

Plant Structure and Function

2014 Master Gardener Core Course
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Plant Structure and Function

■ Structure:

- Anatomy – internal
- Morphology – external

■ Function (Physiology):

- Photosynthesis
- Respiration
- Pollination and Fertilization
- Germination

Our discussions will center on the structure of plants and the basic functions that allow plants to live, grow and reproduce. Discussions of structure will be primarily morphological, that is, the gross structure of plants. A little time will be spent on anatomy as a means of explaining various responses to environmental and maintenance variables. What the heck does that mean? Why do leaves wilt? How does deicing salt drift affect foliage? What internal effects are the result of cold winters?

Plant Classification Systems

- Botanical
- Life Cycle
- Use

Different plant classification systems are useful for different reasons. Botanical classification is essential for plant identification, ordering the exact plant that is wanted, or diagnosing plant problems. The life cycle classification system is convenient when describing plants to “normal” people (non-horticulturists). For instance, “How about using some annual plants as seasonal attention-getters in the landscape?” Finally, use classification systems are equally useful, especially when describing landscape designs. Example: “A large shade tree on the west side of the house will lower energy bills in the summer.” Or, “How about installing a privacy hedge between the deck and the highway?”

Botanical Classification System

- Kingdom *Plantae*:

- Vascular Plants:

- Seed Plants

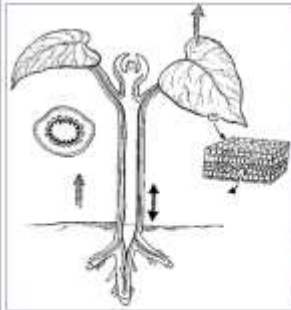
- Phylum *Ginkgophyta* (ginkgo)

- Phylum *Coniferophyta*
(conifers)

- Phylum *Anthophyta*
(angiosperms)

We will be focusing our core course studies on plants that belong to three phyla: Ginkgophyta represented by the tree *Ginkgo biloba*; coniferophyta and Anthophyta, the true flowering plants. Most of our time and examples will involve the phylum Anthophyta.

A Vascular Plant



Vascular plants are those [plants](#) that have [lignified tissues](#) for conducting [water](#), minerals, and photosynthetic products through the plant.

Non-Vascular Plants



Non-vascular plants is a general term for those [plants](#) without a [vascular system](#) ([xylem](#) and [phloem](#)). Although non-vascular plants lack these particular tissues, a number of non-vascular plants possess tissues specialized for internal transport of [water](#).

Meet the Generals: Ginkgo, Conifers and Flowering Plants



By learning about the general plant groups, we can effectively learn a lot about the specific plants that belong to each phylum. For instance, all plants within the phylum Anthophyta have the ability to reproduce by seed.

Meet the Conifers



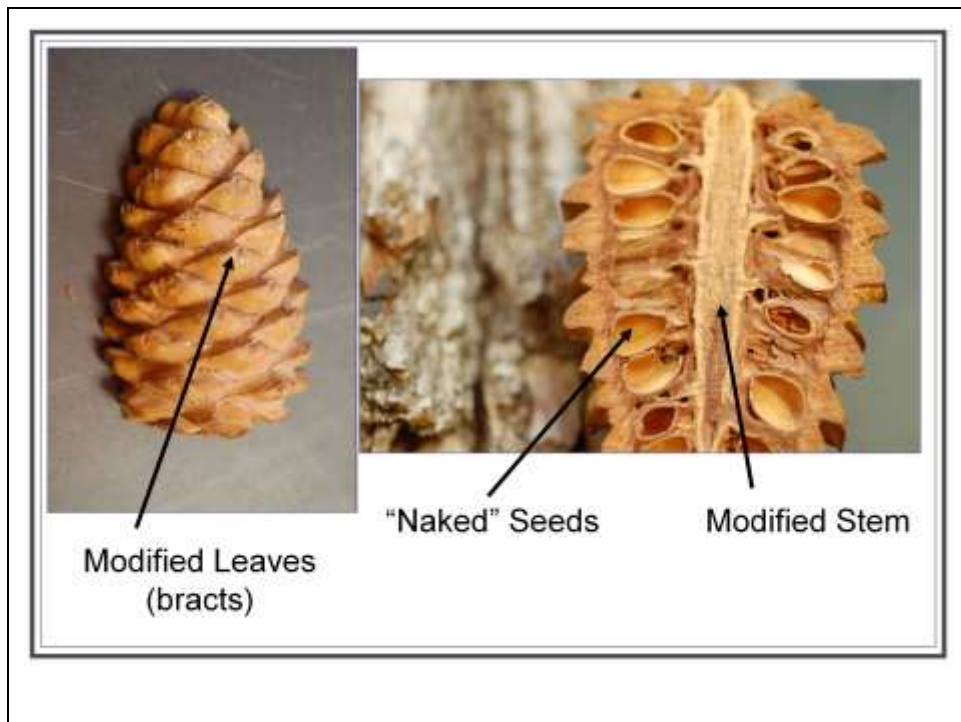
Coniferophyta

- "Naked" Seeds
- Woody
- Resin Canals
- Most are Evergreen
- "Softwoods"
- "Needle-like" Leaves

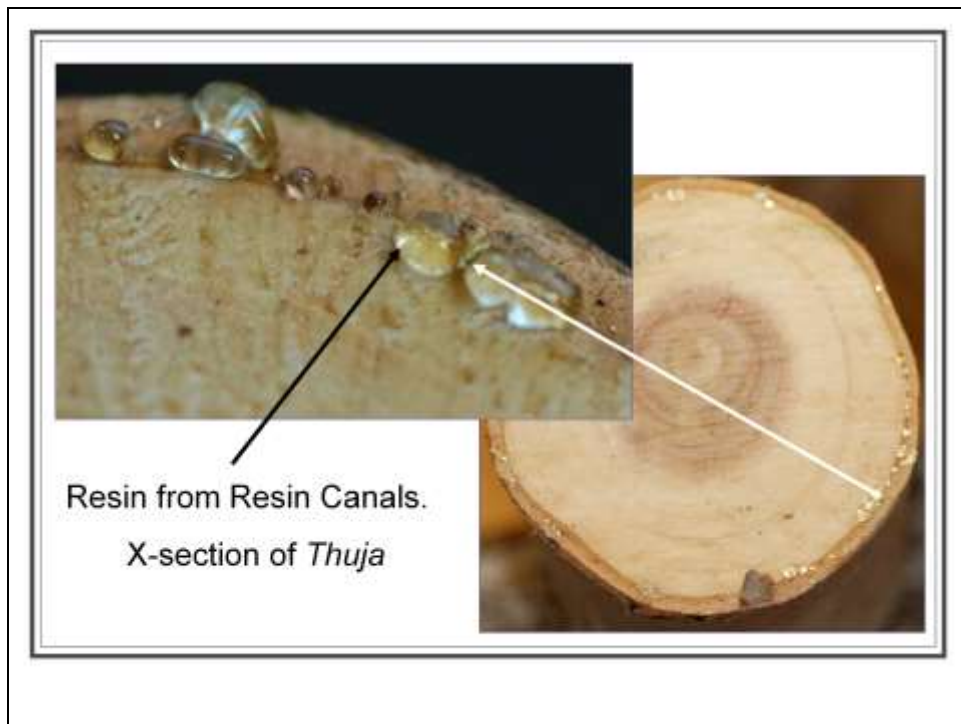


Botanical classifications allow us to make some generalizations about the members of a particular group of plants. For instance, those plants that fall into the phylum Coniferophyta (i.e., the conifers) have several commonalities ranging from the morphology of their leaves to the anatomy of their stems.

Most conifers, especially those that we enjoy in Minnesota, are evergreen. However, there are a number of deciduous (loses the foliage in the autumn) conifers, even one that's native to Minnesota. Deciduous conifers that grow in Minnesota include the native *Larix laricina* (larch), three other species of *Larix* and *Taxodium distichum* (baldcypress). The beautiful dawn redwood is also a deciduous conifer.




Note the anatomy of a conifer seed cone. Conifers have "naked seeds" as one commonality. The seeds are actually enclosed in a seed cone, which is a modified stem and leaf structure. Still, the seeds are botanically classified as "naked" because they are not enclosed in a fruit (ripened ovary). Strictly a botanical definition and classification so don't get upset if it doesn't conform to your logic or what you would prefer to name it.



Another anatomical characteristic that many conifers share, especially those conifers that grow in Minnesota, is the presence of resin canals. Note the exuding resin in the sapwood/cambium area of this *Thuja occidentalis* (northern white cedar). Resin is used to make medicines and furniture finishing products among other useful by-products.


Meet the TRUE Flowering Plants




Fiddle-leaf Fig


■ Anthophyta

- Seeds Enclosed in Fruit
- True Flowering Plants
- Herbaceous and Woody
- Deciduous or Evergreen
- "Hardwoods"
- Broad, Thin Leaves.



Pea





Boxwood

The phylum Anthophyta represent the largest collection of plants that we work with and enjoy. Our grain crops, landscape plants and vegetable gardens are dominated by these plants that are also referred to as the true flowering plants.

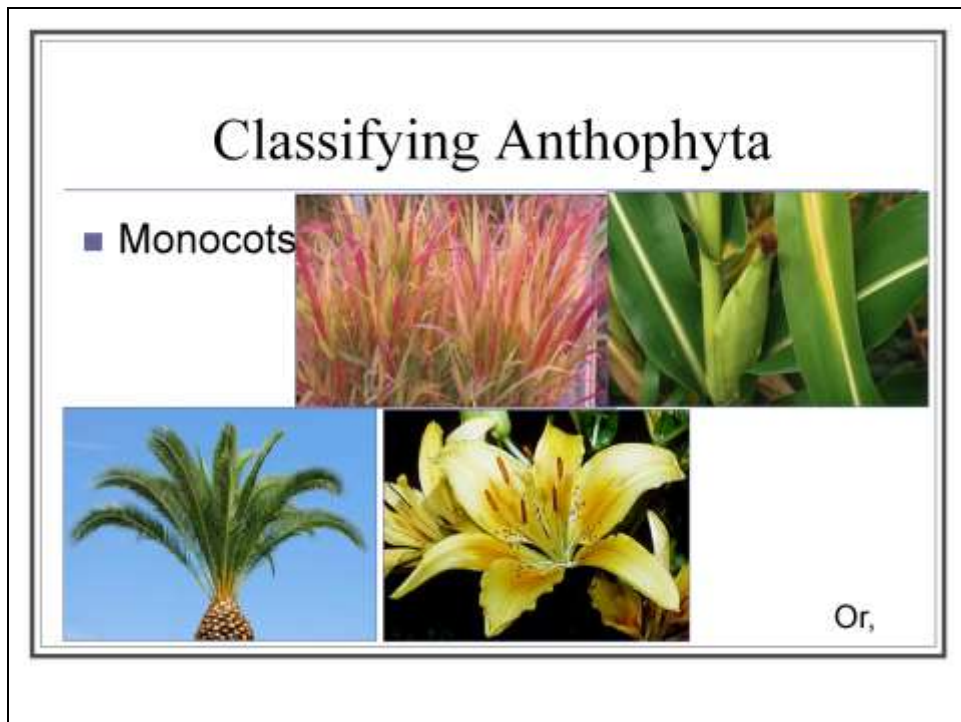
As with the conifers, the true flowering plants – a.k.a. angiosperms – have several commonalities among the members. Most notable, the seeds are enclosed in a fruit, or botanically speaking, enclosed within a ripened ovary. Ovaries are part of the female reproductive portion of a flower, hence the label “true flowering plants.” Conifers produce pollen, female cones, seeds, but do not produce flowers with ovaries that ripen to contain the seeds.

Angiosperms may be herbaceous (all vegetative tissue) like lettuce, woody like lindens or both like alfalfa. They may be deciduous (lose the vegetative foliage in autumn) as with maples, or evergreen where foliage remains on the plant for 2-3 years commonly as with pine trees.

Botanically, conifers are referred to as “softwoods” and angiosperms are “hardwoods.” This has nothing to do with the relative strength of the wood, and all to do with the type of tissues found in the wood. Conifers do not have fluid-conducting “vessels” in their woody tissues whereas angiosperms do. Vessels are the conductive tissues that are often referred to as “pores” and are clearly visible in annual growth rings of many trees such as ash, oak, elm.

Finally, leaves of angiosperms are primarily much broader and thinner than

conifer leaves, essentially providing them with a much larger leaf surface area to capture light for photosynthesis. This is one of the reasons that more angiosperms grow in low light conditions than conifers...broader leaves are more efficient at capturing available light than narrow, thick leaves.



Angiosperms (again, a.k.a., plants within the phylum Anthophyta, or a.k.a. true flowering plants) can be further classified as either monocotyledonous or dicotyledonous plants. This is yet another botanical classification that helps with the identification of plants and provides some general information about the members of these groups. Monocotyledonous plants, abbreviated as monocots, characteristically have one cotyledon (a.k.a., seed leaf) when they germinate from seed. As opposed to monocots, dicotyledonous plants which are abbreviated as dicots, are characterized as having two seed leaves when they germinate from seed.

The term “characteristically” is used instead of “always” because there’s always an exception to the rule. Cotyledons can break off or be eaten during the germination process. Some species don’t always have obvious seed leaves. Even some members within a species may mutate and lose the characteristic number of seed leaves. Nature can’t be pigeon-holed 100%, which is why it’s interesting!

Classifying Anthophyta

■ Dicots



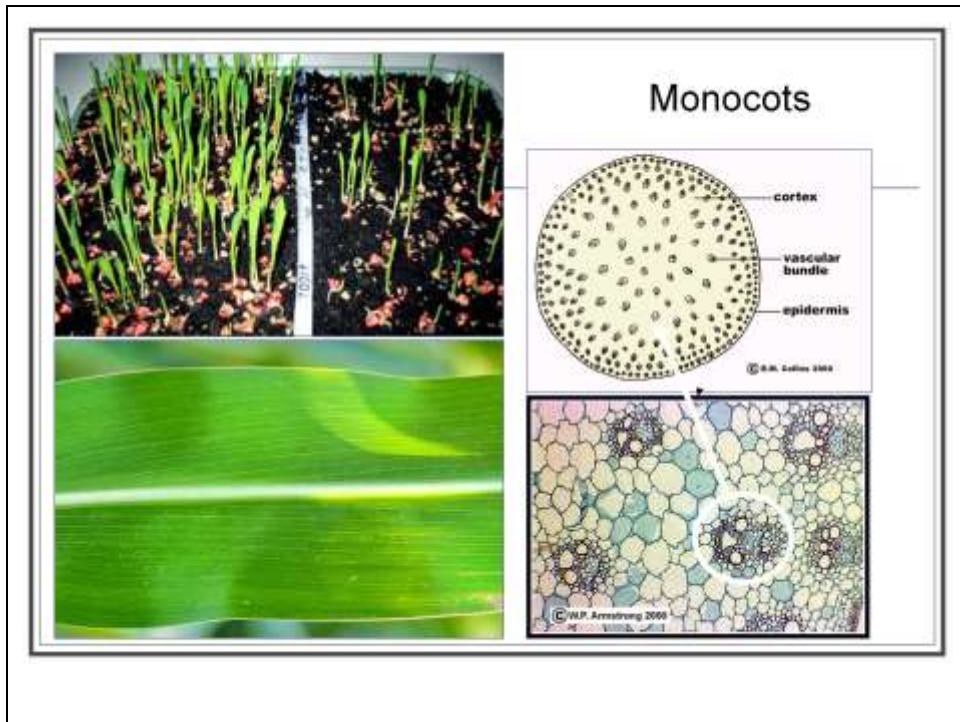
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Monocotyledonous Flowering Plants

- 1 Seed leaf (cotyledon)
- Parallel leaf venation
- Floral parts in 3's or multiples of 3's
- Scattered vascular bundles

So, the characteristics of monocots include parallel venation in their leaves (think of a corn leaf), floral parts (specifically the petals, sepals and stamens) in three's or multiples of 3's (e.g., 6, 9, 12), and vascular bundles that appear scattered in a cross-section of a stem. Vascular bundles are comprised of phloem and xylem, the "plumbing pipes" of a plant. Water, nutrients, sap are passed throughout the plant via the vascular bundles.

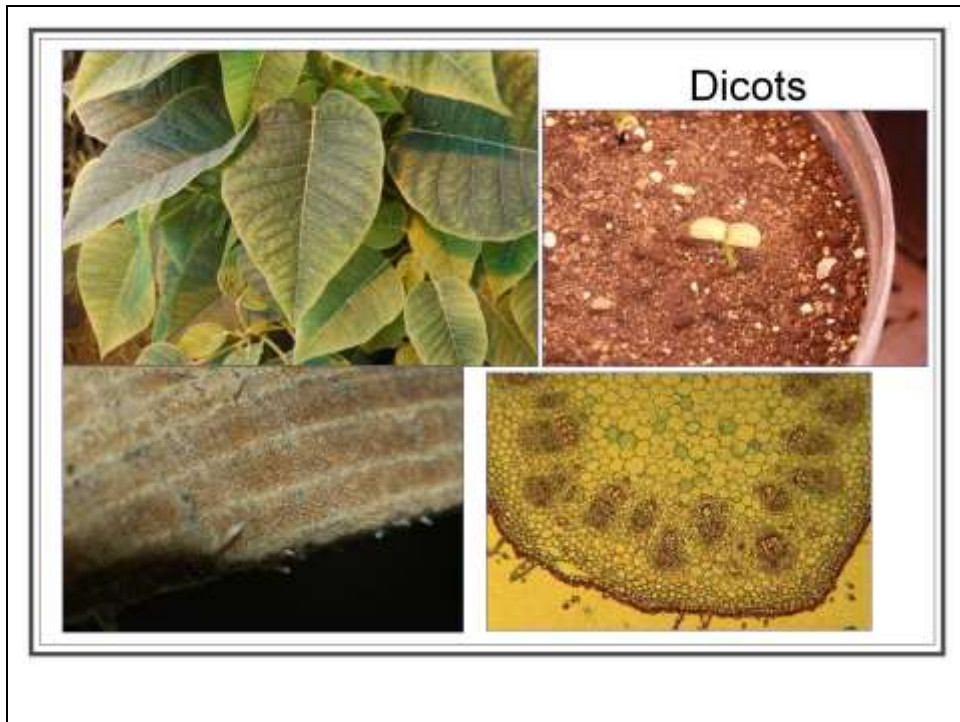


Note in the top left photo the single cotyledons of the germinated grasses in the pot. The photos to the right illustrate the scattered, random vascular system (bundles of xylem and phloem) characteristic of monocots. Finally, the lower left photo shows the characteristic parallel venation of monocots. Grain crops are monocots and are arguably our most economically important angiosperms.

Dicotyledonous Flowering Plants

- 2 Seed leaves (cotyledons)
- Netted leaf venation
- Floral parts in 4's or 5's or multiples
- Vascular bundles arranged

Dicots characteristically have netted leaf venation patterns as opposed to the parallel patterns of monocots. Netted venation patterns can be as complex as a pinnate pattern (a central vein with smaller veins branching off, similar to a bird's feather) or as beautiful as a palmate pattern (similar to the fingers radiating out from the palm of your hand). Floral parts are arranged in groups of 4's or 5's (or multiples of those numbers) and vascular bundles (a.k.a. pores) are arranged in a very tidy manner, rather than scattered randomly throughout the stem cross-section.



The upper left photo shows a pinnately-veined leaf, one of the netted venation patterns of dicot leaves. The upper right photo shows the characteristic two seed leaves of a dicot and the lower photo illustrates the orderly arrangement of vascular bundles into what is termed annual growth rings in woody, perennial plants.

There are literally tens of thousands of plants in North America. By recognizing whether a plant is a monocot, dicot or conifer by its germinating seedling, its flower or its stem, at least you've narrowed down the possibilities of what kind of plant you may be looking at. It's kind of a handy way of managing a large number of plants. And even if you don't know exactly what kind of plant you're looking at, you can still make some cultural judgements. For instance, if you have sown a packet of petunia seeds in a garden or flat, and all you see are seedlings with single seed leaves germinating...you know you have a problem! Namely, a weed problem! All you would need to do is look up information on petunias in a botanical reference and you would find out that they are dicots. So, either you purchased a mis-labeled packet of seeds or you inherited a pretty severe weed problem in the soil that you sowed the seeds.

Kingdom *Plantae*

- Phylum *Anthophyta*
 - Class *Monocotyledones*
 - Order *Commelinales*
 - Family *Poaceae*
 - Genus *Zea*
 - Species *mays*
 - botanical variety
 - cultivated variety
 - CORN!

The botanical classification system allows a gardener or botanist to positively identify the exact plant they are trying to grow, purchase or diagnose problems affecting the plant. Sometimes, it's important to know plants a bit more specifically than just identifying them as a monocot or dicot. For instance, if you wanted to grow the native corn plant, you would need to purchase *Zea mays* seed. You couldn't just walk into a store and pick up a packet of "monocot" seed and expect to grow corn.

Family Values



Meet the Rose Family

Often, just knowing which botanical “family” a plant belongs to is sufficient. For instance, members of a family have a lot of common traits, which may be all that you are interested in knowing or learning about. The Poaceae family (grass family) is made up of many genera of plants that have similar characteristics: similar flowers and fruit, herbaceous in nature, quite often are very good ground cover plants, usually are lousy shade trees! And most often, require full sun to grow best (yes, there are exceptions to these “rules”...remember, it’s biology not math).

Family Values

■ Family Characteristics:

- Common Floral Features
- Common Uses
- Common Ranges



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Family Values

■ Family Characteristics:

- Common Floral or Reproductive Features
- Common Uses
- Common Range Characteristics



*Poaceae or Grass
Family*

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Family Values



Legume or Pea Family and bacterial nodules on roots

Often, just knowing which botanical “family” a plant belongs to is sufficient. For instance, members of a family have a lot of common traits, which may be all that you are interested in knowing or learning about. The pea (legume) family is characterized by flowers that look like pea flowers, fruits that are simple, dry fruits that have seams on two sides. These seams then open when the fruit is ripe, releasing the seeds. Additionally, all members of the legume family have nitrogen-fixing, bacterial nodules associated with their root systems. Legumes range from soybeans to Kentucky coffeetrees.

Family Values



Deadly
Nightshade



Tomato



Petunia...yes, Petunia!

The family Solanaceae is also informally known as the **nightshade** or [potato](#) family. Many members of the Solanaceae family are used by humans, and are important sources of food, spice and medicine. However, Solanaceae species are often rich in [alkaloids](#) whose [toxicity](#) to humans and animals ranges from mildly irritating to fatal in small quantities.

Botanical versus Common Names

■ Botanical

- Unique
- Provides general information
- Same in India and Canada
- Makes you sound really smart

■ Common

- Often Regional
- Often very descriptive
- Sometimes easier to pronounce, remember
- Makes you sound like a normal person

Both botanical and common names are useful, but each has its place. Botanical names are exact and the same no matter where they are in the world. *Acer campestre* is the same in Russia as it is in Bolivia. Using botanical names is absolutely essential when diagnosing plant problems or purchasing that exact plant that you saw at the Arboretum. Having said that...

Common names are more comfortable and seemingly easier to remember. Quite often, they are very descriptive, such as white birch or red bud or ornamental kale. A problem, though, is that common names are often regional, making sense to people in the southeast U.S. but no sense to people in the Rocky Mountains.

Common Names

- Turkey Corn?
- Squirrel Corn?
- Bleeding Heart?



Every one of these common names have been used regionally to describe this flower that's native to the Appalachians.

Answer?

■ *Dicentra eximia*, a.k.a.,

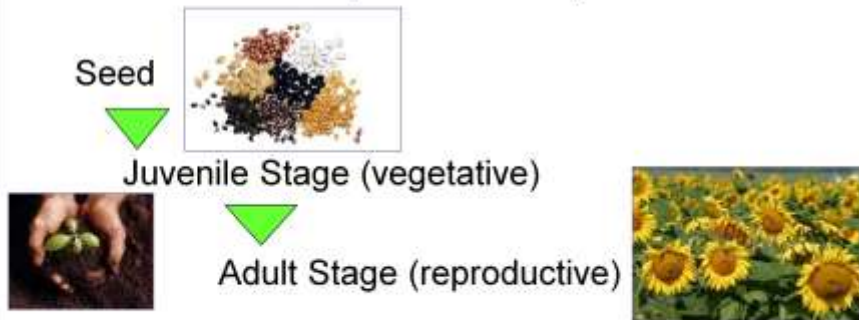
- Squirrel Corn
- Turkey Corn
- Wild Bleeding Heart
- Fringed Bleeding Heart



However, there is only one botanical name for this plant...*Dicentra eximia*.

Life Cycle Classification System

- Indicates the (relative) amount of time to complete a life cycle.



There are other classification systems that have their place, too, for instance life cycles. To begin, life cycle refers to the amount of time (relatively) that it takes for a plant to germinate, pass through juvenility and reach the reproductive (adult) phase.

Life Cycle Classification

- Annuals: Life Cycle Completed in One Growing Season.



Snapdragons



Soybeans

Annuals take one (or less) growing season to complete the life cycle. Most people know what you mean when you recommend annual flowers for a landscape. They're relatively inexpensive and quick color...but they generally last only one season.

Life Cycle Classification

- Biennials: Life Cycle Completed in Two Growing Seasons.
- Season One: Vegetative
- Season Two: Reproductive



Hollyhocks year 1



Hollyhocks year 2

Biennials require two growing seasons to complete their life cycle and then it's over. During the first year, biennials are solely vegetative and often don't even look like the pictures in the seed catalogue. However, hollyhock is in this picture and is one of the most beautiful garden and field flowers...and is a biennial or perennial, depending on the species and variety.

Life Cycle Classification

- Perennials: Lifespan of More Than Two Years.

- Herbaceous: Renewal buds at or below ground.



Hoary Puccoon



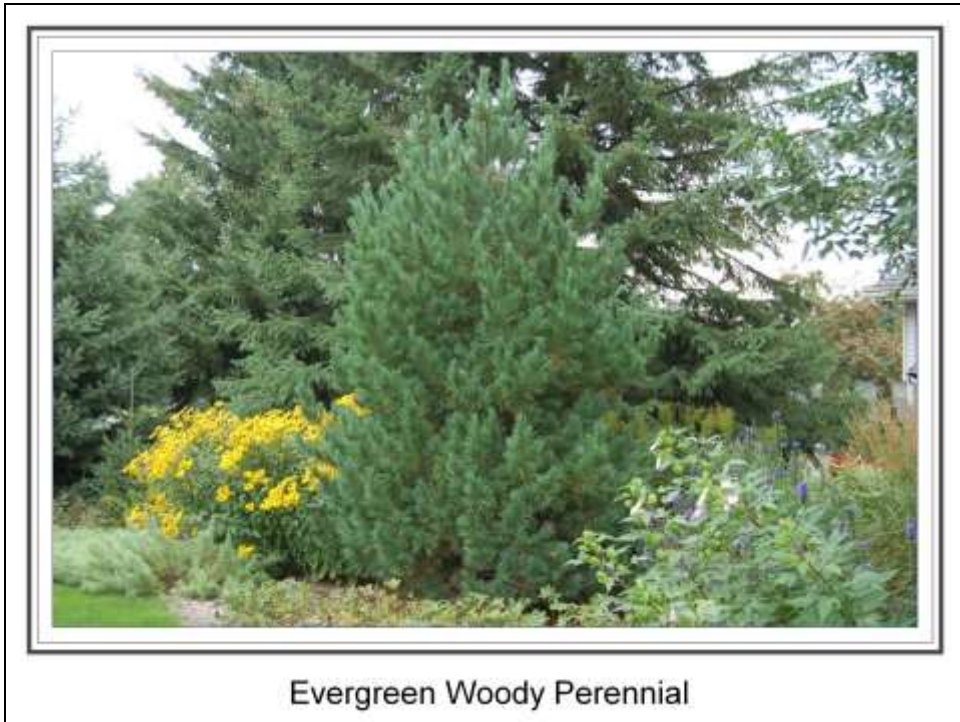
Gooseneck Loosestrife

Perennials live for longer than two years. Some may reach adult hood in their first growing season and are ready to reproduce, but they don't die after that. Perennials have renewal buds that survive winter/resting periods. Herbaceous perennials die back to the ground each winter, but have renewal buds located either at or right below the ground level, such as the hosta pictured in this slide. The vegetative foliage dies back each year but renewal buds survive and start a new and larger plant the next growing season.

Life Cycle Classification

- Perennials: Lifespan of More Than Two Years.
 - Woody: Renewal buds above ground.
 - Evergreen
 - Deciduous
 - Deciduous Conifer

Woody perennials, like herbaceous perennials, have renewal buds, sometimes even underground. However, they also have renewal buds on woody branches and stems above ground that survive winter seasons and then generate new leaves, shoots and flowers the next growing season.

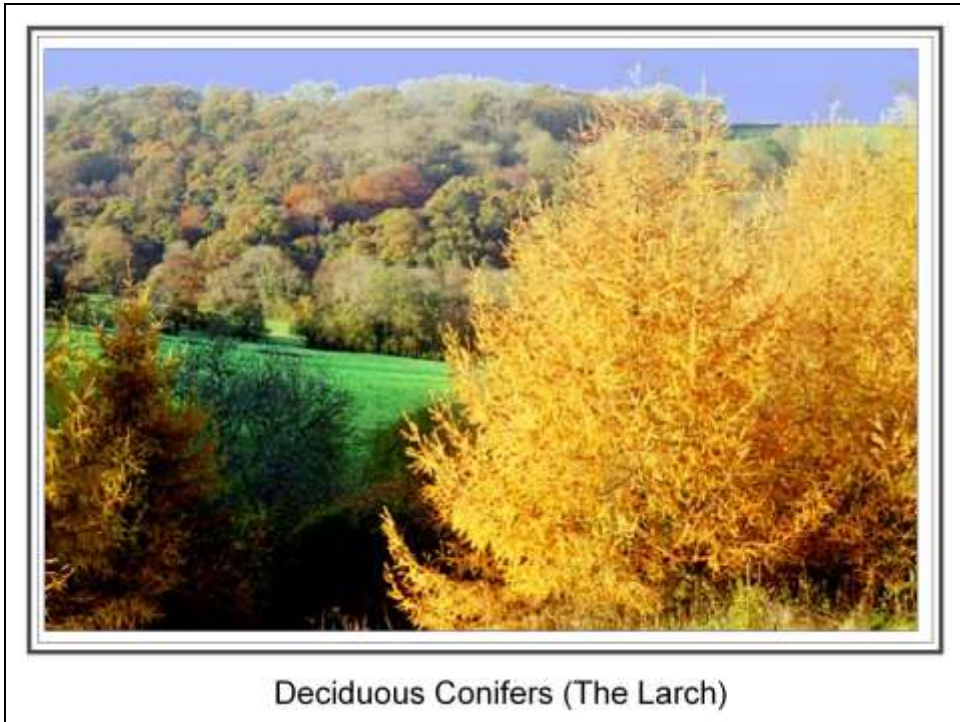


One example of a woody perennial would be evergreen woody perennials, such as this *Pinus cembra* (Swiss stone pine). Evergreen woody perennials have foliage that commonly survives for two to four growing seasons before the foliage dies and falls off.



Deciduous Woody Perennials

Deciduous woody perennials have foliage that ages and falls off (senesces) at the end of each growing season. The renewal buds then generate new leaves the following growing season.



It's assumed that all conifers are evergreens but as with just about everything biological, there are exceptions to the rule. For instance, there are several deciduous conifers, and some of them grow in Minnesota. The *Taxodium distichum* (bald cypress) and our native *Larix laricina* (American tamarack) shown above, are two deciduous conifers that do quite well in many parts of Minnesota.

Plant Classification System

- Classified by Use:
 - Shade Tree
 - Edible Landscape
 - Something Attractive in the Winter
 - Plants That Attract Wildlife
 - Plants That Screen: views, sound, odor
 - Plants That Can Tolerate Traffic

But wait, there's more! Yet another classification system that has its place, especially when you're talking with "normal" people. Shade trees, hedges, fruit trees, windbreak trees...all lump plants into "use" categories.

*“We want plants that attract
butterflies”*



Some people only want plants to bring them other living things, and could care less about the names of the plants.

"We want trees that provide a canopy over our street."



Yet one more “use” category...street trees. A “normal” person probably could care less about the botanical name...that person just wants to see street trees in their neighborhood that provide a green canopy over the pavement.

Plant Anatomy

■ Leaf Anatomy

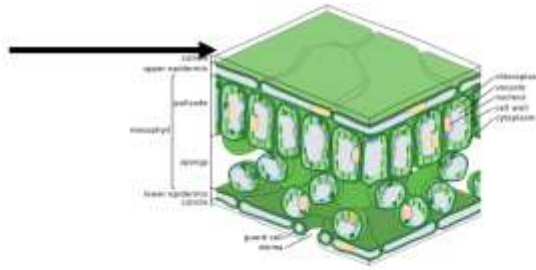
- Cutin
- Epidermis: Upper and Lower
- Mesophyll: Chloroplasts, Water, Storage and Veins
- Stoma



Plant anatomy refers to the internal structure of plants and the corresponding parts: leaves, stems, roots, flowers, etc. You as a Master Gardener are not likely to spend a lot of time discussing plant anatomy with your “clients,” but there are instances when some knowledge of anatomy helps you explain a plant function or problem to someone. The anatomy of a leaf is actually fascinating, both simple and complex. Cutin is a waxy layer covering the typical leaf surface and serves as a physical protectant and helps plants retain moisture within the leaves. The upper and lower epidermis is a second layer of protection and is cellular, usually a single layer. The mesophyll is the largest area of the leaf. The cells in the mesophyll contain a lot of water, the chloroplasts that are the sites for photosynthesis, storage for photosynthates (sugars, starches, lipids) and waste products. Finally, within the leaf are the veins, essentially the continuation (or perhaps the beginning) of the vascular system that flows throughout the entire plant and through the root system. Stoma are actually openings in the leaf surface, generally on the underside of the leaves. The stomata are opened or closed via guard cells around the opening. When guard cells are filled with water, the stomata are open. When the cells have lost water and become flaccid, stomata are closed.

Leaf Anatomy

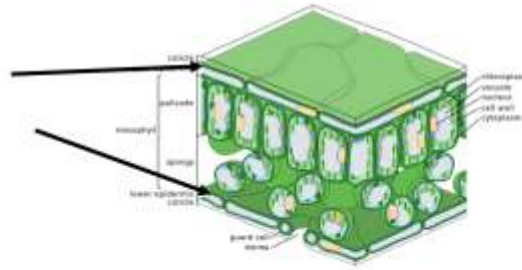
- Cutin or Cuticle: protective waxy covering produced only by the epidermal cells of leaves.



Cutin is non-cellular and protects the epidermal cells from drying out. One of the damages that deicing salt inflicts on plants is the degradation of cutin, which then leads to leaves drying out and turning brown.

Leaf Anatomy

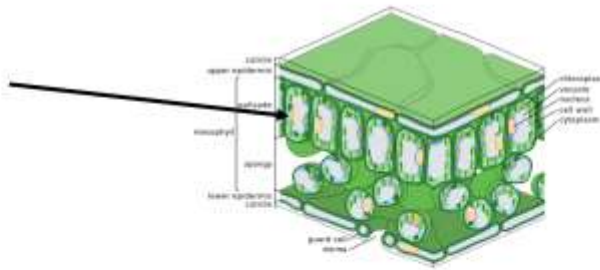
- Epidermis: a single-layered group of cells that covers plants' leaves, flowers, roots and stems.



The epidermis protects the more internal cells of the leaf, is one-cell layer thick, and is non-photosynthetic.

Leaf Anatomy

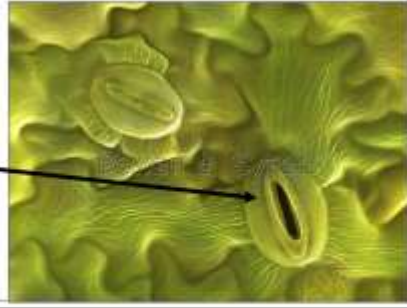
- Mesophyll: the primary location of photosynthesis.



Chlorophyll a is contained in the mesophyll cells and is the primary site of photosynthesis in a living plant. Additionally, the mesophyll is the primary area for water storage.

Leaf Anatomy

- Stoma: a pore, found in the leaf and stem epidermis that is used for gaseous exchange: e.g. carbon dioxide



The stoma is an opening that allows for the movement of water vapor and more importantly, carbon dioxide. Without carbon dioxide, photosynthesis cannot occur.

Plant Anatomy

■ Stem Anatomy

- Epidermis
 - Bark: Outer and Inner
- Cortex: Sapwood
- Vascular Bundles
 - Cambium
- Pith
 - Heartwood



Stem anatomy is equally beautiful. Again, stems have an outer protective layer when young or herbaceous that is called the epidermis. With woody plants, the epidermis is replaced by bark. The outer bark is often coarse and fancy...but it's dead for the most part (but again, this is biology and there are exceptions). The inner bark is often functional tissue and often thinner. Cortex is the inner tissue of stems, and is a major storage area for excess photosynthates, a.k.a., energy reserves. With woody plants the cortex develops into sapwood. The pith is in the center of the stem...or not. Some plants, like sumac (*Rhus* species) lose the pith and the stems become hollow. There are still some Yankees that use sumac twigs to tap sugar maples in place of metal or plastic "taps." Vascular bundles, also called pores, are evident within the stems and once again, are loosely referred to as the "plumbing" of a plant.

Okay, now the real news...many people buy plants because of their bark and often we identify them via their bark. The top photo is the bark of *Betula nigra* "Heritage," the Heritage river birch. Also called copper birch. Native (the species) to Minnesota. I'd plant it solely for the bark. On the bottom, the at-risk green ash. Green ash has a very characteristic bark. Note the deeply fissured bark, but in particular, the way that the fissures cross over each other, creating diamond-shaped or "canoe" patterns.

Plant Anatomy: Bark



Amur Maackia

Bark can be beautiful and the main reason why some people select plants. Exfoliating bark as on this maackia is particularly attractive. Also note the yellowish-colored bark: like most colored bark, it's photosynthetic.

Plant Anatomy: Bark



Yellow Birch

Yellow birch gets its name from the golden or yellow-ish colored, exfoliating bark.

Plant Anatomy: Bark



Red Pine

Sycamore

Amur Chokecherry

Each of these bark patterns is interesting and beautiful and a reason to select these plants for a landscape. Note the strong, horizontal lenticels on the chokecherry bark.

Photosynthetic Bark



Aspen

Dogwood

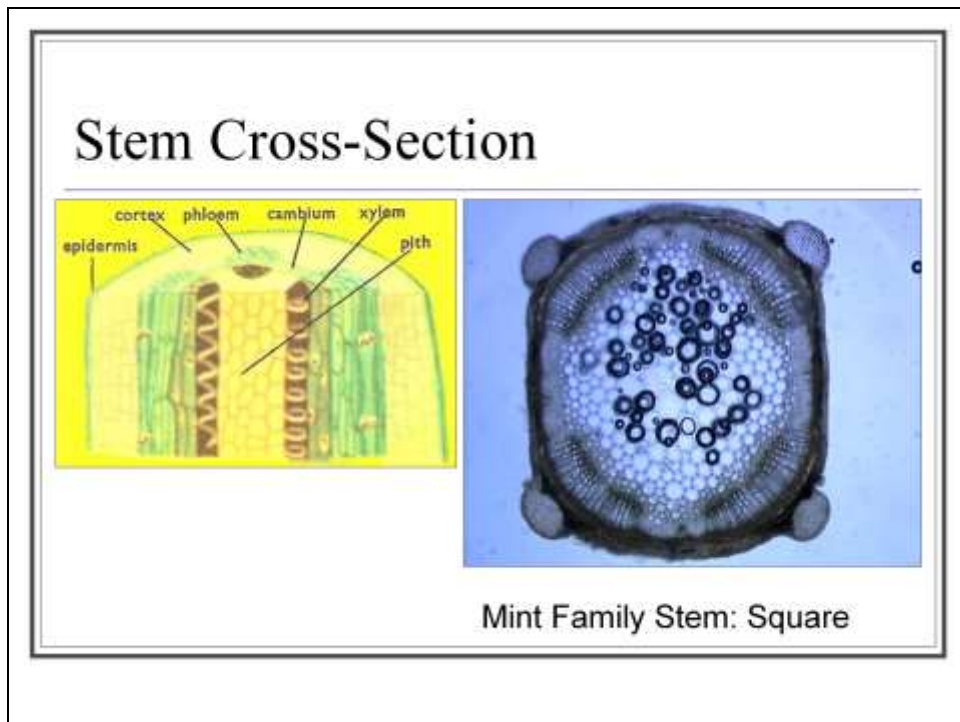
Burning Bush

Most bark and almost all bark on young trees and branches contains chlorophyll and is photosynthetic, some more than others. Since it's photosynthetic, it's also vulnerable to accidental herbicide sprays that can be taken up by the photosynthetic bark. Once the bark thickens and is covered by dead outer bark, photosynthesis stops as well as the danger of taking up herbicides.

Bark Lenticels



Lenticels like stoma are a pathway for gasses, including carbon dioxide and moisture. They are also a way for bacteria to enter a plant's stem, and likewise, scale insects.



The anatomy of a stem, for instance dicot stems such as these, reveal the functioning tissues. The epidermis of a young plant is very thin and vulnerable. The cortex can eventually become pretty good storage tissue for starches. The phloem tissues function primarily to move photosynthates – the products produced as a result of photosynthesis – which are the sources of energy for all plant functions. The xylem moves water and nutrients from the roots to the far-reaches of the plant...the leaves. The cambium is the cell layer that produces phloem tissues to the outside and xylem to the interior. All of these tissues are dangerously close to the outside of a stem or branch of a younger plant.

Stem Cross-Section



As woody plants mature, they often lose much of their interior structure to decay, yet they still live on as healthy (if not unstable) plants for many years. It's because the working tissues of the plant are located near the outside. The sapwood (the light-colored wood in this picture) stores energy and provides support. The cambium that produces annual layers of phloem and xylem is located under the outer bark area, and technically, the cambium and phloem is considered "bark." From the xylem inward, the botanical name is "wood."

Stem Cross-Section



Just kind of an interesting note. Beautiful lumber cut from ring-porous trees like oak and black ash is highly valued for furniture. The reason it's so expensive is that the logs are processed as "quarter-sawn," as illustrated in the picture to the left. That leaves a lot of waste wood, but beautiful lumber, showing off the grains of the host tree trunk.

Plant Morphology

- Form
- Color
- Size
- Fragrance?

Plant morphology, on the other hand, is usually the reason why people buy plants. Morphology is the “gross” or obvious appearance of plants. Most of the time (with the exception of vegetables), people select plants based on their size, shape, color, texture and/or fragrance.

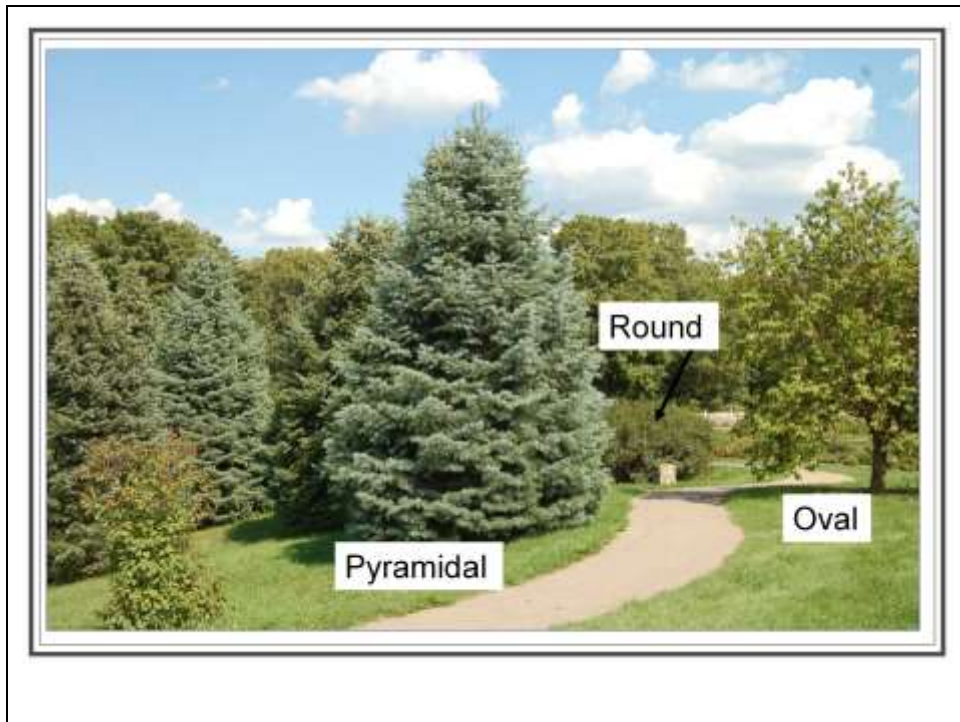
Morphology

■ Form:

- Upright
- Spreading
- Arching
- Weeping
- Rounded
- Prostrate
- Climbing



One of the more common morphological terms used is a plant's form, or growth habit. For many people, form is the reason that they select a plant. Listed are seven different forms, each either having an aesthetic appeal and/or a functional appeal. For instance, a weeping plant is almost like a sculpture that photosynthesizes. A climbing form allows a plant to grow tall and proud in space-limited environments.



People love Colorado spruces because of their tight, pyramidal shape and blue color. Both morphological features. However, the broad base of a pyramidal evergreen also is functional in the respect that it is a great barrier...to winds, sounds, sights.



Midwesterners love bur oaks because in part of their broad-rounded form, a morphological feature. The prairie grasses are also preferred because of their changing seasonal colors, finer textures and movement in the winds, all either morphological features or the result of morphological features.

Morphology

- Color:
 - Foliage
 - Flowers
 - Bark
 - Fruit/Seeds

Color is a commonly sought-after morphological feature, whether it's colored foliage, brightly colored flowers, multi-hued bark or fruits and seeds that attract not only our attention but wildlife.



Coleus

Coleus is one of the most popular bedding plants due primarily to one morphological feature...it's variegated foliage.



Like coleus, Canada red cherry (*Prunus virginiana* 'Canada Red') is loved for its striking foliage, despite the fact that it suckers profusely, is short-lived and very susceptible to black knot disease.



Virgin's Bower Clematis

The yellow to white flowers and seed heads of a native clematis, virgin's bower, may not be the flashiest in color but they are a beautiful contrast with the dark green leaves.



An overlooked morphological feature is the bark of a plant. In this case, the peeling, copper-colored bark of the river birch (*Betula nigra*).



The seeds of the Douglas-fir (*Pseudotsuga menziesii*) are enclosed in an attractive seed cone with 3-pronged bracts defining its unusual morphology. Bracts are modified leaves.



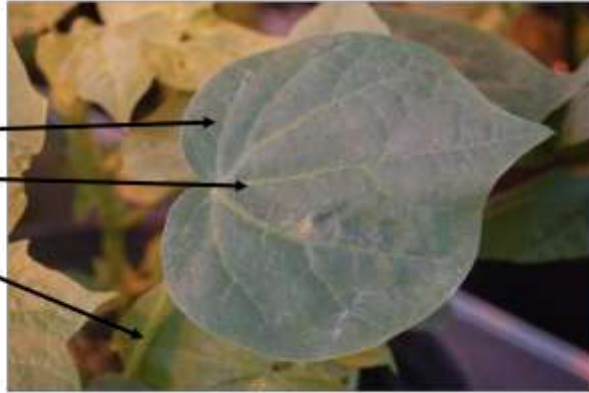
Jack-in-the-Pulpit

The beautiful flower of Jack-in-the-pulpit.

Plant Morphology

■ Leaves:

- Blade
- Veins
- Petiole



Leaves consist of only three morphological parts: the leaf blade where most of the photosynthesis takes place, the veins that transport cell sap, water, photosynthates, etc., and the petiole that is the direct connection between the veins and the vascular system of the plant (the xylem and phloem).

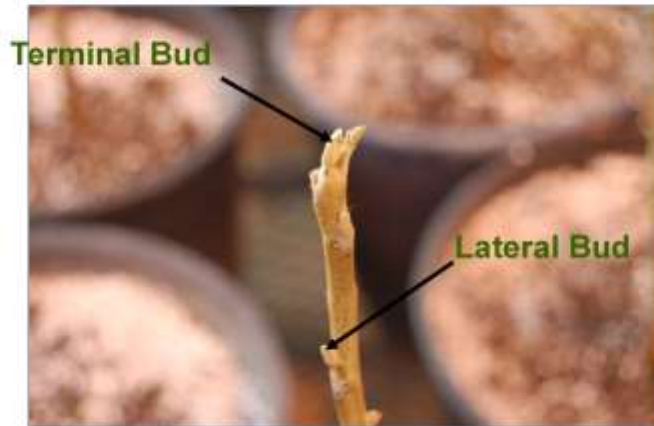
Stem Morphology

- Buds: Terminal, Lateral, Latent
- Nodes
- Internodes
- Modifications

Stems are simpler. Stems have buds (vegetative or reproductive) that are either on the ends of the branches/twigs (terminal), on the stem at the base of leaf blades or other nodes (lateral) or buds that seem to be dead but are just waiting for the chance to break their dormancy and show you what they can do (latent), like after a hail storm destroys all of the existing foliage in early June.

Nodes are growing points and only found on stems. Buds are located at nodes. Internodes are the spaces between nodes. Finally, something that makes sense.

Stem Morphology: Buds



Note that sometimes there is a terminal bud and sometimes there are several. Lateral buds can be prominent such as this one or very tiny and subtle.

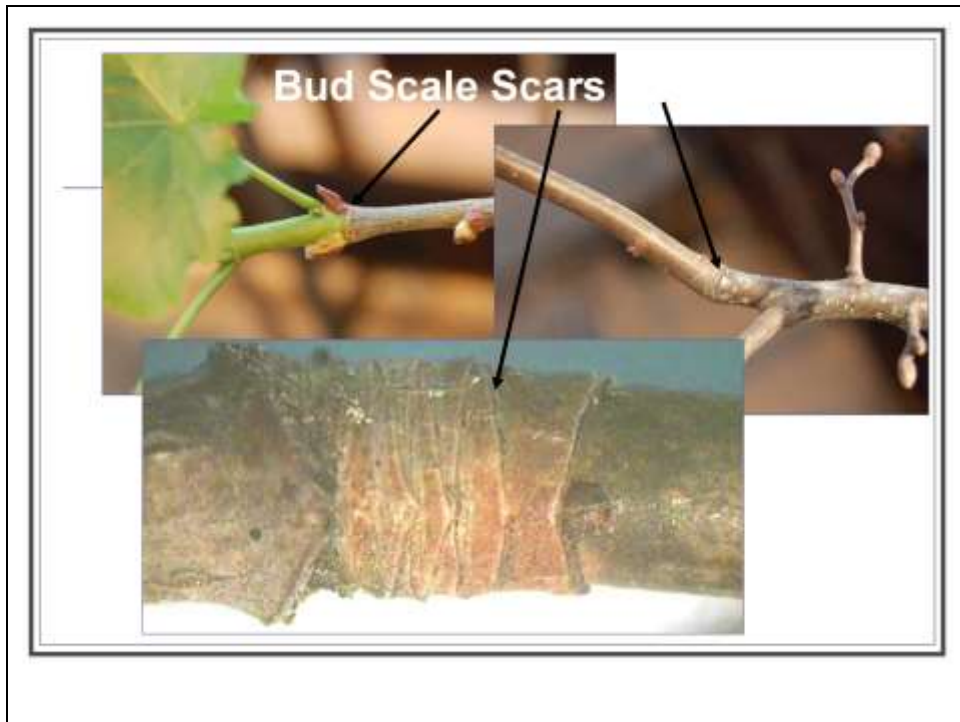
Stem Morphology: Latent Buds



Re-sprouting Forsythia

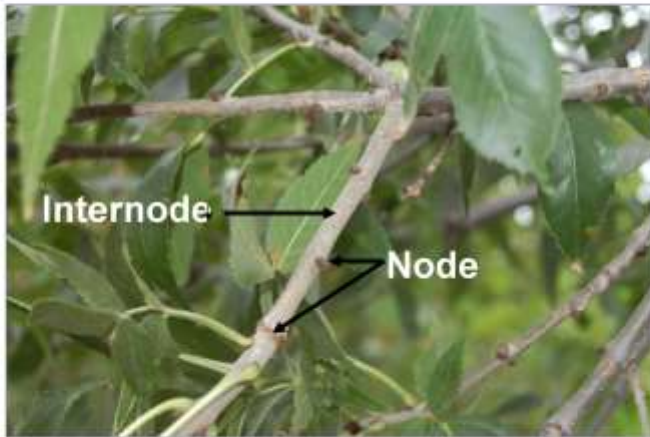


Note that sometimes there is a terminal bud and sometimes there are several. Lateral buds can be prominent such as this one or very tiny and subtle.



Terminal buds are very revealing. In temperate climates, when a terminal bud opens up in the spring, all of the bud scales fall off and leave a ring of scars around the end of the twig. If you want to measure the “annual twig growth rate,” just measure from one set of scars to the next. That’s in a perfect world. Unfortunately, with some plants there can be two or more “growth spurts” a year, so you can’t assume that one distance from leaf scars to leaf scars represents one year. It’s still a good way of recording/gauging twig growth rate, especially when you compare it to past years or other similar plants in the area.

Stem Morphology



There is also a value to recording/monitoring internode length because it is another measure of growth rate. The further the distance between nodes (internodal length) for trees, the better. Trees should have branches separated by 18-24 inches. Not so for bedding plants or poinsettias. Can you imagine a petunia with 18-24 inches between leaf sets? Charlie Brown petunia comes to mind, doesn't it? Therefore, depending on the plant, a grower/gardener manipulates the internodal length for beauty and structure.

Stem Modifications

- Crowns
- Spurs
- Thorns
- Stolons
- Stollens
- Rhizomes
- Tubers
- Bulbs
- Corms

All 8 of these botanical vegetative or reproductive elements are modifications of stems. Only one is a tasty dessert.

Crowns: Compressed & Short Internodes



Dandelions are good examples of modified stems, in this case, crowns. The crowns are generally close to or at the soil surface and are the source of renewal buds. Many turfgrasses also have crowns.

Spurs: Flower/Fruit-Bearing Side Stems

Dormant



Apple spurs and fruit



Some, definitely not all, fruit-bearing trees bear from modified stems called “spurs.” Spurs are lateral stems terminated by a flower bud. They are very slow-growing stems, for example, the 5-year old (approximate) spur on the apple tree on the left photo. Here’s the importance: don’t prune these off if you want flowers and fruit. There are vegetative buds on these trees (most spur-bearing fruit trees are apples), but they are much smaller and thinner than the spur flower buds and are not located on the spurs.

Thorns: Modified Twigs



Thorns are modified stems that served to keep animals from damaging the plants. For instance, this three-pronged thorn on a honeylocust (*Gleditsia triacanthos*), would keep just about any critter away from the branch or tree trunk. These modified stems called thorns are also referred to as “vestigial,” that is, they once served as regular stems/branches, but now serve a different purpose and look different.

Stolons: Above-ground Horizontal Stems



Spider Plant



Strawberry

Stolons are fairly common and are described as stems (they have nodes, so they are stems) that grow horizontally above ground.

Stollens: A Traditional German “Christmas” Season Cake



A stollen, spelled differently, is a pleasant, traditional German Christmas cake, and not to be confused with stolons.

Rhizomes: Underground Horizontal Stems



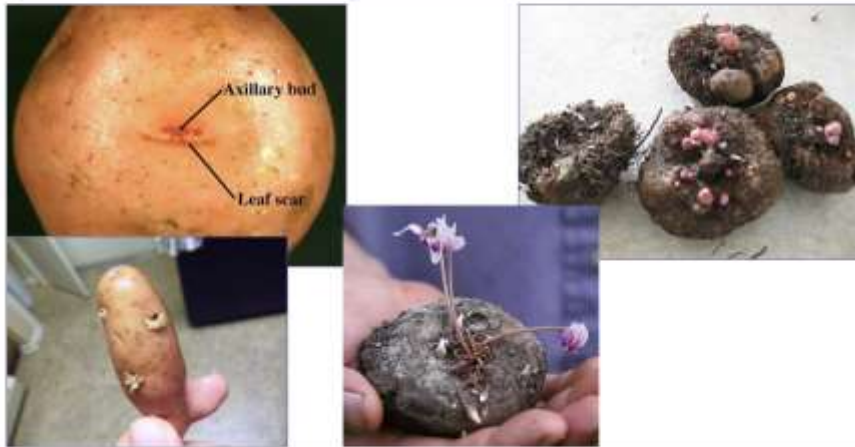
Iris



Quackgrass

Once again, even though these plant parts seem like roots, even though they have roots connected to them, they are in fact stems...because they have nodes. Rhizomes are then underground, horizontal stems. Like stolons, if you want to propagate these plants from “stem” cuttings, you’ll need to make sure the stem section you are hoping will produce a new plant has at least one node...which is not difficult.

Tubers: Thickened Stems



Potato

Cyclamen

Dahlia

Tubers are probably the best-known modified stems. The "eyes" of a tuber are in fact nodes, hence the tuber is botanically a modified stem. Cut into a tuber and it's solid stem tissue with nodes.

Tubers: Eyes Present



Four-Eyes

When the eyes sprout, new shoots emerge. By-the-way, I, too, wear glasses.

Bulbs: Underground Stems with Leaves



Tulip



Onion

Bulbs are still modified stems but unlike corms, most of the mass of a bulb is modified leaf tissue. The stem is usually a small area at the base of a bulb, the location of the node.

Corms: Underground Stems no Leaves



Crocus



Gladiolus

Corms, like tubers, are almost all stem tissue. The nodes are the points where flower/leaf shoots emerge. Corms unlike bulbs, are not a series of leaf layers; rather, they are stems with a thin layer to the outside of the stem material.

Propagating From Stems

■ Above-ground Stem Cuttings



Adventitious roots emerge from stem or leaf cuttings. True roots emerge from seeds. Adventitious (a word that means something is there that normally wouldn't be there) roots are the basis for clonal propagation of plants. Adventitious shoots can form off of roots, as roots can form off of stem or leaf cuttings. Therefore, they are modified stems, abnormal stems, but very functional, very valuable.

Propagating from Stems

■ Below-ground Stem Cuttings



White Poplar

Iris

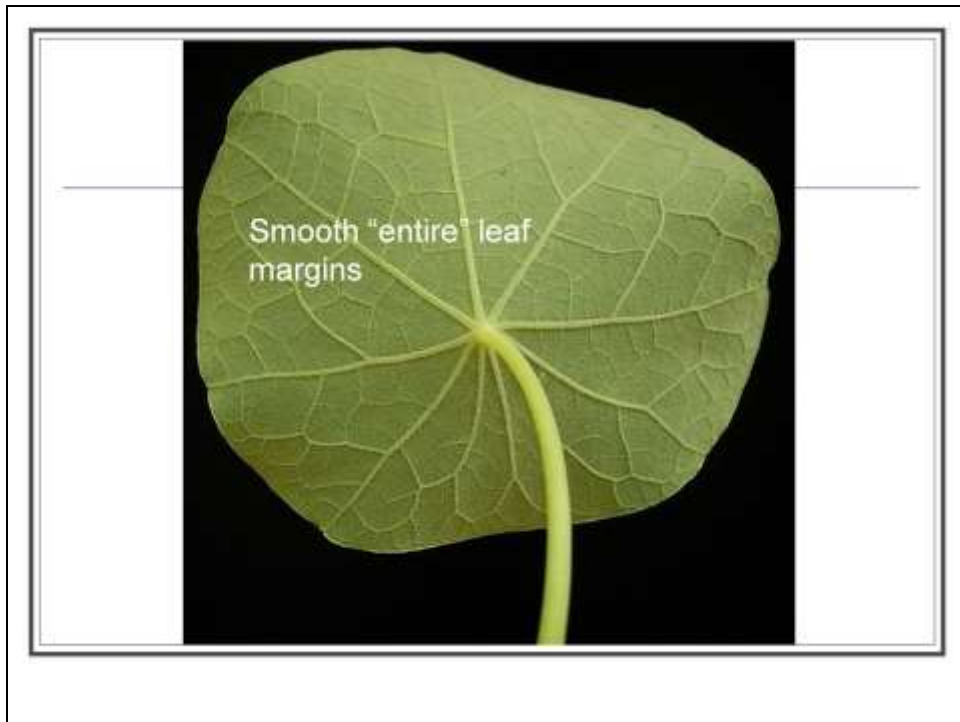
White poplar (*Populus alba*), like iris, can produce adventitious shoots from underground roots. This is a major problem if you ever want to remove a white poplar. Expect a sea of shoots forming in your landscape if the dominant tree trunk and other above-ground parts are removed because all of the growth regulators will be distributed to these adventitious shoots.

Leaf Morphology

- Margins

- Entire
- Toothed (serrate, dentate)
- Lobed

Leaf margins have their own character and are used to help identify plants. For instance, margins are either entire (smooth, no indentations), toothed (indentations that are either blunt or sharp) or lobed (deep sinuses or “valleys” in the margins).



This nasturtium leaf has the characteristic "entire" leaf margin that is used to help identify this species.



These coleus leaf margins are toothed. There are several sub-classifications of toothed margins: serrated, dentate, doubly-serrated or doubly dentated, and there are probably more.



This variety of silver maple (*Acer saccharinum* 'Laciniatum') not only has sharply lobed leaf margins, they're also sharply toothed. You may laugh, but people pay extra money for leaf margins in some cases.

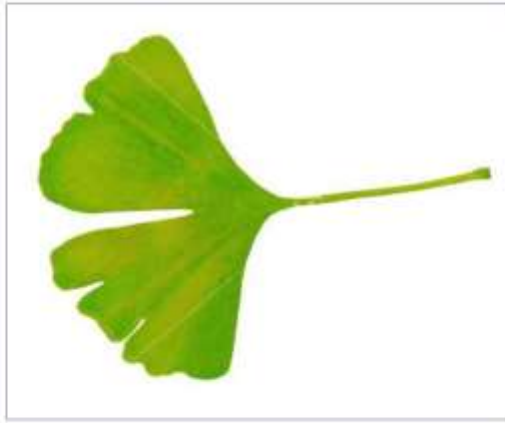
Leaf Morphology

■ Venation Pattern

- Dichotomous (Ginkgo)
- Parallel (monocots)
- Netted (dicots)
 - Pinnate
 - Palmate

Leaf venation patterns are also distinct and help identify plants. As previously discussed, Ginkgo leaves have a dichotomous venation pattern. The veins emerge from the base of the leaf blade, grow for a bit and then diverge into one of two directions. Within each direction, the veins are parallel to each other. Parallel venation patterns are 'only' found on monocotyledonous plants such as corn or grass. Netted venation patterns are characteristic for dicotyledonous plants, and are usually either pinnate or palmate in arrangement. Pinnate venation looks similar to bird feathers with a mid vein and smaller veins that branch off of it. Palmate is as it sounds; veins arise from the base of the blade and then grow off to the various lobes, usually 5 but it can be more or less. Regardless, it has the appearance of fingers emerging from the palm of a hand.

Dichotomous Venation: Ginkgo



The dichotomous venation pattern of the ginkgo (*Ginkgo biloba*).

Parallel Venation



The parallel venation pattern of corn, a monocot.

Pinnate Venation



The pinnate venation pattern (netted) of a dicot, poinsettia.

Palmate Venation



The beauty of palmate venation patterns in nasturtium (left) and red bud (*Cercis canadensis*, center), and maple (*Acer saccharum*, right).

Leaf Morphology

- Simple
- Compound
 - Pinnately Compound
 - Palmately Compound
 - Leaflets vs. Leaves

Leaves are either simple or compound. A simple leaf has a renewal bud at the base of a single blade. A compound leaf has smaller leaflets attached to a rachis that is attached to the twig or branch. At the base of the rachis is the renewal bud. At the base of leaflets, no renewal buds are present. Therefore, a compound leaf has several to many leaflets which are individual blades. To further complicate something that doesn't deserve to be complicated, compound leaves are classified as either pinnately or palmately compound. A pinnately compound leaf will have leaflets arranged on either side of one rachis. Palmately compound leaves have leaflets attached to a single point with the leaflets radiating out like the fingers of a hand. I hate to do this to you, but there are doubly-compound leaves, too: honeylocust (*Gleditsia triacanthos*) and Kentucky Coffeetree (*Gymnocladus dioica*). All of this helps you identify a plant once you learn the nomenclature.

Simple Leaves



The simple leaves of a nasturtium.

Pinnately Compound



The pinnately compound leaves of a hickory (*Carya* species).

Palmately Compound



The palmately compound leaves of castor bean plant (Ricinus communis).

Leaves versus Leaflets



Compound leaves have several to many leaflets. Can you imagine how bare this tree looks when it drops its leaves? That's one reason why compound leaved trees are favored for solar efficient buildings...they offer very little resistance to sun penetration in the winter.

Root Morphology

- Herbaceous Roots
 - Fine Roots
 - Symbiotic Roots

Finally, the last 50%+ of a plant's morphology...the root system. All vascular plants have herbaceous roots, that is, vegetative and tender roots. Some are termed "fine roots," "root hairs," and "symbiotic" roots. Symbiotic roots are either bacterial, fungal or actinomycete organisms that set up a mutualistic beneficial relationship with root tips. They are the norm in nature, not root hairs.

Herbaceous Root Morphology



This is kind of an odd photo but it's the underside view of a flat of Kentucky blue grass. Note the extensive network of fine roots, those very vegetative, very fragile roots that take up the majority of water and nutrients.

Herbaceous Root Morphology

■ “Infected, Symbiotic” Fine Roots:

- Mycorrhizal
 - “Fungus-Root”
- Actinorhizal
 - Actinomycete and root
- Bacterial Nodules

Symbiotic root/microorganism relationships are the norm in nature. Only in sterilized, artificially-grown (e.g., greenhouses) plants are they absent. These relationships are termed “mutualistic symbiotic” relationships, where both the microorganism and the plant benefit. Almost always, it’s carbon that is traded to the microorganism for more efficient uptake of water and nutrients for the plant.

Symbiotic relationships with roots benefit both the plant as well as the organism. In these relationships, which by the way are totally normal not the exception, the plant benefits by being more efficient at absorbing water and nutrients. It also benefits from a chemical and physical protection from some diseases, insects and nematodes that the symbiotic partner (mycorrhizal fungus, actinomycete or bacteria) provides. The organism benefits by having access to carbohydrates produced by the plant. It’s a botanical, win-win situation.

Mycorrhizal Roots



Mycorrhizal roots are the most common relationship and almost all woody perennial plants have micorrhizal roots after about a year following planting. The spores for the mycorrhizal fungi are found in most soils and “infect” the new roots of their host plants, allowing the plants to be much more adept at taking up water and nutrients from the soil. In return, the plants pass on carbon to the fungus. These fungi also provide some chemical protection against pathogens and soil fauna that can cause health problems for the plant. There has been some good research documenting that woody plants with mycorrhizal root relationships better tolerate deicing salt run-off, too.

Bacterial Nodules



This is a similar relationship to the mycorrhizal roots except this is specific to members of the legume family (beans, clover, red bud, locust trees), and is the result of a bacterial “infection.” The bacterium is very efficient at “fixing” unavailable nitrogen and thereby making it available to the plant. Again, the payment to the bacterium is carbon.

Actinorhizal Nodule



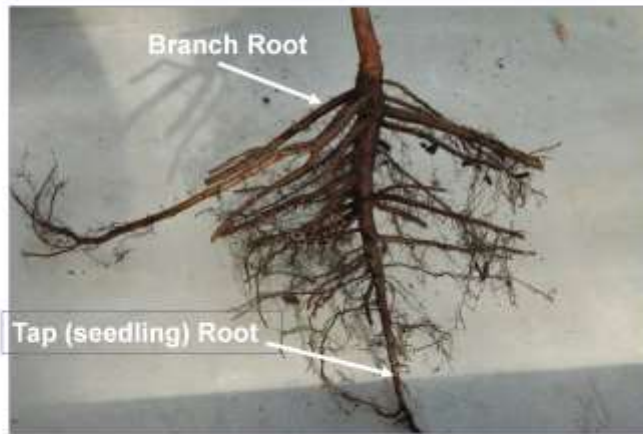
The third type of mutualistic, symbiotic relationship occurs with alder trees (*Alnus* species), and involves an actinorrhiza, which is similar to a bacterium. As with bacterial nodules, it allows the host plant access to previously unavailable nitrogen in exchange for carbon.

Root Morphology

- Woody Roots
 - Tap Roots
 - Branch Roots
 - Striker (a.k.a., Sinker) Roots

Woody roots are categorized as tap roots, branch roots or striker (sinker) roots. As the name implies, they are multicellular and woody compared to herbaceous fine roots. A common myth is that herbaceous plants don't have woody roots. Wrong. Alfalfa, snapdragons and broccoli have woody roots.

Woody Root Morphology



Branch roots are primary support roots. They also store a significant amount of energy reserves, such as starch. Additionally, they are the roots where fine roots originate. Tap roots are essentially seedling roots, and rarely last beyond a few years. As soon as the tip of a tap root is bent, broken, eaten by a critter or pruned by a grower, that's the end of it. They don't reform. While they are operative, they are sites for energy reserves storage, take up a little water and nutrients, and provide some support.

Root Morphology

■ Horizontal Distribution:

- Genetics
- Ease of Penetration
- Obstructions

It's not easy to exactly predict the ultimate spread of roots, but it's guided by genetics (guess what, a pine tree's roots will spread further than a petunia's), the relative looseness of the soil which allows the roots to penetrate, and any obstructions that a root may encounter, such as curbs, patios, planter edges.



This is a good visual of how obstructions alter the spread of roots. The branch roots of these green ash (*Fraxinus pennsylvanica*) grew out about two feet from the tree trunk before they hit the curb (that's been removed). When they hit the curb, they turned and followed the direction of the curb.

Root Morphology

■ Vertical Distribution:

- Soil Oxygen
- Soil Moisture
- Ease of Penetration
- Obstructions

Root depth is a bit easier to predict. In most situations, roots of woody plants rarely grow deeper than 3 feet, with the fine roots growing in the upper 12 inches. Why? Roots need soil oxygen for respiration (the release of energy for growth) as well as water. If there's insufficient soil oxygen (for instance, due to a compacted or water-logged soil) roots of most plants will barely grow if they grow at all. As the depth of soil increases, there is less water and oxygen available. Along with those two variables, ease of penetration and obstructions in the soil also limit the depth of root penetration. It is a myth that roots descend to an equal distance as they grow above ground. A 50 foot tall tree doesn't normally have roots growing 50 feet deep...they are usually less than 3 feet deep.



Here's a good example of root depth. The roots that you are looking at are less than 24 inches deep and they are from a 75 foot tall bur oak in St. Paul, MN. The soil is pretty good, too, so the main reason they are so shallow is that optimum soil oxygen and water is near the surface.

Functions of Roots:

- Fine and Symbiotic Roots
 - Majority of Water, Nutrient and Oxygen uptake;
Some Support and Storage.

The majority of water and nutrients (>90%) are taken up by fine and symbiotic roots...so don't do anything to damage or remove them. They also take up most of the oxygen that roots need for respiration, and they are as important as any other root for supporting the plant. As with branch and tap roots, fine roots store energy reserves within the plant.



Note the arrow. That root was pruned 4 months prior to this photograph. It demonstrates a couple of things. First, roots don't have nodes, so wherever they are pruned/cut, new roots can potentially form. Second, where one root was cut, many new roots form. This is a good, visual example of the benefits of root pruning.

New roots originate from within the cut root, from an area of cells called the pericycle. No nodes necessary.

Functions of Roots:

- Branch Roots

- Support, Storage, Some Water, Nutrient and Oxygen uptake.

Branch roots are primary support roots. A plant is much more stable with a broad-based support of branch roots as opposed to a deep tap root. This is why plants, especially trees, become so unstable after portions of their branch root system are damaged or removed. Branch roots do take up some water, nutrients and oxygen, but this is a very small function compared to the fine roots.

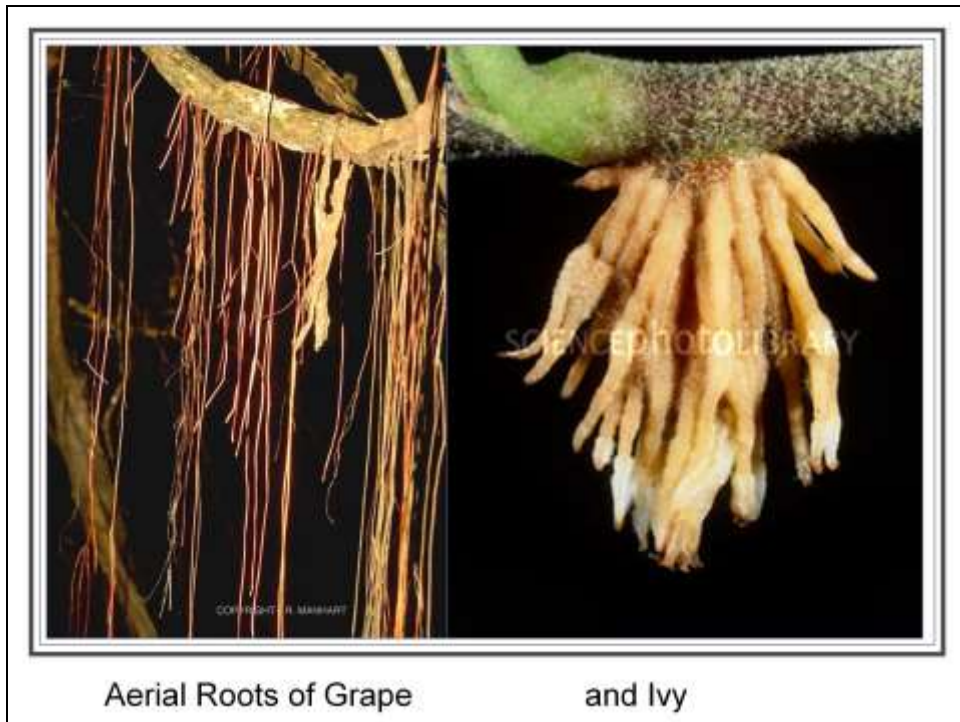


This is a good example of a branch root system, although it's a bit abnormal. These are aerial roots on a ficus tree and carpet the ground with branch roots. The branch roots are on the surface of this fairly rocky soil (actually, coral-based) but the fine roots that grow off the branch roots extend down into the soil to absorb water and nutrients.

Functions of Roots:

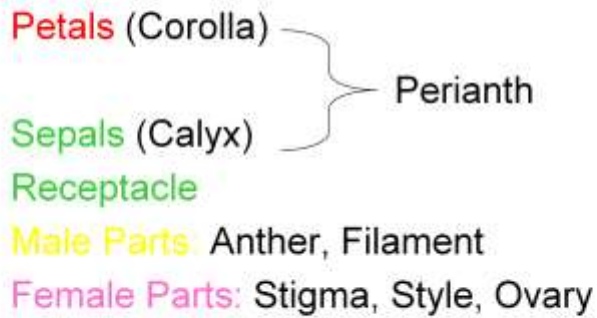
- **Striker/Sinker/Tap Roots**
 - Primarily Support and Energy Storage; Some Water, Nutrient and Oxygen uptake.

As noted before, tap roots do not last very long in nature or nurseries. Once the tip of a tap root is lost or bent, the tap root's aggressive growth is ended. However, striker/sinker roots (same thing just different names) are vertically growing roots that originate off of branch roots. Most of the time they occur within a relatively short distance from the plant's stem and are more commonly associated with woody plants. They, like tap roots provide stability to the plant, and take up some water, nutrients and oxygen.

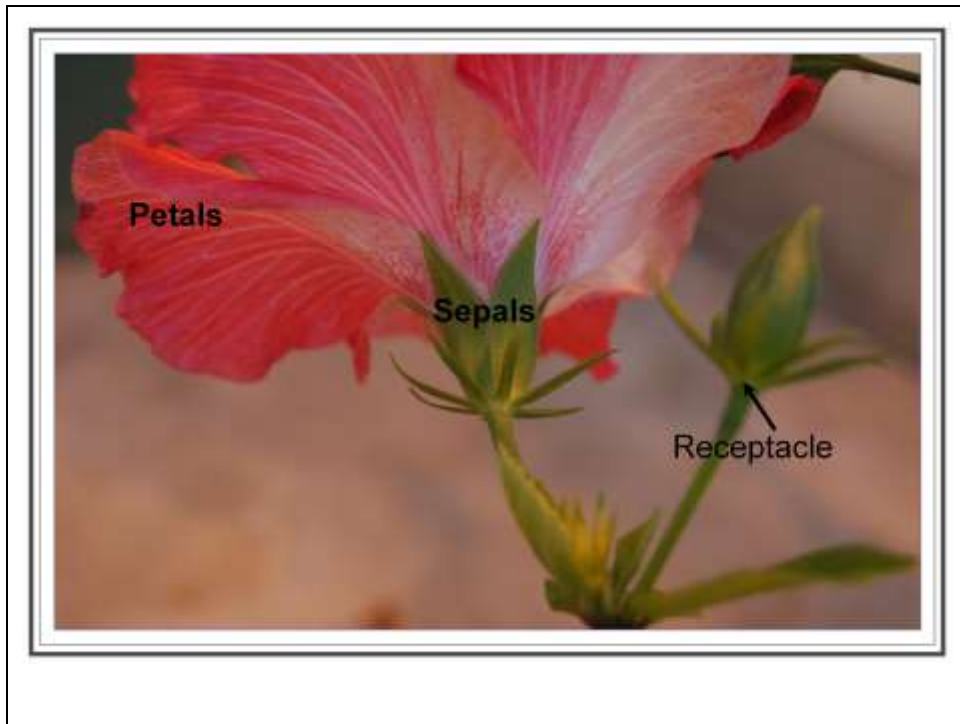


A close-up view of the aerial roots of grape and ivy, descending to the ground where they then develop the extensive branch root network.

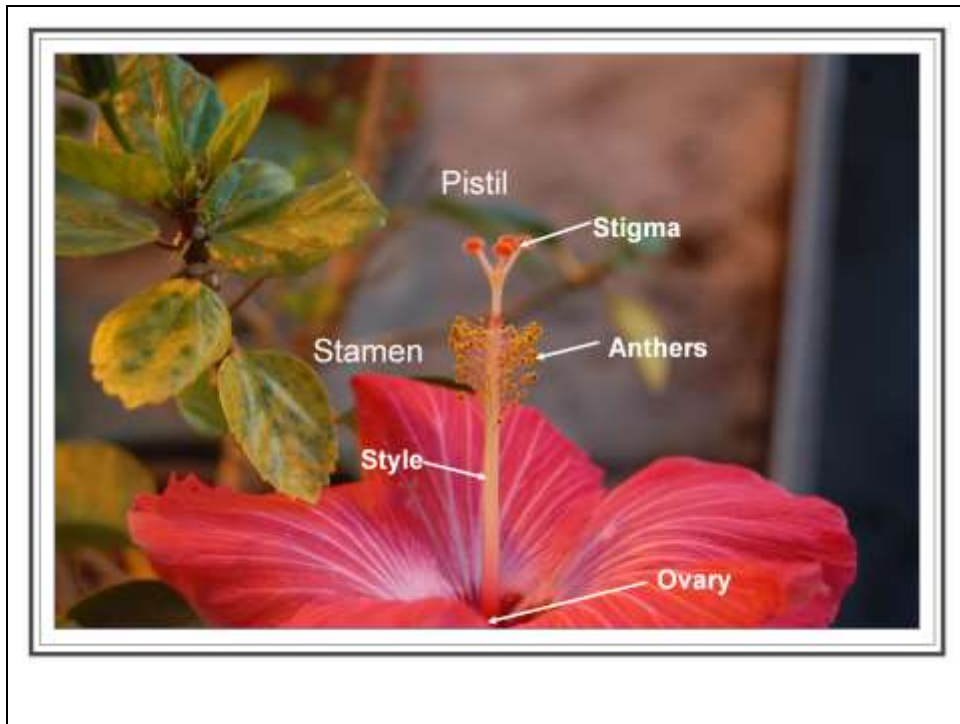
Morphology of Flowers



The morphology of a flower is probably a little easier to learn, probably because flowers are more visible and examined more frequently than roots! All the petals are collectively termed the corolla. The sepals are collectively termed the calyx. All of the petals and sepals together are termed the perianth. The base of the flower where often the sepals and petals originate is termed the receptacle, which is actually stem tissue. The male reproductive structure in a flower is termed the stamen and consists of the filament and the anther. The female organ, termed the pistil, has the ovary, style and stigma.



This photograph clearly shows the petal, sepals and receptacle. Sepals and receptacle tissues are almost always photosynthetic.



This is a beautiful structure. Focus on the reproductive structures within this hibiscus flower. The stamens are arranged on the style (which is kind of unusual) but you can clearly see the anthers perched on the ends of the filaments (like little stems). The pistil is one of the most beautiful ones I've ever seen. The stigmas are perched on the end of the style, perfectly located to capture the pollen from the anthers. The ovary is located at the base of the pistil. In this flower, the ovary is clearly visible, but that's not always the case. Sometimes the ovary is buried in or under the receptacle, out of sight.

Types of Flowers

- **Complete:** All Parts Present



If a flower has all of the parts present - corolla, calyx, receptacle, pistil and stamen – it is botanically classified as a “perfect” flowers.

Types of Flowers

- **Incomplete:** 1 or More Parts Missing



If one or more parts are missing, it's botanically classified as incomplete such as this poinsettia which has showy bracts (modified leaves) but no floral petals.

Types of Flowers

- **Perfect:** All Reproductive Parts Present



If all reproductive parts of the flower are present, it is botanically classified as a perfect flower. So, a flower can be incomplete (e.g., missing calyx) but perfect.

Types of Flowers

■ Imperfect: Female or Male Parts Missing



Male Flower

Female Flower

Ovary



If flower are imperfect, it means they are either male or female flowers (contain only stamens or pistils). Note the imperfect (but pretty) flowers from this wax begonia.

Types of Plants With Imperfect Flowers

- Monoecious Plants:

- Male and Female Flowers on Same Plant



Red Maple

If a plant has imperfect flowers, but both sexes are on that plant (i.e., male and female flowers), the plant is botanically classified as monoecious. The red maple is a monoecious plant, which explains why not all of its flowers produce samaras. Its flowers are further incomplete because they lack petals.

Types of Plants With Imperfect Flowers

- **Dioecious Plants:**

- Male and Female Flowers on Separate Plants



**Female
Bittersweet**

If a plant contains imperfect flowers of only one sex, the plant is botanically classified as dioecious. In this case, plants with male only flowers are called male plants, and female plants only have female flowers. To have fruit produced, it will only form on the female plants and there must be a male plant nearby to provide the pollen required for fertilization. If you want the beautiful fruit of bittersweet, you must purchase a female plant and convince your neighbor to plant a male plant within a mile of the female plant.

Types of Plants With Imperfect Flowers

- **Dioecious Plants:**

- **Male and Female Flowers on Separate Plants**



**Female
Winterberry Holly**

Minnesota's native winterberry holly is another dioecious plant with very attractive fruit only produced on the female plant.

Pollination and Fertilization

- Pollination: Placement of pollen on stigma
- Fertilization: Union of gametes

Okay, on to the birds and the bees. For fertilization to begin, pollen must be transferred from the anther to the stigma. That is pollination. If the pollen that is transferred to the stigma is accepted by the pistil (it's a chemical thing) then the pollen "germinates," travels down the style and into the ovary where it is united with eggs. The union of the pollen gamete (sperm) with the ovary gamete (egg) is termed fertilization.

Successful Fertilization



If fertilization is successful, the union of gametes produces a zygote (or more) which becomes an embryo which eventually becomes a new plant. Once the fertilization process starts, the ovary begins changing. This change is termed “ripening,” and is a chemical response to the stigma accepting the male gamete. Even if something aborts the fertilization process and no seeds are ever formed, the ovary still ripens and forms what you call a “fruit.”

Unsuccessful Fertilization

■ Incompatible Chromosomes



Pollen from different plants can land on the stigmas of many flowers, but that doesn't mean that fertilization will occur. Pollen from pines (gymnosperms) can land on stigmas of poinsettias, but the plants are so completely different that there can be no chromosomal pairing. If no chromosomal pairing can happen, no chemical signal will be given to the pollen from the stigma and germination of the pollen grain (which releases the gametes) will never occur. All that will result is a poinsettia flower with pine pollen on it.

Unsuccessful Fertilization

- Weather Extremes:
 - Heat
 - Cold
 - Drought
- Chemical Drift
- Poor Pollination
 - Insects absent
 - Wind and/or rain during season

Other than poor or no chromosomal pairings, there are many other situations in which fertilization is either prevented or aborted. Weather extremes are probably the most common, especially temperature extremes and wind. Non-target (or sometimes, even targeted) chemical drift can cause aborting of the process. Finally, the relative decline in insect pollinators has had a dramatic effect on pollination in many parts of the country on many crops. If your client claims that their fruit trees have no fruit this year, despite having regular crops for many years, become suspicious of these chronic problems (especially as they relate to weather extremes) and start asking questions.

Products of Fertilization

■ Dry or Fleshy Fruit



The products of fertilization can be edible fruits, seeds and/or receptacles...or they may not be edible, only good for reproduction. Generally, fruits (remember, ripened ovaries) are classified as either dry (Jimson weed, *Datura stramonium*) or fleshy (tomato, *Solanum lycopersicum*) and can only be produced by angiosperms.

Products of Fertilization

- Seeds in Seed Cones (modified leaves/stems)



When conifers reproductive organs are fertilized, fruits aren't formed because conifers don't have true flowers with ovaries. The "cones" of conifers are either male (pollen) cones or female (seed) cones. The seeds are the embryos produced as a result of fertilization, but they are enclosed in a modified stem and leaf structure (cone) instead of a ripened ovary.

Germination



If all goes well, fertilization is completed and embryos survive, the seeds can be the source of new plants. Germination is a process by which respiration is regulated to either keep the seed embryo in a very low state of growth (quiescent) or to speed up the growth rate of the embryo to the point where it can break through the seed coat and form a new plant.

Germination

■ Requirements:

- Viable Embryo
- Moisture
- Oxygen
- Heat

For successful germination, a few requirements must be met. First, the embryo within the seed must be alive (viable) and healthy. Just because a seed is found in a fruit doesn't mean that a viable embryo is within it. Second, adequate moisture must be available to satisfy the requirements for respiration...the release of energy. Even though moisture is a requirement, it can't be at the expense of oxygen, another bare necessity for the respiration process. Finally, heat must be supplied in a range that can accelerate respiration without stopping it. Seed storage uses the same principles, but instead of speeding up respiration for growth of the embryo, it slows it down so the embryo doesn't consume the stored energy it must rely upon until the plant can begin to photosynthesize. Lowering the temperature (near 38 degrees F. or lower) and reducing the seed's moisture content by drying them out can enable seeds to survive for a very long time in their quiescent state. However, when the goal is new plants, provide enough moisture in the soil without driving out the required soil oxygen and supply heat by either using a heating pad, sow the seeds in the soil when the soil has warmed up sufficiently or cover the soil with black plastic that will absorb sun and warm up the soil for the embryo's sake.

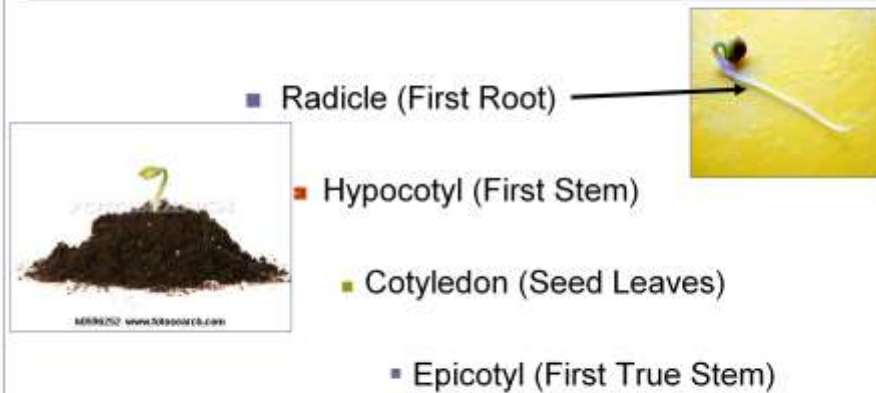
Germination

■ Inhibitors

- Stratification (temperature treatment)
- Scarification (physical disruption of the seed coat)
- Immature embryo (“not ripened”)
- Double-dormancy

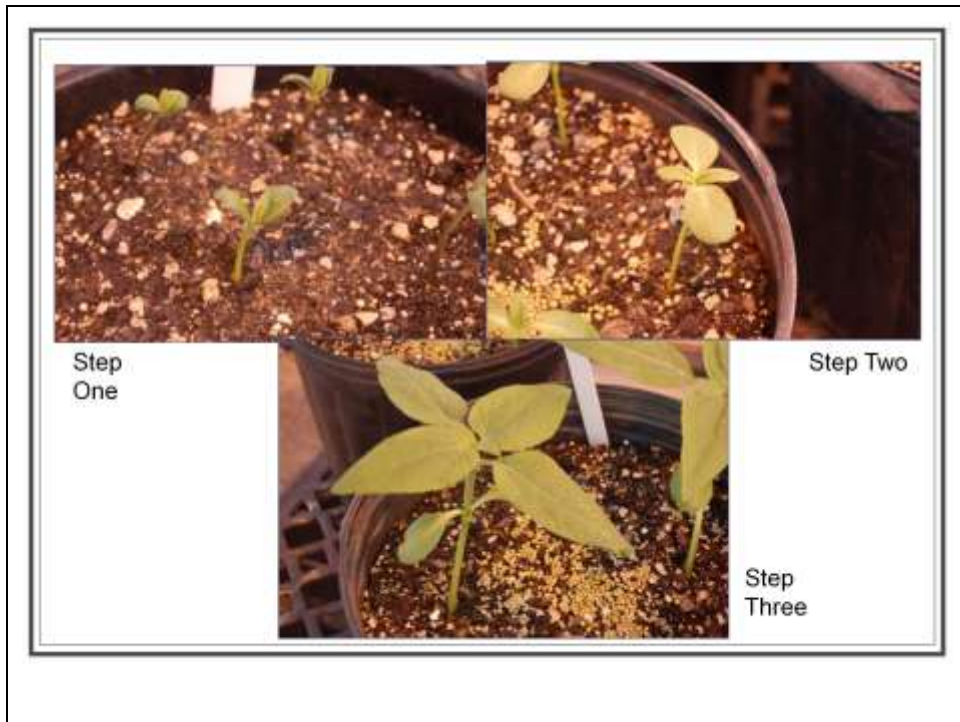
As with everything, there are several potential roadblocks to successful germination. One, sometimes (not always) embryos require a temperature treatment before they resume active growth. Stratification is the process whereby embryos are subjected to warm temperatures, cold temperatures or both to get the embryo to begin growth. This is often referred to as using temperatures to “break” seed dormancy. Sometimes, seed coats are so hard that moisture can’t get through the coat and into the embryo to begin accelerating respiration. In this case, the process can be speeded up by weakening the seed coat or by opening up a hole in the coat. This process is called scarification and can be accomplished by soaking the seed in acid for a few seconds to a few minutes, nicking the seed coat with a knife or file, or roughing it up with sand or sand paper. If the embryo is not fully developed, it’s called unripened. Only time will heal this deficiency. When the embryo is fully developed and ready for germination, it is termed “ripened.” Not all seeds have this lengthy time requirement. Finally, some seeds experience what is termed a “double-dormancy,” or a “cotyledon dormancy.” In this case, as with red oaks, the radicle (seed root) emerges from the seed in the autumn and puts on quite a bit of growth. However, before the hypocotyl (seed stem) can emerge, it must go through a lengthy winter stratification.

Germination “Timeline”



Once all germination requirements have been met, order of the process is generally as follows: 1st, the radicle emerges, then the hypocotyl.

The hypocotyl is normally bent when it's underground, allowing it to grow up through the soil without damaging the cotyledon. Once the hypocotyl reaches sunlight, it straightens up and then the cotyledons emerge. Finally, step four is the formation of the first true stem, the epicotyl. From that point on, the plant looks pretty normal and begins photosynthesizing normally.



Step one in the germination process of this dicot is the emergence of the hypocotyl and subsequent straightening. Then the 2 cotyledons open up. In step two, the cotyledons are fully opened and the epicotyl is beginning to grow. In step three, the epicotyl has fully developed as well as the first true set of leaves. Note how the first true set of leaves look completely different from the cotyledons.

Photosynthesis

- The Conversion of Light Energy into Chemical Energy (sugars)



Photosynthesis is arguably the most important chemical reaction on earth. We all depend upon it, even though it may not be completely responsible for cell phones. At its simplest level, photosynthesis is the conversion of light energy into a chemical energy that plants can use for growth. The chemical that is produced is glucose, a sugar.

Photosynthesis: Limiting Factors



- Light:
 - Quality
 - Quantity
 - Duration

For photosynthesis to proceed normally, there are several requirements, including light. When these requirements are limited, then photosynthesis is negatively affected. Light requirements are three-fold: light quality, quantity and duration. Light quality refers to the wave length requirements of plants. Quantity refers to the intensity and is often referred to as low light or high light. Duration is as the name implies, the length of time that light is available. For a southern exposure, the duration and intensity of light is at its maximum and most plants grow very well in this situation. For a northern, shady exposure, relatively few plants do well in this compromised environment where light quality, quantity and duration are all extremely different from a full sun situation.

Photosynthesis: Limiting Factors

- Chlorophyll A
- Moisture
- Oxygen
- Temperature
- Carbon dioxide



All of the chemistry goes on in plant parts that contain chlorophyll, specifically chlorophyll A, the green of plants. If chlorophyll A is removed (over pruning, hail storms, insect defoliators), there's not a lot of photosynthesis that can go on. Moisture is an absolute requirement and is responsible for keeping leaf stomata open and taking in carbon dioxide, another critical ingredient for the process. Oxygen levels must be sufficient for the chemical process to proceed and finally the temperatures must be within a workable range for the process to move forward smoothly. Very cold temperatures and very hot temperatures effectively shut down photosynthesis. And if photosynthesis is compromised, the release of the accumulated energy for all of the growth processes is compromised.

Respiration: The Release of Energy

- Release is dependent upon:
 - Temperature
 - Oxygen
 - Moisture
 - Amount of energy reserve (sugars or complexes)

Respiration is an equally important and beautiful chemical reaction. Without respiration, the sugars would accumulate or be stored in more complex forms such as starches, but could never be used. Respiration releases that energy and allow every single action within the plant to take place...growth, recovery from defoliations, formation of fruit and seeds, etc. As with photosynthesis, a number of factors can limit the rate of energy release, most importantly: temperature extremes, oxygen levels, moisture levels and the amount of sugars or stored energy available within the plant for respiration. As with photosynthesis, temperature extremes (below 40 degrees F. and above 85 degrees F.) retard the process. If oxygen and water is not sufficiently available, then respiration slows down to a crawl. As you begin to appreciate both photosynthesis and respiration, common gardening practices begin to make even more sense: watering, but not flooding plants; planting sun-loving plants in sunny spots and vice-versa; over-pruning slowly kills plants. By the way, plants can't release energy from fertilizer. Adding fertilizer may increase a plant's photosynthetic potential by increasing leaf (chlorophyll A) area, which would in turn provide more energy that could be released.

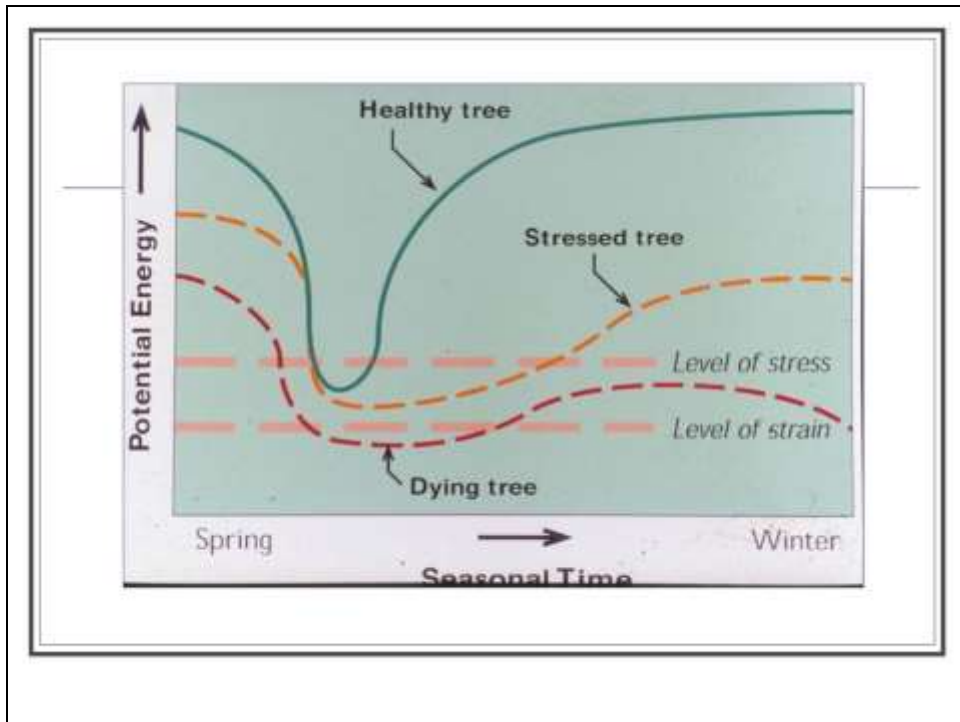
Respiration: The Release of Energy

- Energy for growth
- Energy for recovery
- Energy as gauge of vitality
- Energy for germination
- Energy for bud break
- Energy for winter hardiness

Literally every growth process within a plant is dependent upon energy. Every living cell within a plant undergoes respiration: flower petals, fruits, seeds, roots, living bark...everything. These are just a few of the basic processes that require a lot of energy to be released. How does energy released influence winter hardiness?



Photosynthetic and respiration rates vary with the seasons and exposures. In the summer, photosynthesis is working its hardest providing there's adequate moisture and optimum temperatures. In the autumn, the chlorophyll A begins to break down, exposing the other wonderful pigments in the leaves, but reducing the plant's ability to produce energy. Grasses, shrubs, flowers and trees all have different photosynthetic rates.



Energy reserves define a plant's overall health, especially a woody plant. This potential energy curve is a description of how perennial plants capture and release energy over the course of a year, and how certain events can temporarily or permanently decline the health of the plant. When plants are coming out of their winter period of rest, sap begins to flow, buds swell, flowers form, shoots and leaves elongate and enlarge. All of those activities take energy, and none of them return energy. So, late winter through spring is a very energy stressful time of the year for perennial plants. As long as they resume normal growth in the summer, they build up the energy reserves necessary for that season's growth and to help them come out of their winter rest period the next season. However, if any activity interrupts that normal recovery, the plant is stressed even more, sometimes to the point that it can never recover. Construction damage that severs roots, over-pruning, insect defoliation, hail and wind storm damage...all can over-stress a perennial plant and cause it to go into a gradual decline of health and eventually a premature death.

Net Effect on Energy Reserves?



When trees are “topped” for any reason, two big things have happened. First, most of the chlorophyll has been removed, so photosynthesis will be severely stunted, limiting the amount of energy the plant can draw upon. Second, huge wounds have been created that need to be sealed over (“healed” in misspoken common language). This sealing over of the wound takes a tremendous amount of energy to accomplish. Therefore, this begins the long, downward spiral of decline.

Exceptions to Every Rule



Adventitious Roots

Finally, a few notable exceptions to rules. Adventitious, in the botanical sense, means something that normally wouldn't be present. A root on a stem is not normal, even though it can be good. With corn, a very tall and top-heavy plant, it's stability is dependent upon adventitious roots that develop into "prop" roots, literally roots that grow out of the stem and prop the plant up.

Adventitious Roots: Clonal Propagation



As noted earlier, adventitious roots are extremely important for clonally reproducing desirable plants, or propagating plants that are not producing reliable seed sources.

Adventitious Roots: Clonal Propagation



All of these roots are adventitious, having formed off the stem cutting of this willow. Now the cutting can be planted and will grow into a tree exactly like the one this cutting was taken from.

Adventitious Roots: Clonal Propagation



This type of propagation is the main way yellow birch (*Betula alleghaniensis*) is commercially propagated.

Exceptions to Every Rule

Spines are
"leaves"



Not all leaves are green and pretty, and not all plants photosynthesize solely through their leaves. In this collection of cacti, not a single one has green leaves, but they all have leaves and they all photosynthesize. With these cacti, their leaves have been modified into protective "spines," and photosynthesis takes place in their green stems. Those stems are green because of chlorophyll A, which no matter where it's located will have the ability to photosynthesize and convert light energy into chemical energy.

Exceptions to Every Rule

No Leaves,
so
Photosyn-
thesis takes
place in
stems



With this succulent desert plant, the stems and branches not only have the chlorophyll necessary for photosynthesis, they store tremendous amounts of water necessary to complete both photosynthesis and respiration.

Exceptions to Every Rule



Water Storage
Leaves



More examples of plants modified to survive in droughty, hot climates. Can you imagine how quickly leaves would die in a desert environment? These plants store water for chemical processes and photosynthesize through their modified, puffy leaves and stems.

Exceptions to Every Rule



Abnormal Leaves



Abnormal Root System

There are lots of abnormalities with plants; some are natural as the spines on the leaf tips of thistle, and others are the results of poor plant cultivation practices like the pot-bound root system on the right. Abnormal doesn't necessarily mean dysfunctional...harmful to the plant. Spines and adventitious roots are abnormal but most of the time very functional. Pot-bound root systems are abnormal and dysfunctional, negatively affecting the growth and health of plants at the very least in the short term, and quite often long-term.