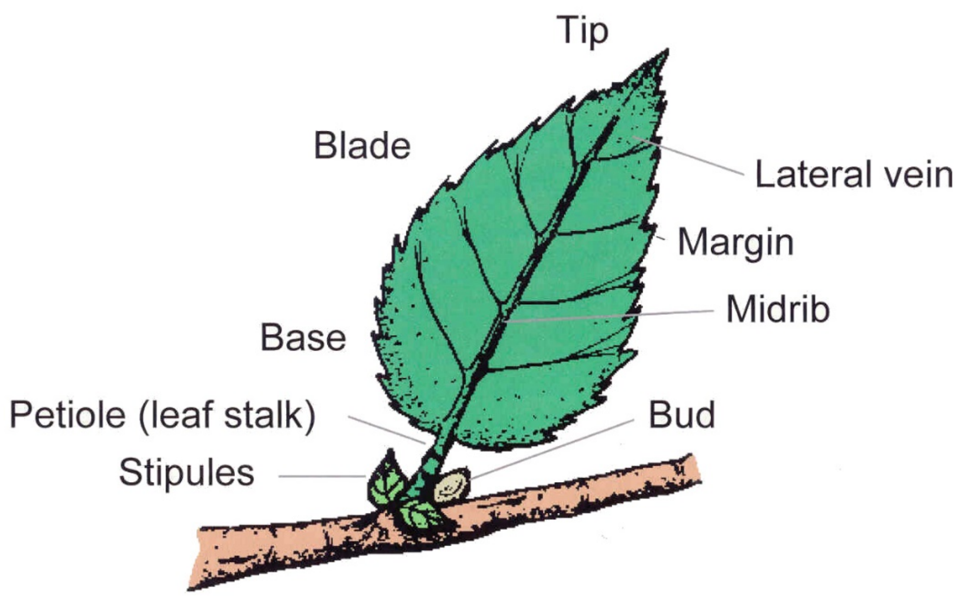
MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION



Botany

Reference / Supplemental Reading

- **CMG GardenNotes** on Botany available on-line at www.cmg.colostate.edu

  #121 Horticulture Classification
  #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 Growth: Photosynthesis, Respiration and Transpiration
  #142 Plant Growth Factors: Light
  #143 Plant Growth Factors: Temperature
  #144 Plant Growth Factors: Water
  #145 Plant Growth Factors: Hormones

- **Reference Books**

  - ***Botany for Gardeners***. Brian Capon. Timber Press.
  - ***Gardener's Latin: A Lexicon.*** Bill Neal.
  - ***Introduction to Botany***. James Schooley. Delmar Publishers.
  - ***Manual of Woody Landscape Plants, Fifth Edition.*** Michael A. Dirr. Stipes. 1998.
  - ***Hartman's Plant Science, Fourth Edition.*** Margaret J. McMahon, Anthon M. Kofranek, and Vincent E. Rubatzky. Prentice Hall.
  - ***The Why and How of Home Horticulture.*** D.R. Bienz. Freeman. 1993.
  - ***Winter Guide to Central Rocky Mountain Shrubs.*** Co. Dept. of Natural Resources, Div. of Wildlife. 1976.

- **Web-Based References on Plant Taxonomy**

  - ***International Plant Name Index*** at www.ipni.org
  - ***U.S. Department of Agriculture Plant Data Base*** at http://plants.usda.gov

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Basic Botany curriculum developed by David Whiting (retired), with Joann Jones (retired), Linda McMulkin, Alison O'Connor, and Laurel Potts (retired); Colorado State University Extension.
Photographs and line drawings by Scott Johnson and David Whiting. Revised by Mary Small, CSU Extension

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Learning Objectives

At the end of this unit, the student will:

- Understand 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.

Note: 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 <u>not</u> the purpose of this training to memorize terms or definitions. When you come across a term that you don't 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:

   a. Warm season and cool season plants
   b. Tender and hardy plants
   d. Alpine, prairie, woodland, wetland, xeric and native plants
   e. Herbaceous and woody
   f. Trees, shrubs, and vines
   g. Deciduous, evergreen and semi-evergreen
   h. Broadleaf, narrowleaf and needleleaf
   i. Annual, summer annual and winter annual
   j. Biennial
   k. 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 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.

   a. Meristematic zone
   b. Primary roots
   d. Lateral roots
   e. Root tip
   f. Epidermis
   g. Root hairs
   h. Tap root system
   i. Fibrous root system
   j. Adventitious roots

9. List the three primary functions of stems.

10. Identify the following parts of a stem:

    a. Nodes
    b. Internodes
    c. Terminal bud
    d. Lateral bud
    e. Terminal bud scar
    f. Leaf scar
    g. Bundle scar

11. Describe how stem characteristics are used in plant identification.

12. Define the following stem terms:

    a. Shoot
    b. Twig
    c. Branch
    d. Trunk
    e. Cane
    f. Bulb

g. Corm
h. Crown
i. Stolon
j. Rhizome
k. Tuber

13. List the two primary functions of leaves.

14. Define and identify the following leaf terms.

    a. Leaf blade
    b. Leaf tip
    c. Leaf base
    d. Mid-vein or midrib
    e. Lateral veins
    f. Leaf stalk or petiole
    g. Stipules
    h. Bud
    i. Pinnate venation
    j. Palmate venation
    k. Parallel venation
    l. Simple leaf
    m. Pinnately compound
    n. Palmately compound
    o. Doubly (bipinnately) compound
    p. Alternate leaf arrangement
    q. Opposite leaf arrangement
    r. Whorled leaf arrangement

15. What is the primary function of flowers?

16. Identify the following parts of a flower:

    a. Sepals
    b. Calyx
    c. Petals
    e. Anthers
    f. Filament
    g. Stamen
    h. Stigma
    i. Style
    j. Ovary
    k. Ovules
    l. Pistil
    m. Floret

17. Define the following flower and plant terms.

    a. Complete flower
    b. Incomplete flower
    c. Perfect flower
    d. Monoecious plant
    e. 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:
    a. Seed coat
    b. Endosperm
    c. Cotyledon
    d. Plumule
    e. Radicle

<u>Plant Growth</u>

21. Define:
    a. Photosynthesis
    b. Respiration
    c. Chloroplasts
    d. Chlorophyll
    e. Transpiration
    f. Stomate

22. Define what is meant by:
    a. Full sun
    b. 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:
    a. Sunscald
    b. Frost crack
    c. 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.

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CMG GardenNotes #121

Horticultural Classification Terms

The earth is unique because of *plants*. They were the first complex organisms to evolve and they are credited with making the atmosphere hospitable for animals and other life forms.

Plants make their own food using raw materials from the environment including carbon dioxide, water, soil nutrients, and sunlight in the process of photosynthesis.

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.

Horticultural – An adjective used to describe something relating to horticulture, or produced under cultivation.

Horticulturist – A noun referring to a specialist in horticulture.

The terms “**ornamentals**,” “**landscape horticulture**,” and “**environmental horticulture**” are common terms used to identify the sub-groupings of horticulture dealing with the landscape setting.

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

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

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

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

Horticultural Classifications

With hundreds of thousands of plants used by humans, it is impossible to talk about each one individually. Plants are grouped by various common characteristics to help us communicate similar ecological adaptations and cultural requirements. For example, the term "shade plants" indicates plants tolerant to various levels of shade. "Xeric" groups those plants requiring less supplemental irrigation in our climate. It is important to point out that any classification system will have plants that do not exactly fit the groupings.

The following are examples of some common classifications used in horticulture.

Classification by Use

- I. 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
- II . Ornamentals/Landscape Plants
  - A. Woody plants
    - 1) Trees
    - 2) Shrubs
    - 3) Vines and ground covers
  - B. Herbaceous plants
    - 1) Flowers
    - 2) Vines and ground covers
  - C. Grass/turf
- III. Potted plants, houseplants, gift plants
  - A. Flowering gift plants
  - B. Foliage plants

> Note: Do not confuse the multiple uses of the word "fruit".
>
> In reference to "fruits and vegetables", "fruit" refers to crops primarily used in some European cuisines as a dessert (peaches, apples, strawberries, and raspberries). "Vegetables" refers to crops served as part of the main entrée (potatoes, carrots, corn, and lettuce). In this frame of reference, tomatoes are vegetables.
>
> In reference to "fruit" as a part of plant anatomy (i.e., roots, stems, flowers, fruits, and seeds), tomatoes, squash and watermelons are fruit.

Classification by Climatic Requirements

Temperature Requirements

Tropical plants originate in tropical climates with a year-round summer-like growing season without freezing temperatures. Examples include cocao, cashew and macadamia nuts, banana, mango, papaya, and pineapple.

Sub-tropical plants cannot tolerate severe winter temperatures but need some winter chilling. Examples include citrus, dates, figs, and olives.

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

Cool season plants thrive in cool temperatures (40°F to 70°F daytime temperatures) and are somewhat 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. Some warm season plants are sub-tropical and tropical plants grown as annuals in Colorado.

Tender plants are intolerant of cool temperatures, frost, and cold winds (e.g., most summer annuals, including impatiens, squash and tomatoes).

Hardy plants are tolerant of cool temperatures, light frost, and cold winds (e.g., 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 zone refers to the average annual minimum temperature for a geographic area. Temperature is only one factor that influences a plant's winter hardiness.

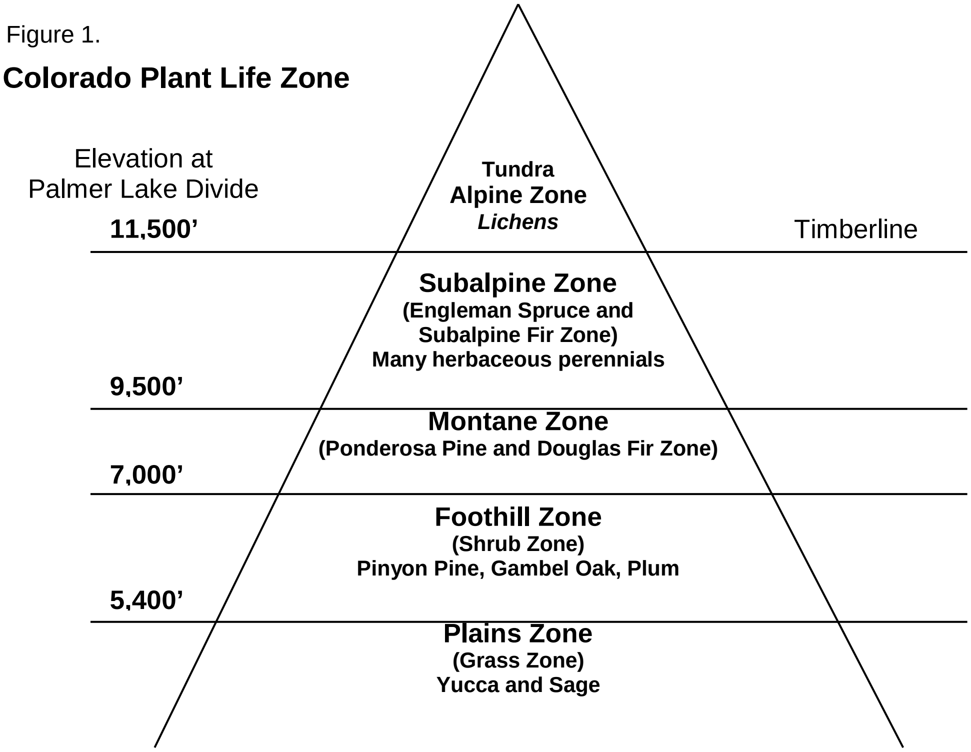
Heat zone refers to the accumulation of heat, a primary factor in how fast crops grow and what crops are suitable for any given area. This is only one factor that influences a plant's heat tolerance.

Classification by Elevation and Plant Life Zones

Higher elevations have increasingly shorter growing seasons due to colder temperatures. High elevations have drier soils, stronger light, persistent winds, and greater temperature changes. Due to this harsh environment, alpine and tundra plants tend to be compact in form. [Figure 1]

Figure 1.

Colorado Plant Life Zone



Note:

1. Elevation of timberline decreases northward.
2. A climb of 1,000' is roughly equal to a trip of 600 miles northward. Average temperature is decreased approximately 3°F for every 1,000 feet gain in elevation.
3. In New Mexico, corresponding plant life zones will be at higher elevations than those given above, but considerably lower elevations in Montana. This does not apply to Alpine zones.

Classification by Ecological Adaptations

Many of our plant care problems arise as gardeners try to grow plants outside of their natural environment or "ecological adaptation."

Characteristics of the Colorado high plains include low humidity, limited rainfall, and alkali soils low in organic matter.

In higher mountain communities, the short frost-free season and low summer growing temperatures significantly limit plant selection.

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. Snow cover depth often dictates the plant's growing height.

Prairie plants are adapted to the open sun and winds of the plains. These plants are further classified into dry, mesic, and wet prairie categories.

Woodland plants are adapted to a low light conditions and soils rich in organic matter. They typically have large leaves and small flowers.

Wetland plants tolerate continually moist soil conditions of a bog or a pond. Wetlands play a primary role in water quality as a filtering system for water-borne pollutants.

Xeric plants tolerate conditions of low water, bright light, and warm temperatures due to a variety of adaptations such as thick, waxy, or fleshy leaves, hairy leaves, small narrow leaves, taproots and succulent stems.

An excellent text on xeriscape gardening is ***Xeriscape Plant Guide***, by Denver Water, published by Fulcrum Publishing.

Native and adapted plants for the urban environment

Native (indigenous) plants refers to plants adapted to a given area during a defined time period. In America, the term often refers to plants growing in a region prior to the time of settlement by people of European descent.

The term is so overused that it has little meaning. With recent interest in water conservation, many gardeners mistakenly consider “native” plants as “xeric” plants, and “xeric” plants as “native” plants. The two terms are not interchangeable”.

The concept of native should not refer to political boundaries, such as state or country, but rather 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. From a chronological reference point, what is now the grassland of the Great Plains 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 (or introduced) plants are those that reliably grow well in a given 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.

Urban environment – For gardening purposes, the urban setting needs to be recognized as a unique ecosystem. Characteristics of the urban environment include:

- Soil compaction
- Rooting areas covered with buildings, roads, and parking lots
- Increased surface runoff creating significant water quality problems
- Higher temperatures and lower humidity

- Air pollution

Characteristics of an urban environment cultivated by humans may include:

- Reduced wind
- Increased availability of water due to irrigation
- Increased organic matter and soil fertility
- Reduced pests
- Increased soil stability
- Slower temperature fluctuations

Classification by Stem and Leaf Texture

Herbaceous plants have non-woody stems.
Woody plants have woody stems that generally live for several years, adding new growth each year.

Deciduous plants shed all leaves at approximately the same time annually. [
Evergreen plants 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 is a natural part of the life cycle.
Semi-evergreen refers to plants that may retain their leaves, depending on the winter temperature and moisture.

Broadleaf plants have a broad leaf blade (e.g., ash, maple, lilac, and beans). [Figure 2]
Narrowleaf plants have needle-like (e.g., pine, spruce) or awl-like (e.g. junipers) leaves. [Figure 3]
Grass-like plants have narrow leaves, usually arising from the base of the plant. The leaves may be soft (ornamental grasses) or stiff (yucca).

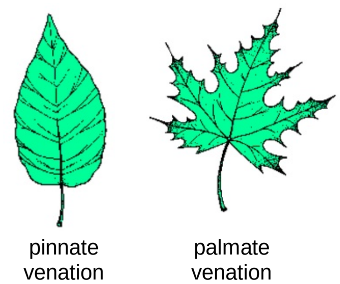


Figure 2. Venation of broadleaf, deciduous trees

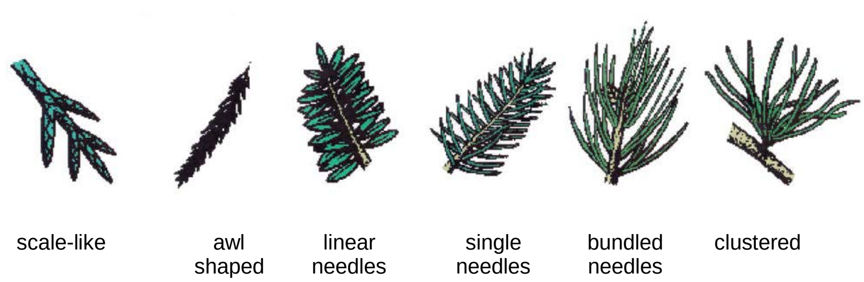


Figure 3. Conifer leaf types

Reminder:

- Some evergreens are broadleaf (e.g., Oregon grape, most true hollies, and evergreen euonymus).
- Some narrow-leaf plants are deciduous (e.g., larch and bald cypress).
- ***Conifer*** refers to cone-bearing. Most conifers are narrow-leaf evergreens. A few conifers are deciduous (larch, bald cypress).

Classification 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 4.]

Trees typically have a single trunk and mature height over 12 feet.
Shrubs typically have multiple-branches from the ground and a mature height less than 12 feet.
Vines have a climbing, clasping, or self-clinging growth habit.

Note: Many landscape plants could be considered small trees or large shrubs. The terms tree or shrub is applied based on the general appearance of the plant.

Plants have vastly different growth habits. It is important to understand growth habits in order to make knowledgeable decisions regarding plant placement, plant selection, pruning and maintenance requirements.

The species, cultivar, and/or variety name sometimes indicates a particular characteristic of growth habit.

Figure 4. Tree Forms

Classification by Life Span

From a horticultural perspective, life span is a function of climate **and** usage. Many garden plants (including tomatoes and geraniums) 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 only from seeds.

Summer annuals germinate from seed in the spring and complete flowering and seed production by fall, followed by plant death, usually due to cold temperatures. Their growing season is 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. Their growing season is from fall to summer. Examples include winter wheat and annual bluegrass. Many weeds in the lawn (such as chickweed and annual bluegrass) are winter annuals.

Biennials complete their life cycle within two growing seasons. Biennials germinate from seed during the growing season and often produce an over-wintering storage root or bulb the first summer. Quite often, they maintain a rosette growth habit the first season, meaning that all the leaves are basal. They flower and develop seeds the second summer, followed by death. Many biennial flowers self-seed, giving the appearance of a perennial growth habit.

In the garden setting, we grow many biennials as annuals (e.g., carrots, onions, and beets) because we are more interested in the root than the bloom. Some biennial flowers may be grown as short-lived perennials (e.g., hollyhocks).

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.

Herbaceous perennials develop over-wintering woody tissue only at the base of shoots (e.g., peony and hosta) or have underground storage structures from which new stems are produced. Note: Golden Vicary Privet and Blue Mist Spirea (*Caryopteris* spp.) can be either herbaceous or woody as grown in Colorado.

Spring ephemerals have a relatively short growing season but return next season from underground storage organs (e.g., bleeding heart, daffodils).

Woody perennials develop over-wintering tissue along woody stems and in buds (e.g., most trees and shrubs grown in Colorado).

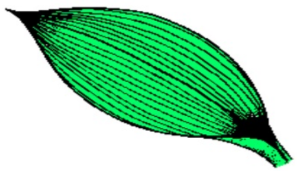
Combinations – Plants are usually classified as annual, biennial, or perennial on the basis of the plant part that lives the longest. For example, raspberries have biennial canes and perennial roots.

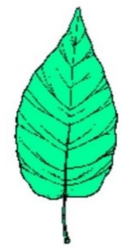
Author: David Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture & LA, Colorado State University. Artwork by Scott Johnson and David Whiting; used by permission.

- Revised May 2016

Monocots | Dicots

Leaf venation


Parallel venation


Pinnate venation

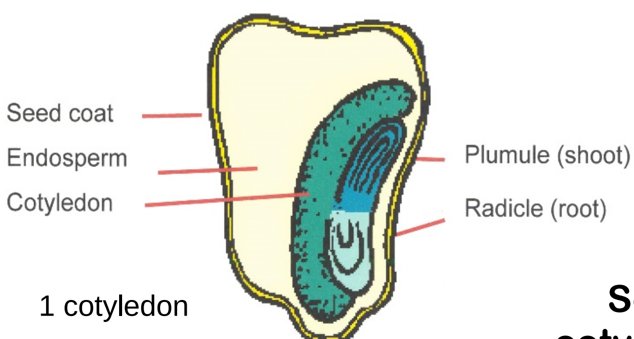

Palmate venation

Flower parts

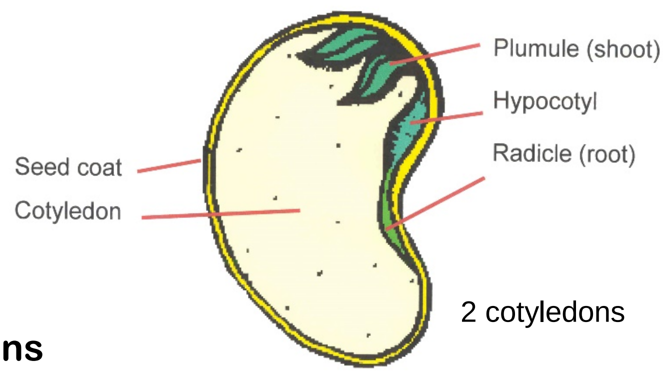

Flower parts in 3s


Flower parts in 4s or 5s

Seed cotyledons

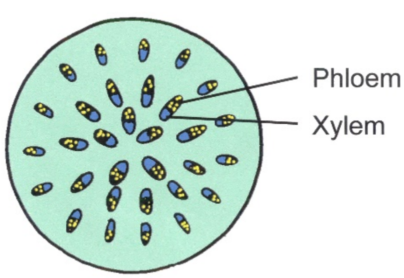


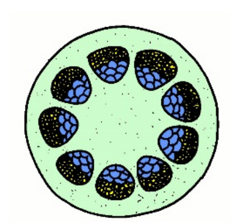
1 cotyledon

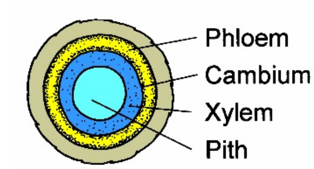


2 cotyledons

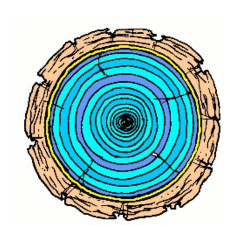
Vascular bundle arrangement




Cross-section of herbaceous dicot plant stem



Cross-section of young woody dicot plant stem


Cross-section of older woody dicot plant stem

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CMG GardenNotes #122

Taxonomic Classification

Outline:

One of the most useful classification systems utilizes plant taxonomy. Taxonomy is the science of systematically naming and organizing organisms into similar groups. Plant taxonomy is an old science that uses the gross morphology (physical characteristics, [i.e., flower form, leaf shape, fruit form, etc.]) of plants to separate them into similar groups. Quite often the characteristics that distinguish the plants become a part of their name. For example, *Quercus alba* is a white oak, named because the underside of the leaf is white.

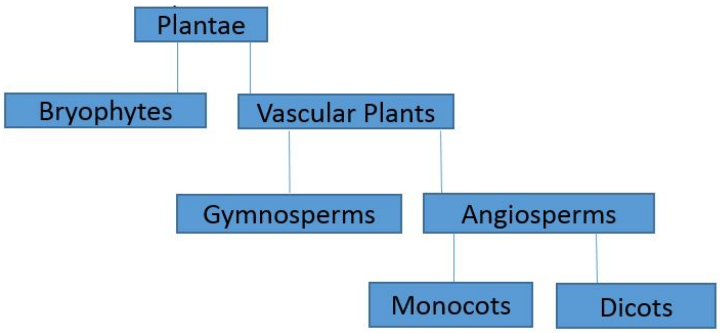
The science of plant taxonomy is being absorbed into the new science of systematics. The development of more sophisticated microscopes and laboratory chemical analyses has made this new science possible. Systematics is based on the evolutionary similarities of plants such as chemical make-up and reproductive features.

It should be noted that plant taxonomic classification changes with continuing research, so inconsistencies in nomenclature will be found among textbooks. Do not get caught-up in which is correct, as it is 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**). Plants are in the kingdom of ***Plantae***. Other kingdoms include ***Fungi***, ***Protista*** (one-celled organisms including yeasts, bacteria, and protozoans), and ***Animalia*** (animals).



The plant kingdom is divided into two taxa: **broyophytes** (including mosses and liverworts) and **vascular plants** (plants with a vascular system of xylem and phloem).

Vascular plants (sometimes called higher plants) are divided into two subgroups: seedless and seeded. The seeded plants divides into two taxa, **Gymnospermae (Gymnosperms)** and **Angiospermae (Angiosperms).** These make up most of the plants in the landscape.

Gymnosperms (meaning naked seed) do not produce flowers, but rather produce seeds on the end of modified bracts, such as pine cones. Many have scale or needle-like leaves. Arborvitae, junipers, Douglas-fir, fir, pine, and spruce are examples of gymnosperms.

Angiosperms (*Magnoliophyta* or broadleaf flowering plants) produce seeds through flowering. Most have broadleaf leaves. Angiosperms are divided into two taxa: ***monocotyledon*** (monocots) and ***dicotyledon*** (dicots). Distinguishing between monocots and dicots is a common practice in landscape management. For example, some of our common herbicides work at the monocot/dicot level. 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).

These taxa divide into ***Divisions*** (or Phylum). Division names end in 'phyta'. Examples of phyla include *Ginkgophyta* (ginkgo), *Pinophyta* (conifers), and *Magnoliophyta* (flowering plants).

Additional taxa in descending order include **family, genus,** and **species**.

Families

Families of higher plants are separated from one another by characteristics inherent in their reproductive structures (flowers, fruit, and seed). Many family members share common characteristics in plant appearances, seed location and appearance and growth habit. However, some families have a lot of diversity in appearance.

Families have primary importance in gardening as they generally share comparable cultural requirements and similar insect and disease problems. Pest management and cultural techniques are often discussed at the family level.

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 Japanese pagoda, 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 beyond the family level are the genus and specific epithet names, together called the species. Plants are named using a binomial system. The genus name comes first and is analogous to a person's last name (like Smith). The specific epithet names follows as a more specific identifier. It would be analogous to a person's first name (like John).

Genus	Specific epithet
Smith	John
Catalpa	*speciosa*

Genera (plural of genus) are groupings whose members have more characteristics in common with each other than they do with other genera within the same family. Similarity of flowers and fruits is the most widely used feature, although roots, stems, buds, and leaves are also used.

Common names of plants typically apply to genera. For example *Acer* is the genus of maples, *Fraxinus* of the ash, and *Juniperus* of the junipers.

Specific epithet generally refers to interbreeding sub-groups of a genus or groupings of individual plants that adhere to essential identification characteristics but show sufficient variation so as not to be categorized as duplicates of one another. The specific epithet name is always used in conjunction with the genus.

When genus and specific epithet names are written, they should always be underlined or italicized to denote they are Latin words. The genus name is always capitalized, but the specific epithet name is not.

The singular and plural spelling of *species* is the same. 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 underlined or italicized.

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

Some suggested sources of scientific names include the following:

- *USDA Plant Data Base* at http://plants.usda.gov/
- *Manual of Woody Landscape Plants*
- *Hortus Third* or *Hortus Fourth*

Variety and Cultivar

The taxonomic divisions beyond the genus and species level are variety or cultivar. This is an even more specific identifier, similar to a person's middle name.

Genus	Species	Cultivar
Smith	John	'David'
Quercus	*rubra*	'Aurea'
Salvia	*greggii*	'Furman's Red'

Variety 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.*

In technical writing, variety and subspecies names must be denoted with 'var.' or 'ssp.' when following a species name. Names are italicized or underlined, while var. or ssp. is not italicized or underlined. 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*.

Cultivar is a sub-grouping of species assigned to cultivated plants ("cultivated variety") that display rather unique differences and, when reproduced by seeds or cuttings, retain its distinguishing characteristics. For example, 'Early Girl' and 'Big Boy' are cultivars of tomatoes.

In technical writing, the cultivar name follows the genus and specific epithet and is always capitalized and written inside single quotes but not italicized or underlined. For example, October Glory Red Maple is *Acer rubrum* 'October Glory'.

It is possible to have a cultivar of a variety. For example, *Cornus florida* var. *rubra* 'Cherokee Chief'.

> **Strain** is a sub-group of cultivar with specific characteristics, like resistance to a disease or better color. An example is 'Early Girl VFN' tomato.

Clone is a sub-group of a cultivar derived by asexual propagation (i.e., cuttings). The offspring have one parent and therefore are identical to the parent because no exchange of genetic materials has occurred.

Line is a sub-group of a cultivar propagated by seed

Form is based on selection by growth habit, not reproducible by seed. For example, Columnar Norway Maple.

Scientific Names

Carl Linnaeus (1707-1778) was a Swedish botanist and is known as the father of modern taxonomy. When Linnaeus published the first books on classification, Latin was used in Western Europe as the language of science. Scientific names of plants are Latinized. Linnaeus continued this trend using Latin and Greek names.

Latin is still a part of science, medicine, law, and philosophy. For example, a prescription for a medication may use, "*quater in die*" (Q.I.D.) meaning "four times a day". "*E Pluribus Unum*", an early motto of the United States, means "out of many, one". Today, Latin has the advantage that it provides lingual neutrality between countries and languages.

Pronouncing Scientific Names

Genus and specific epithet names are universal in spelling (that is, each plant has a single genus and specific epithet name, spelled the same worldwide). By using Latin, plants can be positively identified from over 200,000 known plant species.

However, pronunciation of scientific names is not universal and will vary based on the local language. For example, the tomato may be pronounced 'toe-may-toe' or 'toe-mah-toe'. Based on the native language and local dialect of the user, scientific names may actually sound rather different in various countries.

Many Latin names have become 'generic' common names. For example: anemone, rhododendron, crocus, and viburnum.

Here are a few basic guidelines for American-English:

- Latin was meant to be entirely phonetic. There are no silent letters. What you see is what you say.
- Consonants are pronounced as you normally would. The letters 'c' and 'g' are normally in front of the vowels 'a', 'o' and 'u'. When in front of 'i' and 'e', the sound becomes soft ('Cecil" and "Gentle").
- The letters "ch" are pronounced like "k".
- Vowels are long in an accentuated syllable. For example, *Acer* becomes AY-ser and *Pinus* become PIE-nus.
- There are no silent syllables. For example, *Rudbeckia* becomes rood-BEK-ee-uh and *Miscanthus sinensis* becomes miss-can-thus seye-NEN-sis

- Where the accent goes is a matter of local language styles. Here are some suggestions for American-English.
    - In two syllable words, generally accentuate the first syllable. For example, *Cornus* become KOR-nus.
    - In most other words, accentuate the syllable before the last syllable. For example, *Rhododendron* becomes row-doe-DEN-dron.
    - If the last syllable contains two vowels, accentuate on the third to last syllable. For example, *Buddleia* becomes BUD-lee-ah and *Campanula* becomes kam-PA-nu-la.
- When pronouncing a name based on a person's name, try not to change the sound; accentuate on the first part of the name.
- Examples
    - *Quercus macrocarpa* (bur oak) – KWER-kus ma-crow-CAR-pa
    - *Elaeagnus angustifolia* (Russian olive) – eel-a-EE-ag-nus an-gus-tih-FOL-ee-uh
    - *Ptelea trifoliata* (hoptree/wafer ash) – Tea-LEE-uh try-foal-lee-AH-tuh

Latin Names Add Meaning

Latin names often add meaning about the plant's description, for example:

- ***americana*** **=** of America – *Fraxinus americana* (white ash)
- ***baccata*** = berry bearing – *Taxus baccata* (common yew)
- ***micro*** = little, small – *Antennaria microphylla* (littleleaf pussytoes)
- ***officinalis*** **=** medicinal – *Rosemarius officinalis* (rosemary)
- ***repens*** = creeping, crawling – *Mahonia repens* (creeping Oregon grape)
- ***undulata*** = wavy – *Quercus undulata* (wavyleaf oak)
- ***variegatus*** = variegated – *Miscanthus sinensis* 'Variegatus' (variegated Japanese silver 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

On the other hand, common names are often local in use and many times do not clearly identify the specific plant. For example, *Liriodendron tulipifera* is known as the tulip tree in the north 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 15 English common names, 44 French common names, 105 German common names, and 81 Dutch common names.

References on Plant Taxonomy

Books

- *Gardener's Latin: A lexicon* by Bill Neal.
- *Manual of Woody Landscape Plants* by Michael Dirr

Web based

- *International Plant Name Index* at www.ipni.org/
- *Royal Botanic Gardens, Kew Resource Page* at www.kew.org./data/subjects.html
- *USDA Plant Data Base* at http://plants.usda.gov/

Several web-based sites offer pronunciation guides for plant names. For example, http://www.finegardening.com/pguide/pronunciation-guide-to-botanical-latin.aspx

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Authors: David Whiting (retired) and Alison O'Connor with Joanne Jones (retired), Linda McMulkin, and Laurel Potts (retired); Colorado State University Extension. Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

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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

CMG GardenNotes #131

Plant Structures:

Cells, Tissues, and Structures

Outline: Cells, Tissues, and Structures

Plant cells are grouped into tissues based on similar characteristics, then into five distinct structures (organs).

Cells – Individual building blocks for life processes and growth. Common cells contain genetic matter (deoxyribonucleic acid, or DNA) and metabolic organelles but they are mostly water. In green plants, they are the site of sugar production (photosynthesis). [Figure 1]

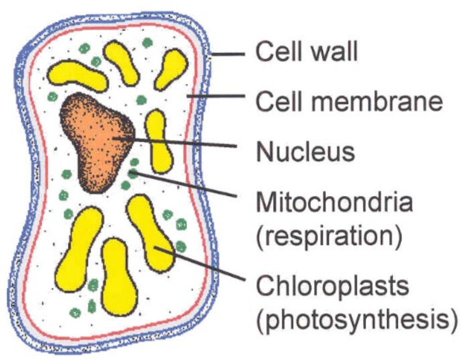

Figure 1. Plant cell

Tissues – Groups of cells that are similar in appearance and function, for example:

- **Epidermis** is the single exterior layer that protects the stems, leaves, flowers, and roots. The outside surface of the epidermis tissue is usually covered with a waxy substance called cutin, which reduces water loss.

- **Parenchyma** tissues are made of simple, thin-walled cells. In a carrot, for example, the parenchyma cells become a storage unit called the cortex. In leaves, a layer of parenchyma tissues under the epidermis is active in photosynthesis. When wounded, parenchyma cells can become meristematic and proliferate to grow over the wound.

- **Meristematic** tissues are comprised of actively dividing cells.
- **Sclerenchyma** tissues are thick-walled support cells found throughout the plant as fiber.
- **Xylem** is a structurally complex tissue that conducts water and nutrients from the roots to all parts of the plant. 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.

Structures (organs) – Groups of tissues working together with a common function, (e.g., **roots, stems, leaves, flowers, fruits**, and **seeds)**.

Plant – Made up of a number of coordinated structures to form a working unit.

Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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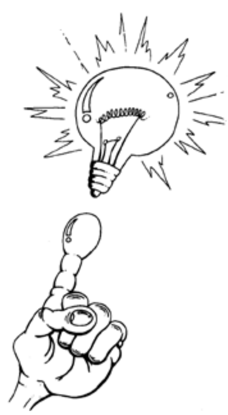
CMG GardenNotes #132

Plant Structures: Roots



Thought questions:

Explain the science behind the question.

- Last summer during a home remodeling project we raised the soil level 12" in the yard. This summer my trees look stressed with small yellowish leaves. I don't see any insects. Could the problems be related to the soil change? My contractor assured us that trees are deep rooted.

- Since you can't see the root system, what are the above ground symptoms of root and soil related

The roots are the beginning of the vascular system pipeline that moves water and minerals from the soil up to the leaves and fruits. Roots make up around one-fourth to one-third of the total dry weight of a plant. The total length of root tissues in a single rye plant is around 380 miles!

To function, roots must have adequate levels of soil oxygen. Soil compaction or waterlogged soil situations, reducing 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

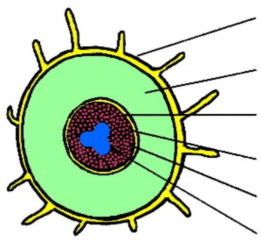
- Size and vigor of the plants
- Adaptation to certain soils
- Response to cultural practices

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

- 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



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 1.]

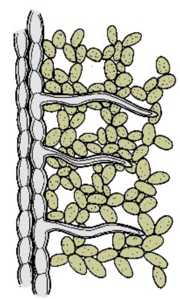


Figure 1. Root hairs are an extension of the epidermis.

Cortex – Primary tissues of a root bordered on the outside by the epidermis and on the inside by the endodermis. In a carrot, the cortex becomes a storage organ.

Endodermis – A single layer of cells in a root that separates the cortex tissues from the pericycle.

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

Vascular system

Phloem tissue conducts products of photosynthesis from leaves throughout plant including down to the roots.
Xylem tissue conducts water and minerals up from the roots up through the plant.

Zone of maturation – Area where cells form distinct tissues that become functioning roots.

Zone of elongation – Area where new cells are enlarging.

Meristematic zone

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 though soil. The root cap protects the tender meristem tissues.

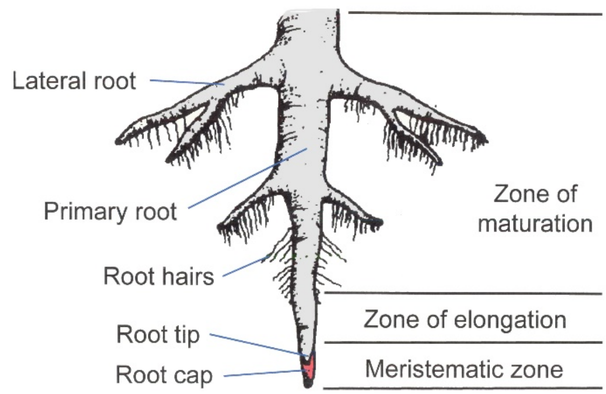


Figure 2. Lateral view of root

Types of Roots

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

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

Adventitious roots arise at an unexpected place. For example, the brace roots on corn and the short whitish bumps along a tomato stem are adventitious roots.

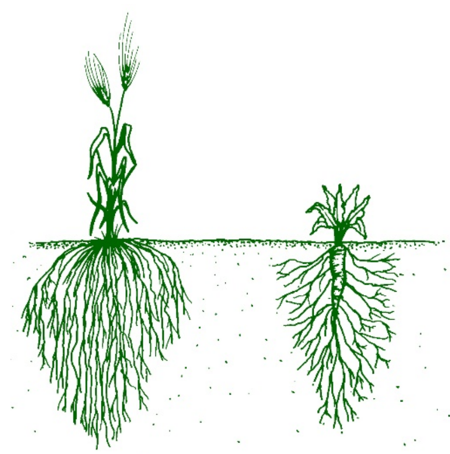


Figure 3. Root types –
Left: Fibrous root system of corn
Right: Taproot system of carrot

Aerial roots arise from above-ground stem tissues. On English ivy and poison ivy, the aerial roots support the vine. Aerial roots are **common on philodendrons, pothos, and Christmas cactus.**

Lateral root – Side root

Sinker roots make a sharp dive into deeper soils, following soil cracks where 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 a factor of the soil's large pore space where oxygen is available.

- In compacted and clayey soils, roots will be shallow, remaining near the surface where oxygen is available.
- In droughty soils, the root system will spread farther, mining a larger soil area for moisture and minerals.

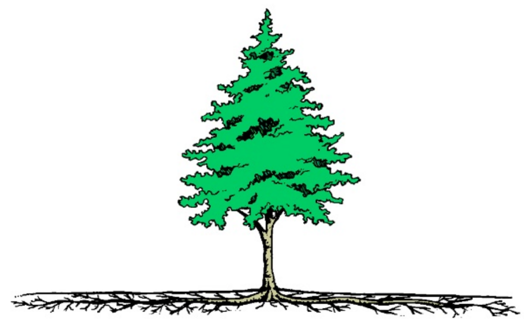


Figure 4. Typical rooting pattern of trees, shallow and spreading

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

- 90-95% in top 36 inches
- 50% in top 12 inches
- Spreads 2-3 times tree's height or canopy (drip-line) spread

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

- 90-95% in top 12 inches or less
- 50% in top 4 inches
- Potentially spreads five plus times the tree's height or canopy (drip-line) 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 18-24"
- Turf 24"
- Vegetables 24"
- Shade trees 24-60"

Beneficial Microorganism Associations

Mycorrhizae are specific beneficial soil fungi forming symbiotic (mutually beneficial) associations with 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. For additional information, refer to the CMG GardenNotes #212, *The Living Soil*.

<u>Rhizobium</u> is a beneficial soil bacterium that forms a symbiotic 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 R*hizobium* in the roots.

Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan, Mary Small, CSU Extension.

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CMG GardenNotes #133

Plant Structures: Stems

Thought questions:

(Explain the science behind the questions.)

- My trees have been severely drought stressed for the past few years. Why are they still showing stress when we had good moisture this year?
- Over the winter, rabbits girdled my tree all the way around down to the wood. My neighbor said it would die, but it leafed out nicely. Will it be OK?
- I planted several new trees over the past few years. How can I evaluate how they are growing? How can I tell if roots are established so I can begin structural pruning?

Stems are the part of a plant that bear leaves and flowers, and they are the continuation of the vascular system pipeline that starts in the roots.

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

Common Types of Stems

Woody Plants

Shoot – First year growth on a woody or herbaceous plant.
Twig – Woody stem less than one year old.
Branch – Woody stem more than one year old.
Trunk – Main support stem(s) of woody plants.
Water sprouts – Juvenile adventitious shoots arising on a branch. Generally very rapid, upright-growth, and poorly attached to the main limb.
Suckers – Juvenile adventitious shoots arising from the roots, generally rapid, upright-growing.
Canes – Stems with relatively large pith and usually living for only one to two years (roses, grapes, blackberries, and raspberries).

Structure

Internal Features

Apical meristem – Tissues at the tip of a stem capable of cell division, gives rise to stem elongation.
Epidermis – Outer layer of wax-coated cells that provides protection and covering
Cortex – Primary tissues of a stem externally bound by the epidermis and internally by the phloem.

Vascular bundle

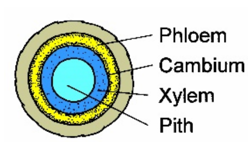
Phloem tissues (inner bark) – distribute sugars (products of photosynthesis) throughout the plant. It is important to understand what happens when the phloem is blocked, as when a tree is girdled with a tie or rope. The stem often enlarges just above the blockage due to the sugars moving down from the leaves for distribution throughout the plant. Tissues below the blockage slowly starve. Roots die back, eventually leading to death of the plant.

Cambium tissues are the single-celled layer of meristematic (dividing) tissues that continually divides to form phloem tissues toward the outside and xylem tissues toward the inside. Cell division of the cambium tissues adds width to the stem.

Xylem tissues – Distribute water and minerals from the roots up through the plant. Xylem provides the structural support in plants, becoming the "woody" tissue.

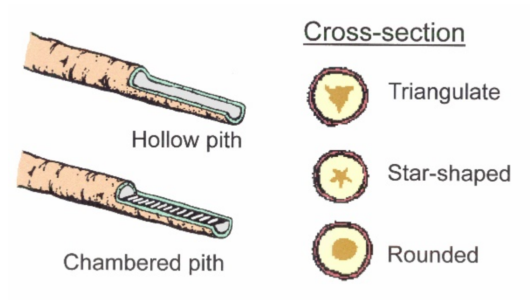
Pith – Center of dicot plant stems. In some plants the pith breaks down forming a hollow stem. In older woody plants, the pith is filled with rigid xylem wood fiber.

Figure 1. Cross section of stem



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

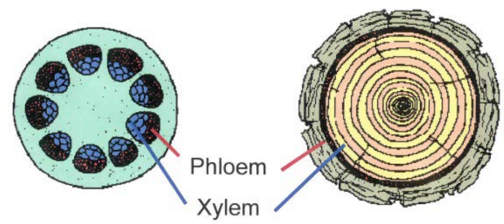
Figure 2. Stem pith is used in plant identification. It may be solid, hollow or chambered. In a cross section, the pith may be rounded, triangular or star shaped.



Tree Rings

In woody dicot plants, the rings grow to make a complete ring around the stem. Xylem growth makes the "annual rings" used to tell a tree's age. In woody dicot plants, water and mineral movement occurs in the more recent years of xylem rings. Drought reduces the size of the annual rings (size of xylem tubes) 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 herbaceous (left) and woody (right) dicot stems



External Features

Bud – A stem's primary growing point. Buds can be either leaf buds (vegetative) or flower buds (reproductive). These buds can be very 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 5]

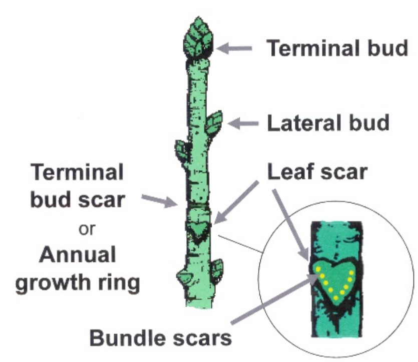


Figure 5. External features of a stem

Lateral buds 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 are an external measure of annual growth. Therefore, they are important in assessing plant vigor. [Figure 6]

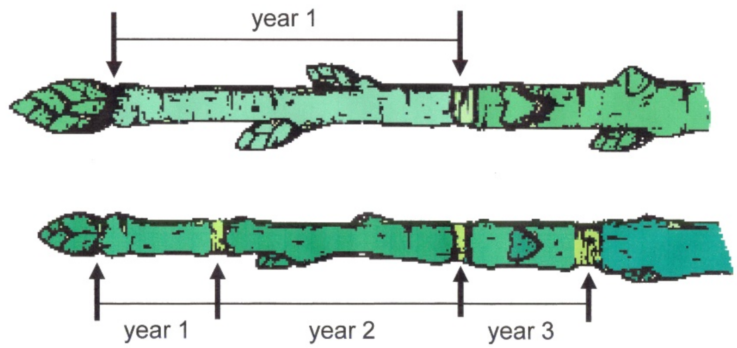


Figure 6. Terminal bud scars or annual growth rings

Node – Segment of stem where leaves and lateral buds are attached. [Figure 7]

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.

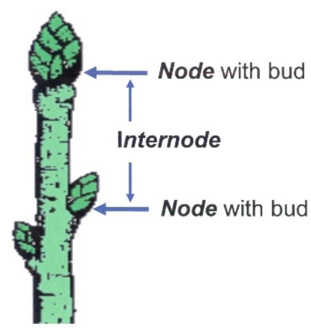


Figure 7. Node and internode

Bud type – The type of bud is also used in plant identification. Figure 8 illustrates bud types used in the *Manual of Woody Landscape Plants*. [Figure 8]

All the features previously described can tell a great deal about a plant pertinent to its identification and health. These are common terms that frequently appear in literature.

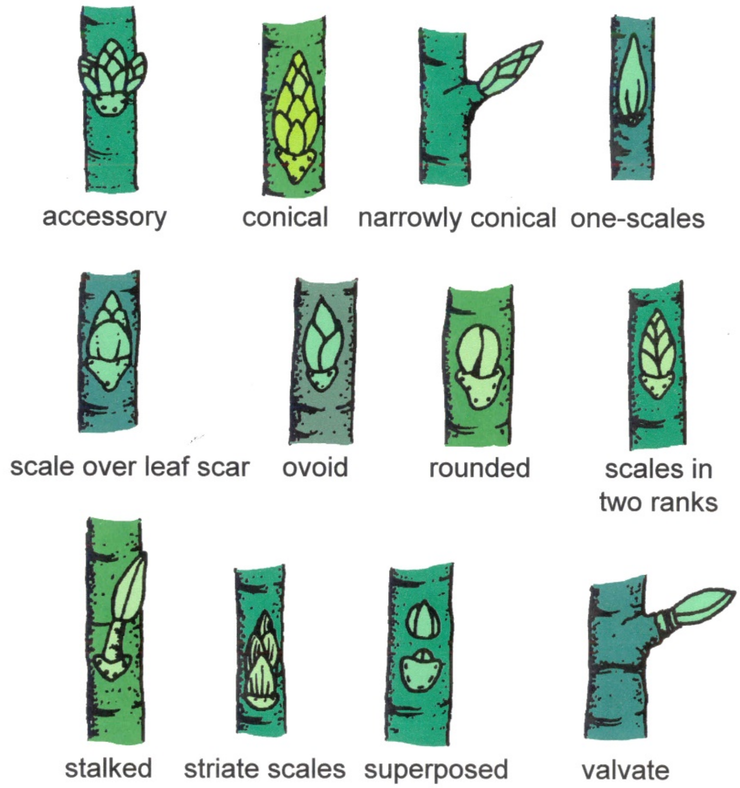
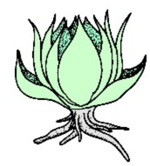


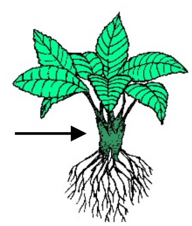
Figure 8. Bud types

Modified Stems

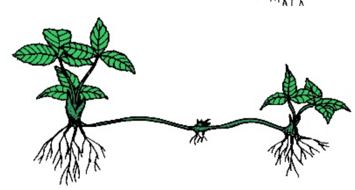


Bulb – Thickened, underground stem with fleshy storage leaves attached at base (tulips, lilies, onions).

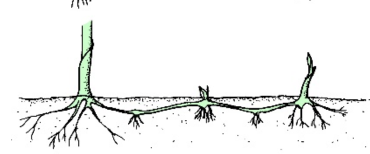
Corm – Short, thickened, underground stem with reduced scaly leaves (gladiolus).



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



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

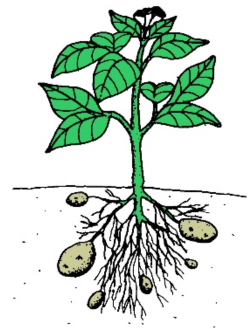


Rhizome – Horizontal, underground stem, typically forms roots and plantlets at tips or nodes (iris, bentgrass, cannas).

Spur – Very compressed, fruiting twig found on some apples, pears, cherries and ginkgo.

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

Tuber – Enlarged rhizome containing stored food. (Irish potato; the eyes of the potato are modified buds.)



Tuberous stem – Short, flattened, modified storage stem (tuberous begonias, dahlias). Unlike tubers, which have buds scattered all over, tuberous stems only have leaf buds on the "up" end.

Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

Revised June 2016

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CMG GardenNotes #134

Plant Structures: Leaves

Thought question:

(Explain the science behind the question.)

- Last spring my tulips were beautiful. As the plants faded, I removed the blossoms and foliage so it wouldn't detract from the landscape.This year, most of the tulips didn't grow back. Why?

Leaves are the principle structure, produced on stems, where photosynthesis takes place. Cacti are an exception. The leaves are reduced to spines, and the thick green, fleshy stems are where photosynthesis takes place.

Functions

- To compete for light for photosynthesis (the manufacture of sugars).
- Evapotranspiration from the leaves to move water and nutrients up from the roots.
- Regulate moisture, gas exchange and temperature through small openings on the leaf, known as ***stomata.***
- Horticultural uses
    - Aesthetic qualities
    - Feed and food
    - Mulch and compost
    - Plant identification

- Propagation from cuttings

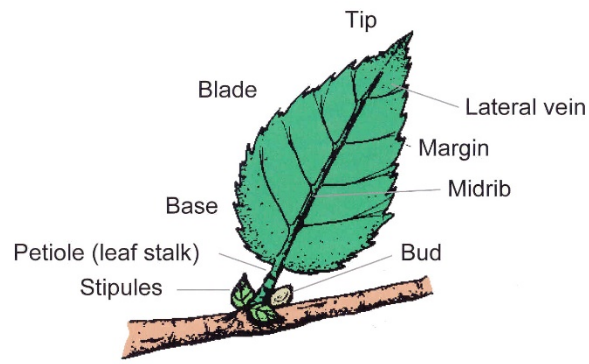
- Summer cooling (Evaporative cooling accounts for 70-80% of the shading impact of a tree.)
- Wildlife habitat
- Wind, dust and noise reduction

Structure

<u>External Features</u>

Leaf blade – Flattened part of the leaf
Petiole – Leaf stalk
Stipules – Leaf-like appendages at the base of the leaf.

Figure 2. 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

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 – Spiral cluster of leaves arranged at the base (or crown) (dandelion)

Figure 3. Leaf Arrangement on Stem

Leaf Type

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

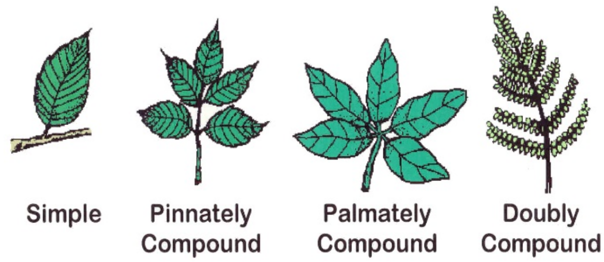
Compound – Several ***leaflets*** arise from the same petiole.

Palmately compound – Leaflets radiate from one central point (Ohio buckeye and horse chestnut).

Pinnately compound – Leaflets arranged on both sides of a common rachis (leaf stalk), like a feather (mountain ash)

Bi-pinnately (doubly) compound – Double set of compound leaflets.

Figure 3. Leaf Types

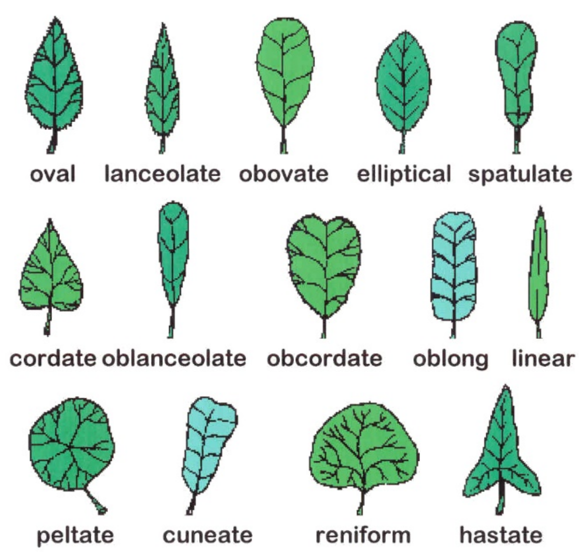


Note: Sometimes identifying a "leaf" or "leaflet" can be confusing. Look at the petiole attachment. A leaf petiole attaches to the stem at a bud node. There is no bud node where leaflets attach to the petiole.

Overall Leaf Shape

Leaf shape is a primary tool in plant identification. Descriptions often go into minute detail about general leaf shape, and the shape of the leaf apex and base. Figure 5 illustrates common shapes as used in the *Manual of Woody Landscape Plants.*

Figure 5. 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 3x or more longer than width and broadest below the middle
Linear- leaves narrow, 4x longer than width and have the same width
Obcordate – reverse appearance of cordate leaves. (Heart shape is upside down)
Oblanceolate – leaf is 3x longer than wide and broadest above the middle
Oblong – leaf is 2-3x as long as it is wide and has parallel sides
Obovate – leaf is broadest above the middle and about 2x as long as the width
Ovate- leaf is broadest below the middle and about 2x as long as the width (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

Shape of the leaf apex (tip) and base is another tool in plant identification. Figures 6 and 7 illustrate common tip and base styles as used in the *Manual of Woody Landscape Plants*.

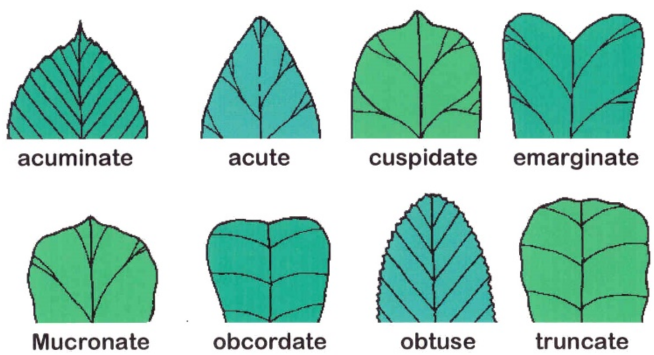


Figure 6. Leaf Tip Shapes

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 2 curves meeting at the tip
Emarginate – tips 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 square-like

Shape of Leaf Base

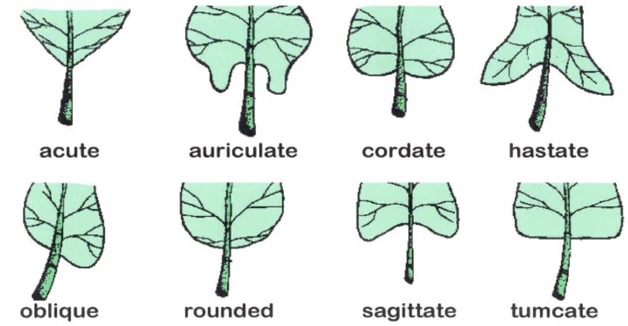


Figure 7. Leaf Base Shapes

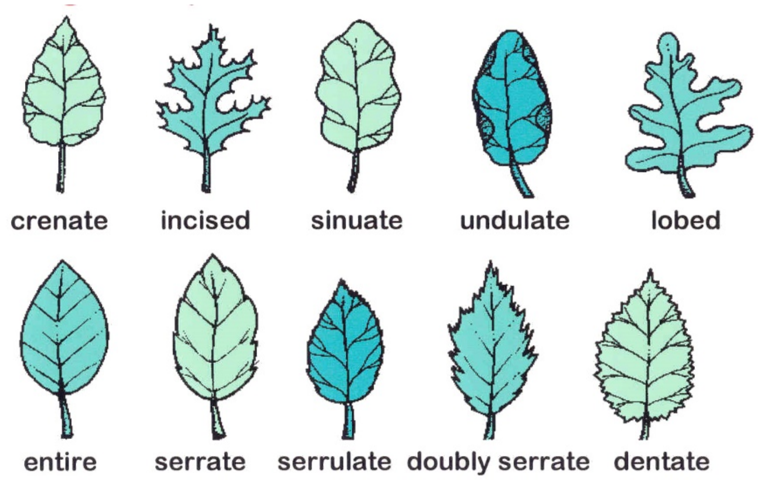
Leaf Base Descriptions

Acute – base is pointed, having less than a 90 degree angle
Auriculate- base has ear-shaped appendages near the petiole
Cordate- base is heart shaped
Hastate- base has pointed, flaring lobes at base
Oblique- base has one side lower than the other
Rounded- circular with no point
Saggitate- lower lobes of leaf are folded or pointed down

Leaf Margins

The leaf margin is another tool in plant identification. Figure 8 illustrates common margin types as used in the *Manual of Woody Landscape Plants*.

Figure 8. 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

Conifer and Ginkgo Leaves

<u>Conifer types</u>

Scale-like – Mature leaves common on most junipers and arborvitae
Awl-shaped – Juvenile leaves common on some junipers
Linear-shaped – Narrow flat needles of spruce, fir, and yews
Needle-like – The cluster of needles in pines creates a rounded shape.

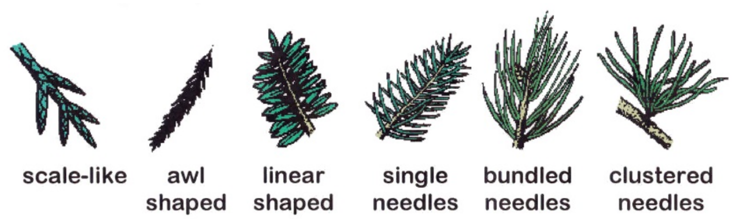


Figure 9. Conifer leaf types

<u>Ginkgo type</u>

Dichotomous venation – Somewhat parallel vein sections, forming a 'Y', found in Ginkgo trees. [Figure 10]

Figure 10. Dichotomous veined Ginkgo leaf

Leaf Venation

Monocots

Parallel venation – Veins run in parallel lines (monocot plants, e.g. grasses, lilies, tulips). [Figure 11]

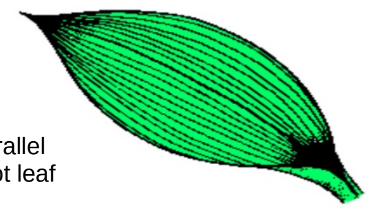


Figure 11. Parallel veined monocot leaf

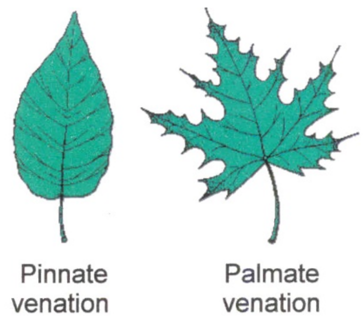
Dicots

Net-veined or reticulate-veined – Leaves with veins that branch from the main rib and then subdivide into finer veinlets (dicot plants**.** [Figure 12]

Pinnate venation – Veins extend from a midrib to the edge (elm, peach, apple, cherry).

Palmate venation – Veins radiate fan-shaped from the petiole (maple, grapes).

Figure 12. 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).

Thorn – Modified leaf (barberry, pyracantha).

Tendril – Modified sinuous leaf used for climbing or as an attachment mechanism (Virginia creeper, peas, grapes).

Figure 13. Thorns are modified leaves.

Internal Features

The leaf blade (flattened part of leaf) is composed of several layers.

Epidermis – Outer layer of tissues

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.

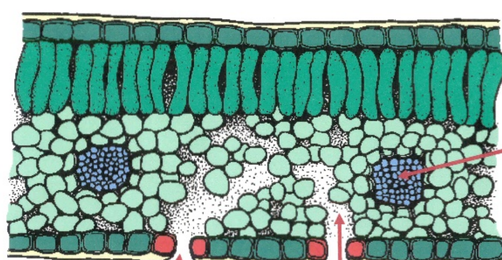
Leaf hairs – Part of the epidermis

Vascular bundle – Xylem and phloem tissues, commonly known as leaf veins.

Stomates (Stomata) – Natural openings in leaves and herbaceous stems that allow for gas exchange (water vapor, carbon dioxide and oxygen) and plant cooling.

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

Figure 1. Leaf Cross Sectional View with Stomates.



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CMG GardenNotes #135

Plant Structures: Flowers

Thought question:

- My zucchini is blooming but doesn't set any fruit. Why?

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

Function

- Reproduction, beginning with pollination and fertilization.
- Advertisement and rewards to lure a pollinator.
- Horticultural uses
  - Aesthetic qualities
  - Cut flowers and potted blooming plants
  - Edible flowers and herbs
  - Plant identification

Structure

Pistil – Central female organ of the flower. It is generally bowling-pin shaped and located in the center of the flower. [Figure 1]

Stigma – Receives pollen, typically flattened and sticky
Style – Connective tissues between stigma and ovary
Ovary – Contains ovules (unfertilized, immature seeds) or embryo sacs
Ovules – Unfertilized, immature seeds

Stamen – Male flower organ [Figure 1]

Anthers – Pollen-producing organs
Filament – Stalk supporting anthers

Petals –Usually colorful modified leaves that make up the "flower", collectively called the ***corolla.*** They may contain perfume and nectar glands and are designed to attract pollinators. [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 [Figure 1]

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

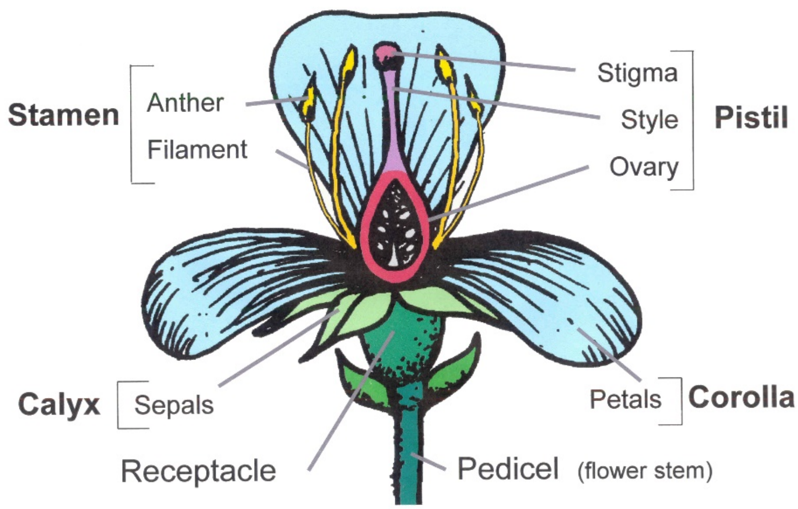

Figure 1. Parts of a Flower

Terms Defining Flower Types

Flowers

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 – Flowers containing only female parts
Staminate – Flowers containing only male parts

Plants

Monoecious (mə-nē'shəs) – Plants with separate male flowers and female flowers on the same plant (corn, squash, and pine)
Dioecious (dī-ē'shəs) – Plants with male flowers and female flowers on separate plants (maple, holly, and salt brush)

Inflorescence (flower arrangement on a stem) [Figure 3]

Catkin – A spike with only pistillate or staminate flowers (poplar, walnut**,** willows)

Composite or Head – A daisy-type flower composed of ray flowers (usually sterile with attractive, colored petals) around the edge and disc flowers that develop into seed in center of the flat head (sunflower and aster) In some composites, the ray and disc flowers are similar (chrysanthemums, dahlias)

Corymb – Stemlets (*pedicels*) arranged along main stem. Outer florets have longer pedicels than inner florets giving the display a flat top. (yarrow, crabapple)

Cyme – A determinate, flat or convex flower, with inner floret opening first.

Panicle – An indeterminate flower with repeated branching. It can be made up of racemes, spikes, corymbs or umbels(begonia).

Raceme – A modification of a spike with flowers attached to a main stem (*peduncle*) by stemlets (*pedicel*) (snapdragon, bleeding heart)

Solitary (or single) – One flower per stem (tulip, crocus)

Spadix – Showy part is a bract or *spathe,* partially surrounding the male and female flowers inside. (calla, caladium)

Spike – Flowers attached to main stem, without stemlets, bottom florets open first. (gladiolus, ajuga and gayfeather)

Umbel – Florets with stemlets attached to main stem at one central point, forming a flat or rounded top. Outer florets open first. (dill, onion)

Symmetrical – Symmetrical flowers (lily)

Asymmetrical – Asymmetrical flowers (snapdragon)

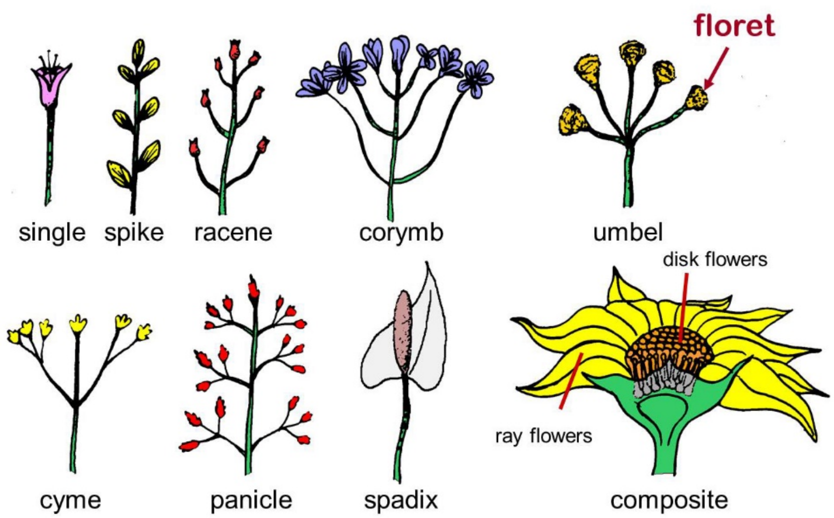

Figure 3. Flower Inflorescences

Nectar guides

To produce fruit and seed and insure 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 the protein rich pollen, is the prize.

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; 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's an example of mutualism which ensures efficient pollination for the plant and fast nectar and pollen collection for the insects.

Fig.4 Nectar guides on *Penstemon* (lines on flower)

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CMG GardenNotes #136

Plant Structures: Fruit

Thought question:

- Why are fading flowers removed from spring flowering bulbs and other flowering ornamental plants?

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

Function

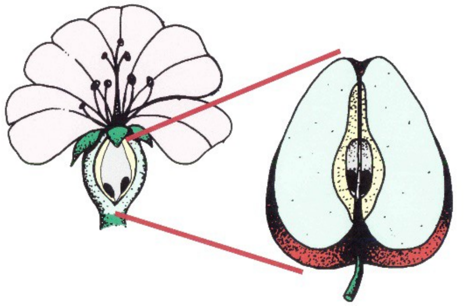
- Reproduction
- Horticulture uses
    - Feed, food, and oils
    - Aesthetic qualities
    - Plant identification

Structure

Fruit consists of carpels where the ovules (seeds) develop and the ovary wall or **pericarp**, which may be fleshy (as in apples) or dry and hard (as in an acorn). Some fruits have seeds (mature ovules) enclosed within the ovary (apples, peaches, oranges, squash and cucumbers). 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.

Other fruit have seeds that are situated on the periphery of the pericarp (corncob, strawberry flesh).

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



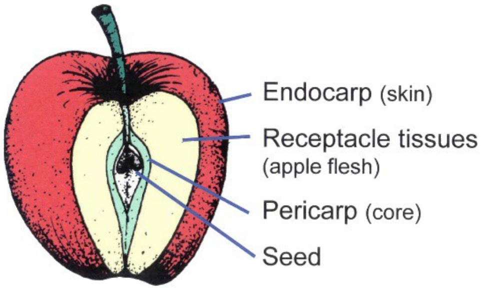
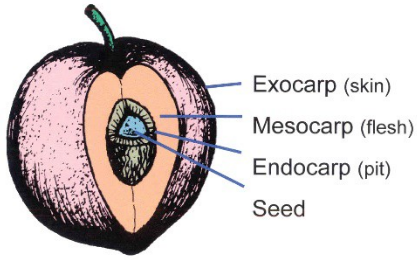


Figure 2. Pome fruit (apple)

Figure 3. Stone fruit (peach)

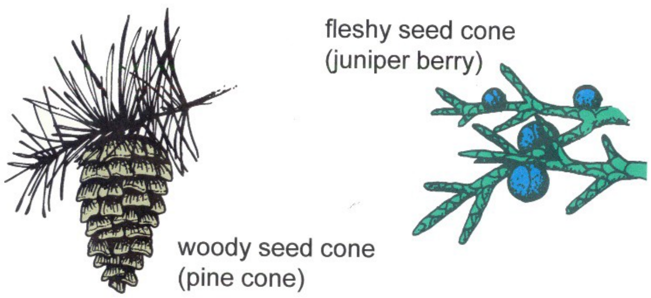


Fruit Types

<u>Conifers</u>

Conifers are best known for their woody cones, pinecones. Junipers are an example of a conifer with a fleshy cone (juniper berry). Upon close examination, the overlapping scales can be observed.

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



Flowering Plants

Depending on flower structure and inflorescence type, fruits may be either simple, aggregate**,** or multiple.

Accessory- fruit having some flesh derived from tissue exterior to the carpel.
Simple – Fruit formed from one ovary.
Aggregate – Fruit formed from a single flower with many ovaries. If not all ovaries are pollinated and fertilized, fruit will be misshapen (raspberry, magnolia).
Multiple – Fruit developed from a fusion of separate, independent flowers borne on a single structure (mulberry, pineapple, beet seed).

Fruit Growth Terms

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

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

Drop – Fruit drops when not pollinated or fertilized and when too much fruit sets on a tree.

Growth –Primarily cell enlargement as the cells fill with water.

Climacteric – Point when a fruit will continue to ripen if removed from a plant; for example, pumpkins turning orange after being harvested.

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CMG GardenNotes #137

Plant Structures: Seeds

A seed (mature ovule) is a miniature plant with a protective cover in a suspended state of development. Most seeds contain a built-in food supply called endosperm (orchid is an exception). The endosperm can be made up of proteins, carbohydrates**,** or fats.

Function

- Propagation
- Feed
- Horticultural uses
    - Feed, food and oil

Structure and Emergence

Seeds of monocots and dicots differ in structure.

Monocot Seeds

Seed coat – Forms the wall of the embryo sack (mother tissue)

Endosperm – Food supply containing 3 sets of chromosomes (2 from the mother and 1 from the father)

Embryo – Immature plant

Cotyledon – Seed leaf
Plumule – Shoot

Radicle – Root

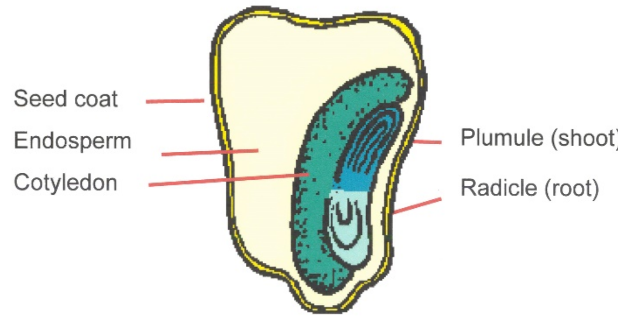


Figure 1. Cross section of monocot seed (corn).

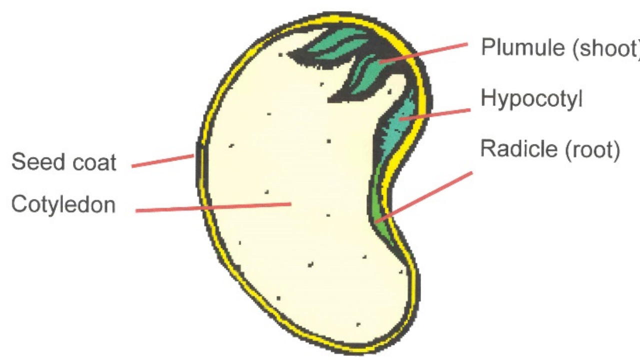
__Dicot Seeds__

Seed coat – The protective outer covering of a seed.

Embryo – Immature plant

Cotyledon – Food storing seed leaf
Plumule – Shoot
Hypocotyl – Stem
Radicle – Root

Figure 3. Cross section of dicot seed (bean).



Seed Growth and Development Terms

Dormancy – State of suspended growth to survive adverse conditions and aid in dispersion. Adapting plants to a variety of hostile environments, nature programs a variety of germination blocks. The following are common types.

Seed coat dormancy – When the seed coat is impermeable to water, and gases (oxygen). It requires action by weathering, microorganisms, passage through an animal's digestive track**,** or fire to soften the seed coat.

Embryo dormancy – Due to physiological conditions or germination blocks in the embryo itself. It requires a specific period of cold (or heat) with available moisture and oxygen. Embryo dormancy is common in woody plants.

Double dormancy – Condition of both seed coat and embryo dormancy.

Chemical inhibitor dormancy – Seed contains some type of chemical that blocks germination. Many desert plants contain chemical germination inhibitors that are leached out in a soaking rain.

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

Stratification – Techniques used to overcome dormancy.

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CMG GardenNotes #141

Plant Physiology:
Photosynthesis, Respiration, and Transpiration

Thought question

Explain the science behind the following question

1. What's the impact on air temperatures when restrictions in landscape irrigation create droughty urban landscapes?

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

- **Photosynthesis –** The process of capturing light energy and converting it to sugar energy, in the presence of chlorophyll using carbon dioxide (CO_2) and water (H_2O).
- **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

Photosynthesis

A primary difference between plants and animals is the plant's ability to manufacture its own food. In ***photosynthesis,*** carbon dioxide from the air and water from the soil react with the sun's energy to form ***photosynthates*** (sugars, starches, carbohydrates, and proteins) and release oxygen as a byproduct. [Figure 1]

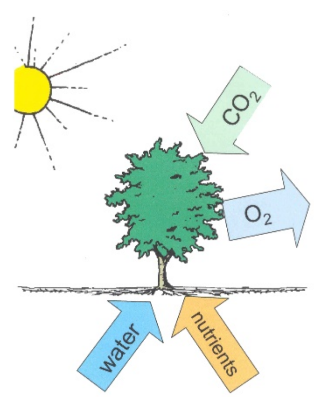


Figure 1. In photosynthesis, the plant uses water and nutrients from the soil and carbon dioxide from the air, with the sun's energy to create photosynthates. Oxygen is released as a byproduct.

Photosynthesis literally means *to put together with light.* It occurs only in the ***chloroplasts***, tiny sub-cellular structures contained in the cells of leaves and green stems. A simple chemical equation for photosynthesis is given as follows:

carbon dioxide + water + light energy = glucose + oxygen

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

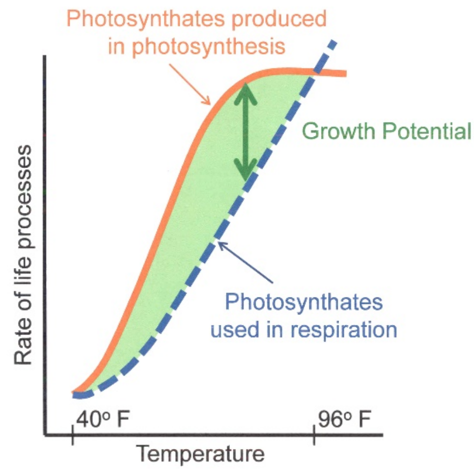
.

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 restrictions on landscape irrigation is a reduction in photosynthesis and thus a decrease in plant vigor and growth.

In a tightly closed greenhouse there can be very little fresh air infiltration and carbon dioxide levels can become limiting, thus limiting plant growth. In the winter, many large commercial greenhouses provide supplemental carbon dioxide to stimulate plant growth.

The rate of photosynthesis is somewhat temperature dependent. For example, when temperatures rise above 96°F in tomatoes, the rate of food used by respiration rises above the rate of food manufacture through photosynthesis. Plant growth comes to a stop and produce loses its sweetness. Most other plants are similar. [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 an ingredient in photosynthesis and cell growth.

Transpiration serves three essential roles:

- **Movement of minerals** up from the root (in the xylem) and sugars (products of photosynthesis) throughout the plant (in the 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 the non-woody plant parts form. Turgidity is important so the plant can remain stiff and upright and have a competitive advantage when it comes to light. Turgidity is also important for the functioning of the guard cells, which surround the stomates and regulate water loss and carbon dioxide uptake. Turgidity also is the force that pushes roots through the soil.

Water movement in plants is also a factor of 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 his "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. The salt level in the soil's water becomes higher than in the roots, and water flows from the roots into the soil's water in an effort to dilute the concentration. So what should you do if you accidentally apply too much fertilizer to your lawn?

Capillary action refers to the chemical forces that move water as a continuous film rather than as individual molecules. 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.

Respiration

In ***respiration***, plants (and animals) convert the sugars (photosynthates) back into energy for growth and other life processes (metabolic processes). The chemical equation for respiration shows that the photosynthates are combined with oxygen releasing energy, carbon dioxide, and water. A simple chemical equation for respiration is given below. 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 combine with oxygen, 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 the more oxygen they need. That 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.

Again, respiration is the burning of photosynthates for energy to grow and to do the internal "work" of living. It is very important to understand that both plants and animals (including microorganisms) need oxygen for respiration. This is why overly wet or saturated soils are detrimental to root growth and function, as well as the decomposition processes carried out by microorganisms in the soil.

The same principles regarding limiting factors are valid for both photosynthesis and respiration.

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 most 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, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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MASTER GARDENER
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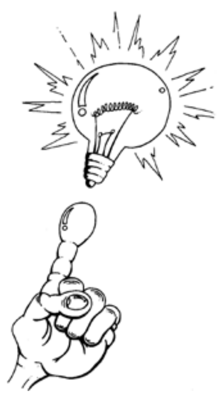
CMG GardenNotes #142

Plant Growth Factors: Light



Thought questions

Explain the science behind the following gardening questions.

- Why won't my African violets bloom? They are on a table near a bright northern window.
- Why is my flowerbed doing poorly? I planted it with a variety of semi-shade annuals since it gets sun only in the afternoon. Plant growth is minimal and foliage is bleached out. The impatiens wilt even when the soil is moist.
- I shear my shrubs a couple of times a year into nice rounded shapes. Why are they becoming thick woody stems at the base with lots of dead twigs?
- Why won't my Christmas cactus blossom? It is in front of a bright window and the plant is full and robust. It is a cutting from my mother's plant that she keeps in the guest bedroom and which blooms profusely each Christmas and again in the spring.

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

Light Quality

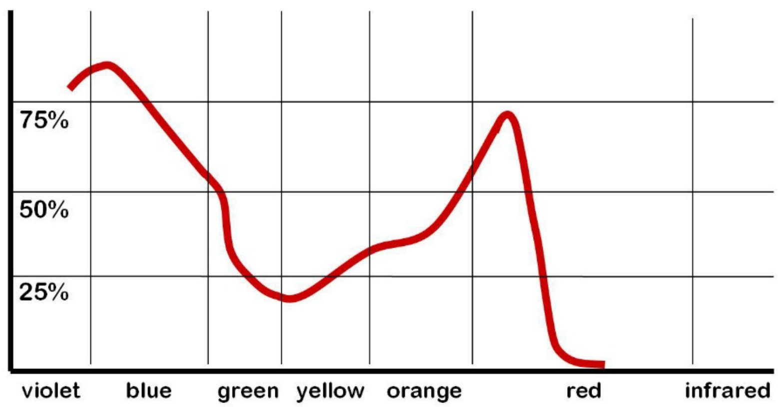
Light quality refers to the color or wavelength reaching the plant's surface. A prism (or raindrops) can divide sunlight into respective colors of red, orange, yellow, green, blue, indigo and violet.

Red and blue have the greatest impact on plant growth. Green light is least effective (the reflection of green light gives the green color to plants). Blue light is primarily responsible for vegetative leaf growth. Red light, when combined with blue light, encourages flowering.

Light quality is a major consideration for indoor growing.

- Fluorescent cool white lamps are high in the blue range, and the best choice for starting seeds indoors.
- For flowering plants that need more red light, use broad spectrum fluorescent bulbs.
- Incandescent lights are high in red and red-orange, but generally produce too much heat for use in supplementing plant growth.

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 sun scorch when moved to a bright location. Over time, as the wax content on a leaf increases, it will become more sun tolerant.

Figure 2. Light Intensity for Various Situations

Light intensity is measured in *lux* or *foot-candles*.

Situation	Foot Candles		Crops
summer full sun	12,000 – 8,000		
bright overcast (0-25% direct)	5,000 – 2,000	4,000 – 1,200	outdoor crops
heavy overcast (100% scattered)	1,000 – 500	1,000 – 500	bright light house plants
		500 – 200	moderate light house plants
home interior	300 – 50	200 – 50	low light house plants

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.

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 differences between these seven degrees of sun/shade:

Full sun – Direct sun for at least 8 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 is most limiting. Only the most shade-tolerant plants will survive this situation, like under a deck or covered patio.

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. For example, dwarf apple trees are pruned to a Christmas tree shape. This gives better light penetration for 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.

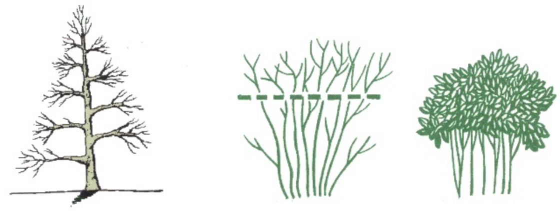


Figure 3. Light penetration is a primary influence in pruning. Left: Dwarf apple trees pruned to a Christmas tree shape allow better light penetration for best quality fruit. Right: Regrowth on flowering shrubs that are sheared on top is a very heavy upper canopy growth. This shades out the bottom creating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

Plants are generally intolerant of continuous light for 24 hours.

Photoperiod

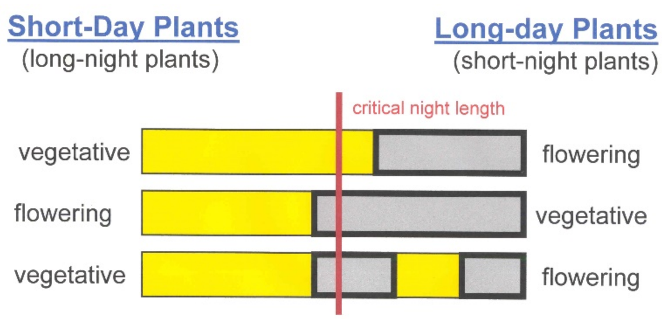
The flowering response of many plants is controlled by the ***photoperiod*** (the length of uninterrupted darkness). Photoperiod response can be divided into three types.

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 short periods of night darkness. Examples include onions 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.



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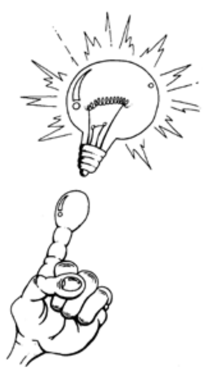
Revised July 2016

CMG GardenNotes #143

Plant Growth Factors: Temperature



Thought questions

Explain the science behind the following gardening questions.

- Why was there so much winter injury on my trees and shrubs? While it was dry and windy, temperatures were not extremely cold.
- My arborvitaes are bleached tan from the winter. Will they green-up with spring temperatures?
- With the rather hot summer, will the apple and peach crop be as sweet as normal?

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.

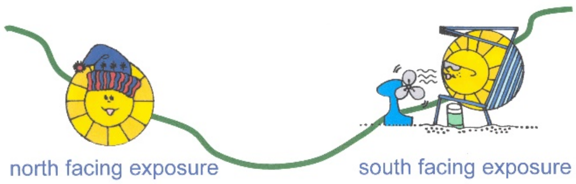
Drainage – At night, cool air drains to low spots. Valley floors may be more than 10°F cooler than surrounding gardens on hillsides above the valley floor. That is why fruit orchards are typically located on the benches rather than on the valley floor.

Figure 1. This garden on the 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.

Based on local topography, buildings, fences, plantings and garden areas may be protected from or exposed to cold and drying winds. They may also be exposed to or protected from warm 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 exposures 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 for enhanced crop growth. In warmer locations, rock mulch can significantly increase summer temperatures and water requirements of landscape plants. [Figure 3]

In Phoenix, Arizona, the urban heat island (with all the rock mulch instead of grass and trees) has significantly raised day and night temperatures. The upward convection of heat has become so strong that summer storms go around the city and are not raining on the urban heat island.

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

Influence of Heat on Crop Growth

Temperature affects the growth and productivity of plants, depending on whether the plant is a warm season or cool season crop.

<u>Photosynthesis</u> – Within limits, rates of photosynthesis and respiration both rise with increasing temperatures. As temperatures reach the upper growing limits for the crop, the rate of food used by respiration may exceed the rate at which food is manufactured by photosynthesis. For tomatoes, growth peaks at 96°F.

<u>Temperature influence on growth</u>

Seeds of cool season crops germinate at 40º to 80º. Warm season crop seeds germinate at 50°F to 90°F. In the spring, cool soil temperatures are a limiting factor for plant growth. In mid-summer, hot soil temperatures may prohibit seed germination.

<u>Examples of temperature influence on flowering</u>

- Tomatoes
    - Pollen does not develop if night temperatures are below 55°F.
    - Blossoms drop if daytime temperatures rise above 95°F before 10 a.m.
    - 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 tomatoes and cool season cole crops.

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

Temperature for	**Cool Season:** broccoli, cabbage, and cauliflower	**Warm Season:** tomatoes, peppers, squash, and melons
Germination	40°F to 90°F, 80°F optimum	50°F to 100°F, 80°F optimum
Growth	Daytime • 65°F to 80°F preferred • 40°F minimum Nighttime • >32°F, tender transplants • > mid-20s°F, established plants	Daytime • 86°F optimum • 60°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 by 10 a.m., blossoms abort
Soil	Cool • Use organic mulch to cool soil. • 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 mulch to warm soil, increasing yields and earliness of crop.

Heat Zone Map

A new concept in plant selection is ***heat zone mapping***, a measurement of the typical summer heat accumulation. It will help identify geographic areas that have adequate heat accumulation to mature various crops.

The American Horticultural Society's Heat Zone Map can be viewed online at: www.ahs.org/publications/heat_zone_map.htm.

Heat zones can be sorted by zip codes. To look up a heat zone by zip code, go

online at www.ahs.org/publications/heat_zone_finder.htm.
It should be recognized that in mountain communities, minor changes in elevation and exposure (for example, south slopes versus north slopes) make significant differences in heat accumulation. A heat zone for a community's zip code may not reflect the actual growing conditions in any specific garden.

Influence of Cold Temperatures

Hardiness Zone Map

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 http://planthardiness.ars.usda.gov/PHZMWeb/. 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

Most of the Colorado Front Range area falls into Zone 5, with cool mountain areas in Zone 4. Warmer locations in the Denver Metro, Fort Collins, El Paso, and Pueblo Counties fall into Zone 6. Warmer areas of western, southwestern, and southeastern Colorado are in Zone 6.

Plant Hardiness

Hardiness refers to a plant's tolerance to cold temperatures. Low temperature is only one of many factors influencing plant hardiness (ability to tolerate cold temperatures). Key hardiness factors include the following: [Figure 4]

- Photoperiod
- Genetics (source of plant material)
- Low temperature
- Recent temperature pattern
- Rapid temperature changes
- Moisture
- Wind exposure
- Sun exposure
- Carbohydrate reserve

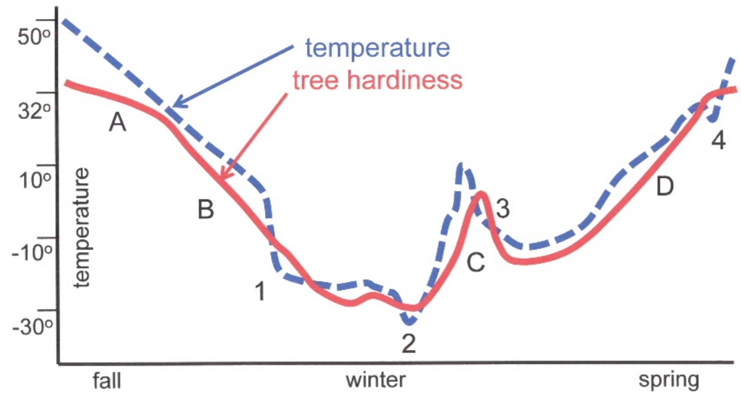


Figure 4. Influence of temperature change on winter hardiness of trees – The solid line represents a tree's hardiness. Regions A-D represents various stages of hardiness through the winter season. The dotted line represents temperature. When the dotted (temperature) line drops below the solid (hardiness)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

A. Increased cold hardiness induced by shorter day length 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]

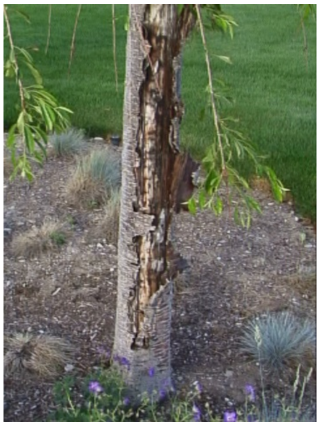


Figure 5. Southwest bark injury is common on trees that are drought stressed, such as this tree with a restricted root spread.

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 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 needles, followed by rapid temperature drop rupturing cell membranes. It occurs typically on 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 below 45°F) required to break bud dormancy includes:

Apricot	350-900 hour	Peach	800-1200 hours
Apple	250-1700 hours	Pear	200-1500 hours
Cherry, sour	600-1400 hours	Plum, European	900-1700 hours
Cherry, sweet	500-1300 hours	Plum, Japanese	300-1200 hours

Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension.
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MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #144

Plant Growth Factors: Water

Thought Question

1. Review how water stress impacts plant growth processes, then list common symptoms of drought stress.

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

Available water limits potential for crops and gardens in many areas of the west. In cities, the cost of the infrastructure to supply water drives the need for water conservation.

Water management is a topic of other Colorado Master Gardener training classes. For additional information on water management, refer to CMG GardenNotes on Irrigation Management and Water-Wise Landscape Design.

Role of Water

Plants are over 90% water. Roles of water are summarized in Table 1.

Table 1.
Role of Water in Plant Growth

Role of water in plants	Impact of water shortage
• Primary component of photosynthesis and transpiration	• Reduced 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 o 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 growth and plant 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
• 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

Common Symptoms 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

Water Logged 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

- Lower interior leaves may yellow

Leaf Scorch (short-term water deficiency in leaves)

- Marginal burning
- Often from the top down, on southwest side, or from the side with root injury or root restrictions

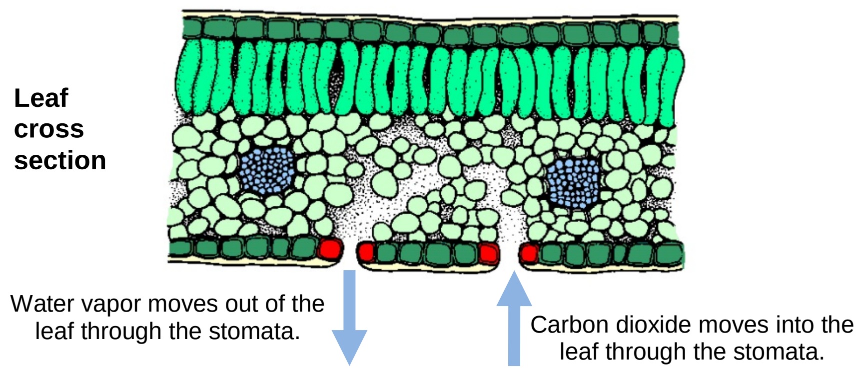
Contributing factors to leaf scorch

- 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
- Excessive canopy growth (from heavy fertilization)

Relative Humidity

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.



Outdoors – In the arid climate of the west, low summer humidity helps manage some insect and disease problems and can aggravate others. The relative humidity returns to normal levels within a few minutes of watering/irrigation.

Indoors – With forced air heating, many homes have very low relative humidity in the winter. Some homes can have excessively high relative humidity due to a large number of houseplants, cooking and frequent long showers. Both extremely high and low indoor relative humidity are health concerns.

Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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MASTER GARDENER
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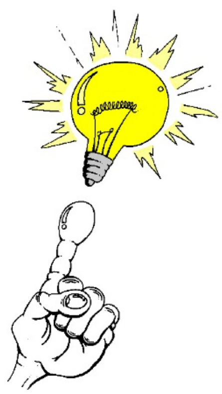
CMG GardenNotes #145

Plant Growth Factors: Plant Hormones



Thought questions

Explain the science behind the following gardening questions:

- A couple of times a year, I shear my shrubs into rounded shapes. Now the shrubs have large woody stems with a lot of dead branches. How do I correct this?
- I put a stake next to a small tree trunk to keep it straight. When I took it off a year later the trunk had a worse bend than before. Why?

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 the growth processes.

Plant growth regulators are chemicals applied to regulate plant growth. 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. Because plant growth regulators are effective in parts per million or parts per billion, they have little application in home gardening.

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, fruit drop or retention.

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 2 to 3 weeks earlier)

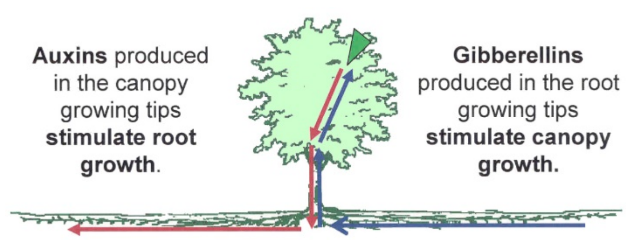
Cytokinins promote cell division, and influence cell differentiation and aging of leaves.

Abscisic acid is considered the "stress" hormone. It inhibits the effects of other hormones to reduce growth during times of plant stress.

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, slowing root regeneration.

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



Heading cuts (removal of a branch tip) releases the apical dominance caused 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 branch back to the branch union (crotch). This type of cut opens the plant to more light. Most pruning should be limited to thinning cuts. For details on pruning, refer to CMG Pruning fact sheets.

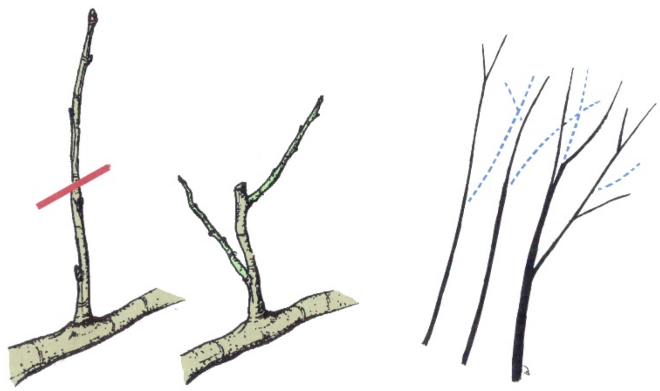


Figure 3. Left: A **heading cut** releases apical dominance and the branch becomes denser as the lateral buds begin to grow. Right: A **thinning cut** removes a branch back at a branch union (crotch), opening the plant for better light penetration. Thinning cuts promote an open growth habit by redirecting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

Tropisms

Auxins also play a key role in ***tropism*** (controlling the direction of plant growth).

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.

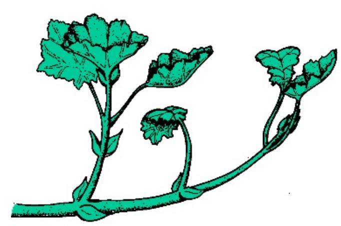
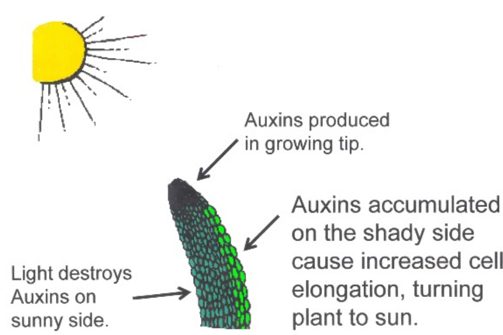


Figure 5. ***Phototropism*** – Auxin concentrations on the shaded side stimulates cell elongation, turning the stem to the sun.



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