MONTANA STATE UNIVERSITY | EXTENSION

Pruning Trees for Health, Shape and After Storm Damage

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Forward

I started my career as a "tree surgeon" in Milwaukee, Wisconsin, often climbing and removing large old American Elm trees that had been planted a century before in narrow spaces between houses and that Dutch Elm Disease had killed. That work started me down the path of forestry, as cutting up trees made me want to know more about how they grew and functioned. It remains a lifelong passion and study as every location influences tree physiology and growth differently. Although I spend much of my time these days studying in an office or pursuing research questions in the field, my happiest times are still outside working with trees, as it is something where you can get a personal sense of accomplishment, and develop a relationship with a tree that if treated correctly will connect with the future generations of the person that planted it. Trees endure without complaint, offering shade to the weary, wood to the industrious and entertainment to the young. It is no wonder they were revered by many ancient cultures. I hope you find this booklet helpful keeping our silent friends healthy and growing.

Pruning and tree removal can be dangerous work. Proper training and equipment is essential to work safely and to implement proper pruning practices. Always ask for credentials and references when hiring an arborist!

Introduction

Pruning can be an important tool for keeping trees healthy as they are not always planted into appropriate locations or grow into a form that is best for them or the surrounding circumstances. Pests, wind, snow and ice damage can also occur where pruning can be an important tool for restoring a trees ability to grow and remain healthy. Although most tree species are very resilient to pruning any time of the year, there are optimum times depending on the species and the purpose of the tree. For all trees where ornamental spring flowering is not their primary purpose, pruning is best done in late winter before the buds start to swell and the tree breaks dormancy. The second best time is mid-summer which allows for better shaping and dead limb removal as the leaves are present on deciduous trees and wounds have some time to start healing before winter. For ornamental flowering trees it may be best to prune mid-summer as pruning in late winter can remove most of the flowering buds, compromising the spring display for that year. Many recommendations for when to prune and how to prune individual species can be found in bookstores or the internet, however, any manipulation of a trees shape and function should be conducted with a basic understanding of how a tree functions.

Tree functional components

A tree is a plant with a tall structure comprised of a **stem** and **branches** to support **leaves**, and a **root** system that anchors the stem *(Figure 1)* and procures and stores essential growth elements such as water and nutrients. Trees are unique from other plants because they can and usually do live for a century or more (the oldest known single-stem tree is a baobab in South Africa measured to be 6000 years old), grow successive layers of woody vascular tissue that is added from growth just under the bark to develop woody stems, and in most parts of the Earth grow taller than surface vegetation, ranging in height from several meters up to 115.55 meters (the tallest recorded tree is a giant redwood in northern California). All tree species have the same basic anatomic characteristics, although their stem shapes, crown structure, leaf shape, wood strength and chemistry, and physiological tolerances will vary.

A tree stem is unique from other plant forms in that its woody stem growth occurs from a thin strip of cells called the **cambium** located just under the outer bark. Each year the cambium adds layers of new

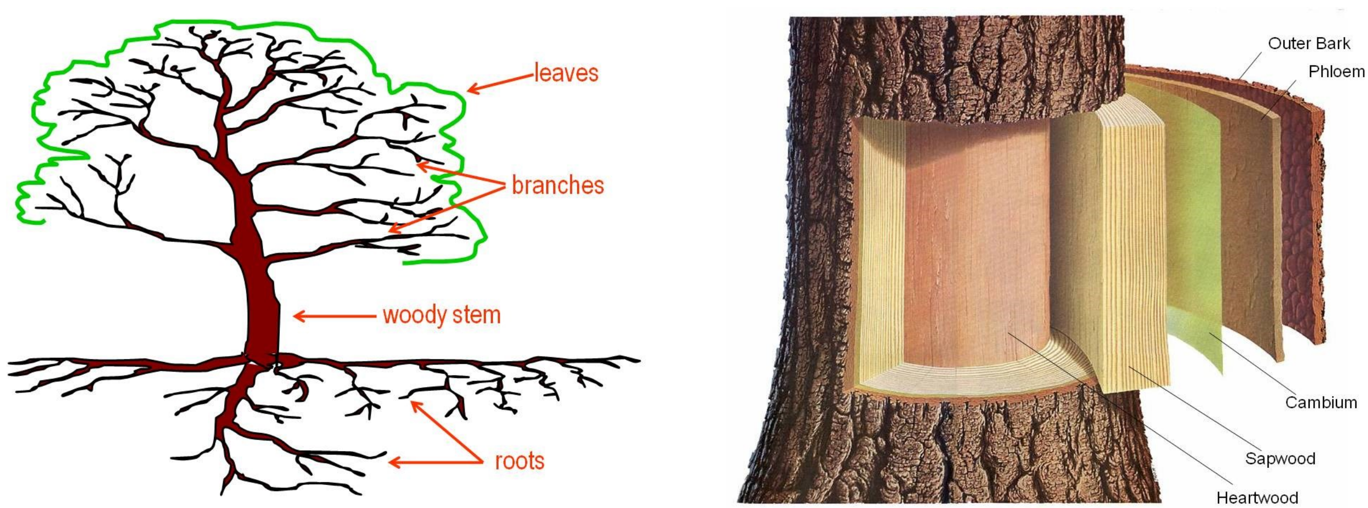


Figure 1. *Components of a tree (left) and the anatomy that makes trees unique from other plants (right)*

growth in both directions - inside to woody tissue and outside to the inner bark. Growth to the outside is called the **phloem** and consists of large diameter cells designed to conduct sugar water from the leaves down the stem to the rest of the tree. Because of their large diameter, these phloem cells are structurally weak and collapse after a year or two and are pushed outwards into compacted layers that become the outer **bark**. Growth to the inside is called the **sapwood** or **xylem** and functions as a living water transport system from the roots to the leaves and a storage site for surplus sugar and starch. Eventually older sapwood dies and becomes the dead central core of a tree called the **heartwood**. Some tree species will also deposit metabolic by-products or waste material into the dying xylem tissue that results in a discoloration and change to the heartwood characteristics. These deposited materials can be fragrant such as incense cedar or white oak (the former acts as a deterrent to moths and other insects and the later imparts the unique smell and flavor of whiskey), specifically colored such black walnut and red oak, or somewhat toxic to insects and fungi such as western red cedar, redwood, or catalpa which is why their heartwood is pest and decay resistant. This is also why lumber cut from tree heartwood is often more durable than the wood cut from the sapwood. Living tissue stores sugars and starch that may become food sources to molds and some insects making it more decay (rot) prone than heartwood. An example might be the uses of dark-red heartwood of cedar trees. Cedar chests have been used to store linens and wool because natural chemical deposits in the heartwood, which people might find pleasant in low doses, are irritants to moths and other insects which keeps them out of the fabric (which is also why in some cases pet-beds infused with cedar chips might result in pet allergic reactions). Likewise redwood decks made out of heartwood are noted for their mold and decay resistance. Chests or decks made out of the light colored sapwood, alternatively, will not have the same insect and decay resistant properties.

Physiology

It is important to know that every tree's roots, stem, branches and leaves have a specific physiological function. Tree physiology functions much as in all other plants: leaves absorb carbon-dioxide (CO_2) from the surrounding air through little pores in their leaves called stomates and use the energy of the sun in a biochemical process called photosynthesis that converts CO_2 and water into the 1carbon-2hydrogen-1oxygen molecule known as sugar *(Figure 2).* Oxygen is also produced as a byproduct of photosynthesis and is released in gaseous form back into the surrounding air. A primary use of photosynthesized sugar is consumption by all the living tree cells to stay alive in a process called "maintenance respiration". Respiration is the chemical reaction between sugar and oxygen that fuels cell function and cell division and is a

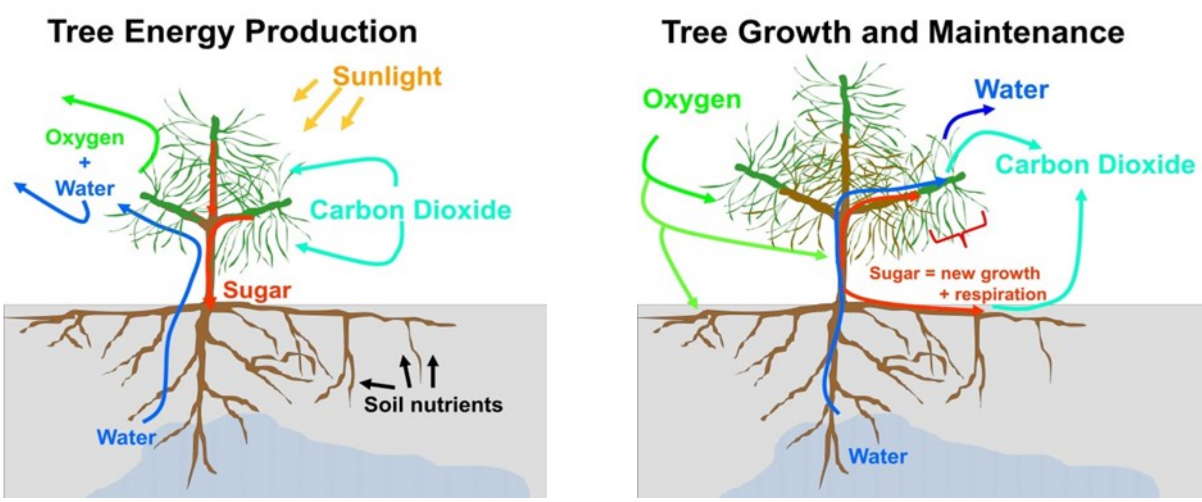
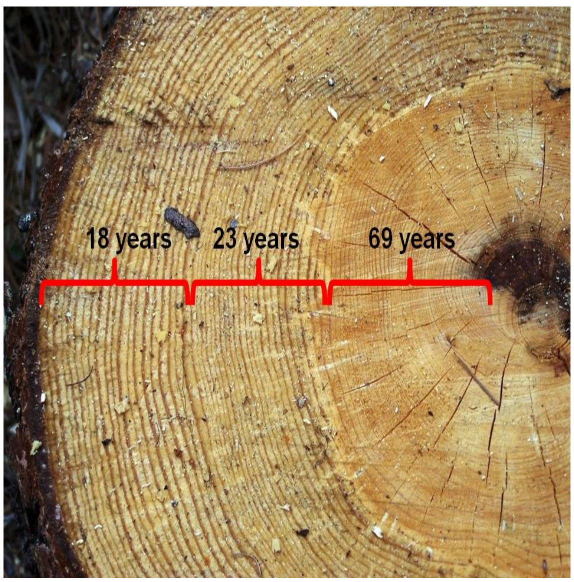


Figure 2. *The physiological processes that allows trees to grow might be called "light" and "dark" physiology. During warm sunny days photosynthesis (left picture) produces energy and atmospheric oxygen whereas during the night, spring or to a lesser significance cold periods, (right picture) respiration occurs that allows cells to grow or just stay alive and consumes stored energy and produces atmospheric carbon dioxide. High temperatures above 95˚F can also cause respiration to exceed photosynthesis thus trees lose energy and are net emitters of* CO_2 *during heat waves.*

basic process of life used by most living organisms (plant and animal). Surplus sugar is converted into starch for storage, and is also used to fuel growth of leaves, roots, branches and the tree stem. Tree growth occurs in a process known as "growth respiration" when optimal temperatures, water supply and energy reserves (starch and sugar) allow for cell division and the production of cellulose, hemi– cellulose and lignin, which are the major components of woody cell walls. Sugar production is therefore directly proportional to how fast a tree grows provided optimum temperatures and adequate water exist.

Respiration is a consumptive process as opposed to photosynthesis, where sugar and oxygen are the fuels that keep cells alive and carbon dioxide is a byproduct that is released into the surrounding air, much like in animals and humans. The difference is that animals must eat carbohydrates whereas a trees produce their own. Maintenance respiration occurs all the time and is a function of temperature, the warmer it is the higher the respiration rate. Temperature optimums for photosynthesis of most northern latitude trees are between 70 and 85˚F. Alternatively maintenance respiration continues to increases with temperature. Because of this disparity, energy consumption from respiration exceeds photosynthesis sugar production near 95˚F, thus extreme heat can cause trees to lose energy (and also produce more carbon dioxide than oxygen). On average throughout a normal year, a healthy and vigorous tree consumes about 10% of its produced energy for maintenance respiration and uses the rest for growth and reproduction. This is also why most healthy deciduous trees have the capacity to regrow their leaves 2-3 times if defoliated since they have enough stored sugar in other parts of the tree. Alternatively conifers can die if they are completely defoliated because they store much of their excess sugar in their twigs, needles and buds and if they are eaten the tree can lack the reserves to grow new needles. This also relates to tree pest and pathogen activity as most tree pests and pathogens need to feed on a tree's stored starch and sugar because they are incapable of digesting wood (termites are the common exception) and thus attack the tree where these reserves exist. This is also why sometimes pests will not attack a severely stressed tree as it does not have enough stored sugar to be a good food source.



***Picture 1**. A tree stem cross-section shows heartwood (darker first 69 years) and sapwood (lighter color) and subsequent 23 and 18 years. Crowding by other trees and thus limited light and water resulted in poor growth the first years whereas removing crowding trees first at 69 years and again after another 23 years resulted in more light, water and better growth.*

In most regions primary tree growth occurs in the spring when temperatures warm-up enough for cell division to occur and water and nutrients are abundant after the snow-melt. During summer, growth slows when drought and/or high temperatures limit photosynthesis and energy sources are diverted to seed production. Where the climate has distinct seasons, tree stem and branch growth can be seen as rings in the woody (xylem) tissue on a cross section of a tree stem *(Picture 1)*. Light colored rings are formed in spring when a tree has abundant water, starch is metabolized into sugar and cell growth is rapid. This produces larger diameter vascular cells for better water transport. As water becomes more limited during the summer, cell growth slows and denser dark rings are produced. Growth stops in winter. A trees age can thus be estimated by counting either light or dark rings. Occasionally weather patterns such as spring drought followed by mid-summer rain can stimulate alternating slow and fast growth resulting in what are known as "false rings" which is why counting rings for age is not entirely fool proof – unless examined closely under a microscope. Ring width is a reflection of energy availability. Wide rings show periods of abundance of resources and thus better growth, narrow rings represent periods of resource limitation and thus poorer growth. Trees growing in more tropical climates may produce rings that correspond to rainy and dry periods, or may not produce rings at all if the differences in resource availability between seasons are not very pronounced.

As summer progresses tree energy priorities may also be redirected towards seed/fruit production. An interesting phenomenon for many trees is the "stress crop" effect. Trees that are stressed may divert energy towards a plentiful seed/fruit crop as a "last gasp" before they die as a mechanism to ensure species survival. A heavy seed crop on a scrawny tree may indicate imminent death rather than health and abundant energy. Fruit growers use this effect by pruning trees every late winter in manner that does not weaken overall tree health but that stimulates a "stress" seed (fruit) crop.

When day-length decreases winter adapted tree species hormone production changes and cold hardiness is initiated before the onset of freezing temperatures. This usually results in an increase of cell sugar content, a decrease in cell water content and the production of glycols that keep cellular water from freezing, which would rupture cell walls. Once temperatures cool to freezing, growth stops and trees go into dormancy, though limited maintenance respiration in living cells still occurs.

It is thought that trees in general prioritize and allocate the sugar they produce in the following order of importance: **1**) Maintenance Respiration (just staying alive), **2)** Growth Respiration (new cell development), **3)** Energy storage, **4)** Defense (sealing wounds and defense chemicals), and **5)** Reproduction (flowers, pollen and seeds, though as previously discussed, a stressed tree may change this priority to #2). In summary, overall tree growth and "health" is determined by a tree species ability to obtain sunlight, water, nutrients, and air on the microsite it is growing in (a factor of the combined effects of soil texture, chemistry, depth; topographic influences on sun, temperature, wind and humidity; competition from surrounding vegetation; local water balance and cycles) which in turn is subject to the dominant influence of the geographic locations overall weather (1-30 year events) and longer term climate (30+ year trends).

Genetic variability

Each tree species has over millennia developed particular growth and reproductive strategies for a specific range of conditions, as well as some additional strategies for coping with historically predictable disturbances such as wildfires, snowpacks, cold, heat, flooding, and even certain insect or disease attacks. These types of adaptation occur due to "selective pressure" where those individuals that have a genetically controlled mechanism to cope with a disturbance will survive and pass those characteristics on to their offspring, and those that do not will die and fail to reproduce. For example, when to prepare for freezing temperatures and the ability to cope with extreme cold temperatures are two key genetically controlled charac-

Picture 2. *Trees from different geographic locations growing in a windbreak such as ponderosa pine (left) show different branch structure, needle density, color, and needle retention. Similarly Colorado blue spruces (right) show different tolerances and/or rates of winter hardening in response to unusual early extreme cold.*

teristics for most northern tree and shrub species and designated for trees by "zones" 1-13 where Montana falls within zones 3-6 ("3" is cold tolerant to –40˚F and typical for the north central Great Plains and "6" is cold tolerant to –10˚F and found only in the valleys of NW Montana). Such genetic control does not only exist between species (such as ponderosa pine versus peach trees), it also exists within species such as ponderosa pine from the western part of Montana versus ponderosa pine from the eastern part of the state (*Picture 2*), Douglas-fir with every 1000 ft elevation change, or different cultivars of spruce. Genetics can have a tight control over how a tree grows and functions, especially where site characteristics (such as a high water table, full sunlight or shade) require specific growth forms in order to survive. These controls can be expressed as a wide range of potential growth characteristics where each individual tree has the capacity to adapt to its surroundings by modifying its growth characteristics (shallow roots versus deep roots, longer thinner needles versus short wide needles, etc.). Alternatively a species might carry a large degree of genetic variability within a population where rather than individual trees adapting, each generation produces individuals with a wide variety of genetic diversity from which some will be better adapted to the location an the others will perish. In some cases when such a strategy exists on one location for a longer period of time the genetic variability can be reduced as continual selection for specific genetics reduces overall population genetic diversity to only the specific genetic code that works best for that locale.

Species with great internal genetic adaptability typically have a wide geographic range such as silver poplar, boxelder, soft maples, green ash, many spruce species, and Russian olive. Due to their adaptability they often naturally propagate and can invade into areas where they may not be wanted and can therefore be labeled a "weedy or invasive species". Their value should not be overlooked, however, because they might be the only tree species that can survive in extremely harsh and variable environments, such as is commonly found across central and eastern Montana. Alternatively, there are species that have very site specific genetically tuned controls such as western red cedar, pacific yew, hard maples, birches and potentially oaks. They must be carefully matched such that the environment of their origin matches the environment into which they will be planted. Such a good genetic match to a site should promote exemplary growth that should be better than the growth of a genetically adaptable species, however, if it is planted outside its more narrow native "environmental" window it will typically exhibit poor growth, significant insect and disease attack, and weather related dieback. This is why landscapes that historically did not support trees because of harsh or unpredictable conditions, tend to have a greater abundance of genetically adaptable species planted because they have better survival rates. Finding individuals from the site specific genetic group takes much longer time as experimentation with different seed sources takes a long time to find the best matches. Old homesteads, farms and ranches where the original owners planted a wide variety of species from many different sources (most of which did not survive) are a highly underutilized source of "proven" trees that could be used as local seed sources for surrounding communities.

With the perspective that there are tree species that trend towards being genetic "generalists or specialists", every tree species has a certain amount of genetic variability built into it. Conifers, especially spruce species, have existed longer than most other tree species and as a population carry within their genome not only multiple codes for a variety of characteristics, but also gene fragments that appear to have no function and are thought to be holdovers from ancient conifer ancestors. Some spruces for example may have 3 times as many chromosomes as humans, and the reason for this remains a mystery to geneticists. Because such variability exists within the species (*Picture 3*), individuals from the same seed source

***Picture 3**. All of these Colorado blue spruces came from the same source and are planted on relatively uniform soil and site characteristics, but each tree exhibits a different color, shape and height. What you see (phenotype) is the combination of genetics, plus the effects of environment, plus the genetic characteristics that might be triggered by the environment.*

may grow, look, and develop with differences even though tree breeders and nurseries work to develop and maintain consistency for each tree species they grow. Common questions asked are why some blue spruces remain blue and others turn green, why some trees from the same nursery planted in a row are attacked by insects, diseases and animals such as sapsuckers, and others appear immune.

Although there are techniques to promote consistency within a species, and unintended result may be genetic similarity or inbreeding. Specific tree varieties or fruit cultivars such as for apples, plums, and pears, or ornamentals such as Japanese maples have been propagated by grafting cuttings from a single tree onto other root stocks to eliminate unpredictable performance. Unfortunately the more specific a population of trees is bred or cloned for some consistent characteristic such as color, shape, flowers or fruit, the more likely the entire population will be susceptible to some super bug that has developed a specific liking for the genetics of that cultivar. Population genetics that are more diverse and thus more inconsistent in their looks and growth, also has been linked to greater stress and pest resistance because they are more likely to have multiple mechanisms to deal with such factors. On the practical side, sometimes out of a population of planted trees there will be individuals that just do not grow well and are constantly attacked by one pest or the other. It can be highly likely that a combination of maladapted genetic codes simply make this tree a poor performer, and it is best to start over with another tree. Determining if a tree issue is caused by the environment or its genetics can be difficult to ascertain. To separate individual genetic maladaption from site problems such as cold, wind, poor soil drainage or chemistry an examination of the pattern of tree characteristics is needed. Whereas genetic variability within a population typically is confined to random individuals, overall population adaption and site gradients are indicated by (poor) performance patterns of multiple trees, and may be associated with locations where physical changes such as soils, buildings, other trees, lawns and gardens modify the environment (*Pictures 4, 5*).

Ultimately a trees shape, growth and resilience is a product of its genetic programming, the local environment, and the feedback the environment has for turning certain genetic traits on or off. We can, however, to some extent modify the tree growth form (pruning), and the environment surrounding a tree (water, pesticides, fertilizer), and thereby change or improve the appearance and growth characteristics of an individual tree.

Picture 4. *The upper picture shows a row of ponderosa pines that are growing poorly except where they are behind the grain silos and protected from direct sun, suggesting drought and heat stress.* ***Picture 5.*** *Ponderosa pines growing robustly behind the house but not next to the house (front right). Those behind the house get water from the lawn and sewer drain field.*

Stem vascular function

During the summer water is pulled up to the leaves (*Figure 3*) by an internal gradient of increasing suction - which is created by several processes including: 1) capillary action that "pulls" water into the tiny pipe shaped cells of the sapwood much like a paper towel absorbing water (called matric potential), 2) sugar gradients within the stem where sugar exerts a chemical attraction to water molecules (also known as osmotic potential), and 3) the suction created by dry air evaporating water out of the leaf surface (vapor pres-

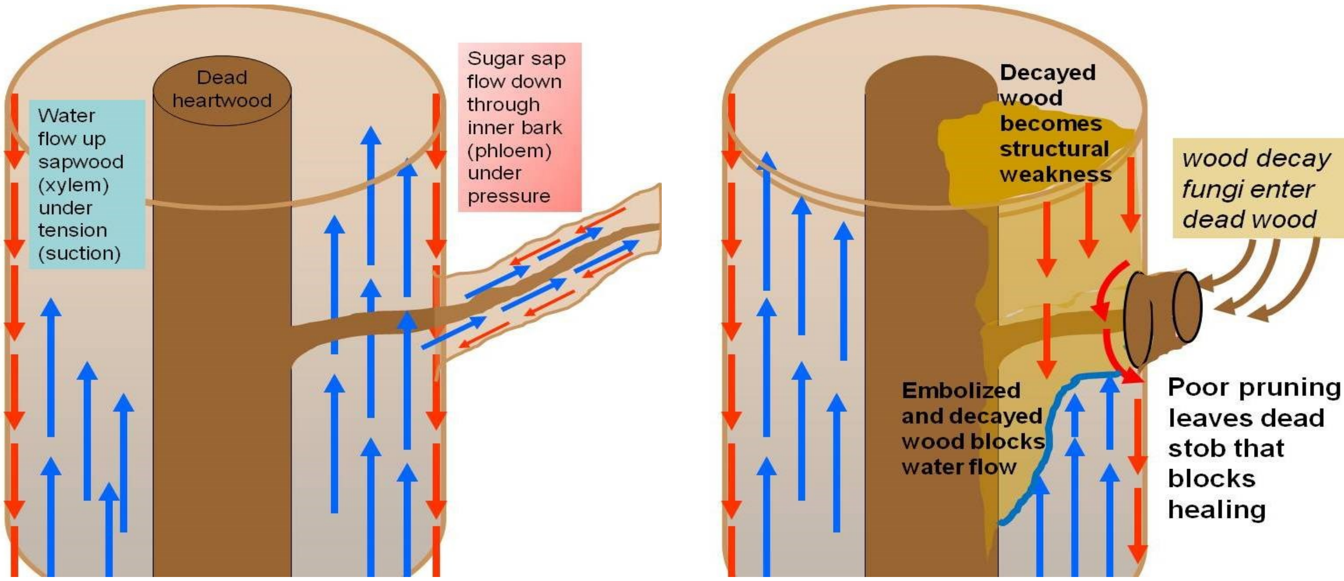
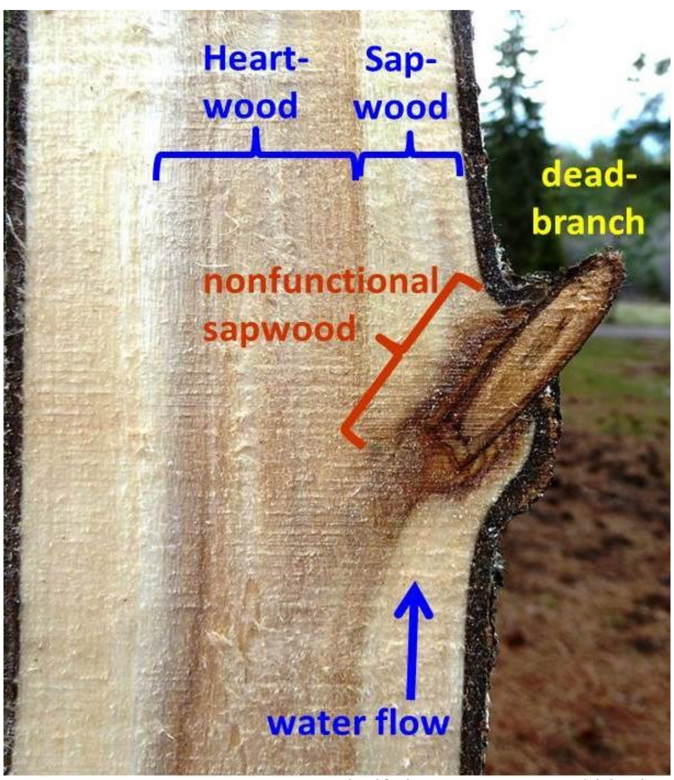


***Figure 3**. How the vascular tissue of a tree functions. If the flow of water is disrupted the tree will have a harder time supplying leaves with enough water to function. The longer a wound remains open the higher the chances that decay fungi will invade and start rotting the wood.*



***Picture 6**. Aspen stem cut in half showing sapwood blockage created by air embolism and subsequent fungal infection that entered after the branch died.*

sure deficit). As the air gets drier (lower relative humidity) the "suction" exerted on a leaf surface increases and may exceed 100 lbs/square inch, which for comparison is double that of a powerful vacuum cleaner. When an injury such as a pruning cut is made into the water conducting tissue of a tree in the summer, the vacuum in the tree can pull air into the water conducting tissue that forms an air pocket or "embolism" blocking further water flow and cell death (*Picture 6*). Similarly, extreme drought can cause air bubbles to form in the sapwood which is called "cavitation", this is partially reversible in drought tolerant species and lethal for less drought tolerant species. Depending on the size of the wound and the vascular system of the tree species, the air pocket formed may have a minimal effect, or act as a serious bottleneck for water and sugar movement. For example, think about how you drink from a straw. If a hole is poked into that straw, suction allows air to be drawn into the hole more easily than water getting pulled up the straw, making drinking very ineffective. The sapwood of a tree is made up of millions of tiny cells that look and act like straws, and although most trees have a mechanisms to block or limit airflow from penetrating into vascular tissue when an injury occurs. The greater the drought stress or the larger the injury the more dysfunctional the sapwood may become in the vicinity of the injury .

In addition, an open wound is an attractive site for infection from decay fungi and wood boring insect pests that will exacerbate sapwood dysfunction. For this reason a pruning wound should be kept as small as possible, and connected to tissue that will stay alive and allow for a new protective layer of bark to quickly grow over the wound and seal off the xylem.

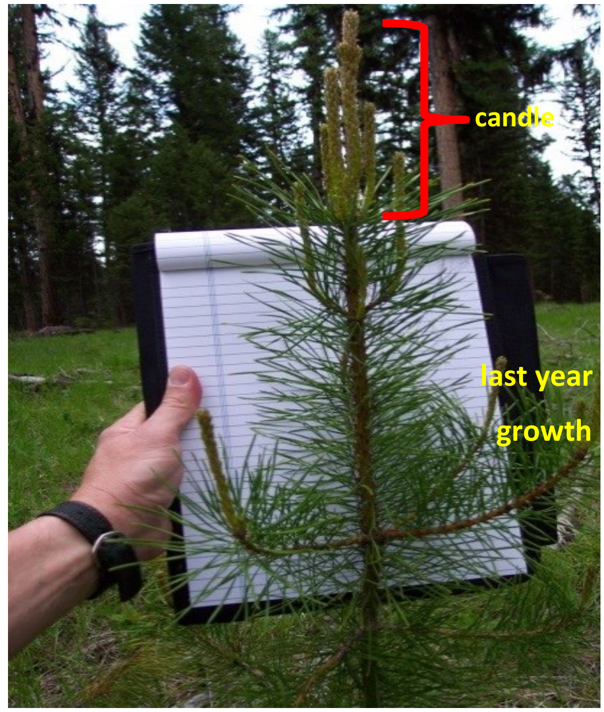
Picture 7. *Weeping birch exhibiting drought stress as top dieback which may attract bronze birch borer.*

The total width of the multiple layers of living sapwood in the stem is often closely correlated to the overall leaf area and water demand of the tree. Keeping living tissue alive is an expense to the tree, and there is some feedback within a tree's physiology that only keeps enough sapwood alive to ensure leaves remain adequately supplied during the growing season. This feedback mechanism may be highly tuned in some tree species and less controlled in others, which is why correlations between sapwood width and leaf area varies among tree species. Most juvenile trees with large crowns only have sapwood, first developing heartwood as their stem width to leaf area ratio gets larger.

Overall tree water balances are impacted by changes in weather, microclimate and longer term climate trends. Warming trends are often associated with lower humidity and thus greater "suction" of water out of the tree, which can lead to tree stress. Also, if a tree experiences a dramatic change in local climate, such as hot air rising off a newly constructed black asphalt paved parking lot next to the tree, the previously developed balance between leaf area and sapwood may be inadequate and the tree will experience drought stress in its leaves because the stem cannot transport water fast enough to meet the new demand. Such drought stress may be exhibited by more frequently wilted leaves, early leaf drop, top dieback and branch dieback. Given time a tree can adjust its physiological balances, though every tree species has different tolerances and strategies in dealing with water, heat, cold and nutrient balances and localized changes in these parameters. For example, many mature weeping or European birch trees (*Picture 7*), that are a commonly planted ornamental yard tree suffer from top dieback and/or predisposition to bronze birch borer across Montana as they get taller because their height growth exceeds their sapwoods capacity to move water rapidly enough to the top branches and leaves during extremely hot days with low humidity. This may likely be because the native habitat they evolved in and adapted to is the wetter and more humid environment of Europe and Scandinavia. The opposite example might be limber pine, native to extremely windy and dry rock outcroppings across central and eastern Montana where most tree insect pests and fungal pathogens cannot survive. This species has, therefore , never had to develop defense strategies against such pests. Planting it into a wet and humid watered back yard where fungal pathogens as well as many needle pests find good living conditions makes it a prime target, which is why many ornamentally planted limber pines are plagued by a wide variety of pests and pathogens. As previously noted, it is always wise to research the native habitat of any tree species you wish to plant in order to help determine if it has the mechanisms to cope with the weather, soil and even pest and pathogen extremes common to your local environment. This helps ensure the physiological capacity of the tree species can adapt and adjust to the conditions of the new planting site. Typically the more exotic the native environment of a transplanted tree species, the more help it will need in the form of pesticides, fertilizer, watering and pruning of cold or heat damage. There are exceptions such as the Ginko biloba, which is the last surviving species of an ancient genus that historically survived across a wide range of environments.

Height growth

Tree height growth occurs when the meristematic tissue in terminal buds *(Picture 8)* at the ends of branches starts to grow and divide. This can be seen in spring as elongating buds or stems just beneath the buds – often called "candle" growth on conifers since the new growth has not yet developed long needles. All trees grow taller only from the tips of branches. Conifers typically grow taller from one main "terminal bud" creating a single stemmed tree whereas most broadleaf trees grow taller from multiple terminal buds creating a multi-stemmed tree (*Figure 4*). Once the woody xylem tissue of the stem and branches is formed it can no longer elongate, thus the basic shape of a tree is fixed by the spring growth that occurs from the branch tips. Once set, the position where branches occur on a tree stem will not change in their relative height from the soil surface as the tree continues to grow.



***Picture 8**. Annual height growth and spring bud elongation "candle" of a ponderosa pine.*

The rate of tree height growth is determined by a combination of stored sugar and starch from the previous year, water availability as growth is occurring, and to some degree by the amount of sun or shade affecting the tree. Stored energy and abundant water is necessary to fuel cell division and cell elongation. Shade across tree leaves impacts not only energy production through photosynthesis, but also growth hormones. Too much shade and the tree foliage will not be able to produce enough energy for significant growth.

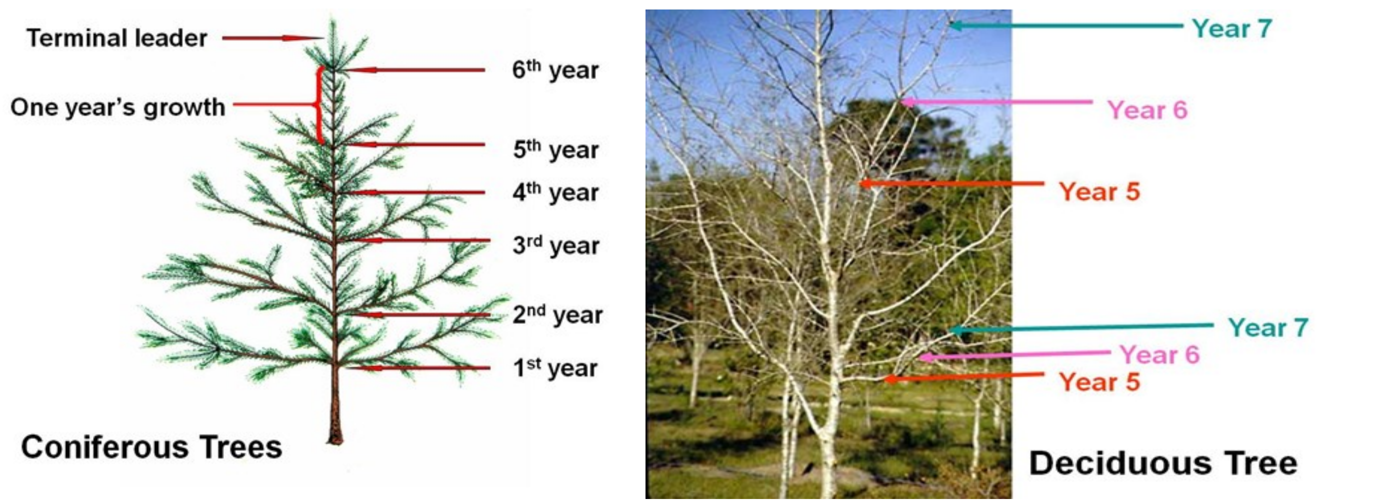


***Figure 4.** Growth characteristics of most evergreen conifers that typically creates a single stemmed cone shape (left) versus growth of many deciduous broadleaf trees (right) that can result in multiple stems or more of a "lollipop or umbrella" shape. A broken off leader on a conifer may result in a multi-forked top as upper lateral branches just below the leader simultaneously assume the "leader" position. The same will occur for single stemmed broadleaf trees.*

Alternatively, partial shade may stimulate growth hormone production that promotes energy allocation to branch elongation into sunlit space. In these cases trees will exhibit rapid height growth at the expense of stem diameter development, often resulting in a tall spindly looking tree versus a slightly shorter but wider and robust tree that has developed a full crown. The final tree height potential is not affected by this type of hormone response, only the rate of height growth. This may be an adaptation for species that evolved in dense forests, where an advantage to outgrow other species was needed to survive. Unfortunately such a shade response does not typically lead to what might be considered a well balanced and attractive tree.

Height growth can also be profoundly affected by water availability to the tree crown, which is influenced by soil water availability, stem water transport capacity and relative humidity (which impacts water loss from tree leaves). Dry soil results in poor water availability to the tree crown, which will inhibit cell division and cell elongation and thus stunt growth even if excess stored sugar is available from the previous year. Extremely dry air during the spring and summer, such as relative humidity less than 30% can pull water out of leaves more quickly than the tree vascular system can replace it, which also inhibits cell division and elongation. Across hot dry areas of the Central Plains, Great Basin and Rocky Mountain valleys only species that have access to water and extremely efficient stem water transport such as cottonwoods, willows, silver poplars, locusts, elms, and Russian olive appear to have the vascular capacity to transport sufficient water through their sapwood to keep their crowns supplied with enough water to replenish what the hot dry air pulls out. As previously mentioned sugar and Norway maples, especially birch trees, some of the hybrid poplars, and ash trees can suffer from some top dieback even with watering as they get taller in hot and low humidity environments (*Picture 13*). All trees will suffer top dieback when extreme heat is combined with lack of soil water. Several species such as poplars, willows, cottonwoods and ash varieties can prolifically sprout new branches after top dieback, though this can later leads to other problems such decay and unstable trees if proper pruning intervention is not practiced.

Picture 13. *Typical top dieback on an ash from high temperatures and low humidity common across central Montana. Note green lawn from frequent watering.*

To defend against low humidity desiccation damage some species more commonly found on upland sites such as ponderosa pine, blue spruces, limber pine, Russian olive and some oaks, have developed needles and leaves that have thick wax on them to limit excessive water loss. Although this allows them to grow on hot, water limited sites, it also limits carbon dioxide absorption resulting in slower growth. Thus sites with consistent low summer humidity and poor soil moisture may only allow for short trees to develop.

In conclusion, a tree's height growth is determined by its local conditions, as well as its genetic programming. A taller tree may simply be growing on better soil conditions than its neighbor, it may have the genetic commands to commit more energy to height growth, or its vascular and leaf structure is better adapted to the overall site conditions. Alternatively growing tall quickly may occur at the expense of using that same energy for defense compounds or root growth and can result in greater susceptibility to attack from pests and pathogens, or a greater risk to drought stress. The "grow or defend" allocation of energy that different tree species and even individuals within a species use can vary greatly by circumstance and is still a marginally understood topic of research. Pruning, watering and fertilizer are methods that can control tree height growth, shape and structure and thus modify a species ability to survive across more difficult environments if done correctly. An extreme example would be the cultured "bonsai" tree that is a normal tall growing species that has been pruned and cultured to grow as a small tree in a small pot.

Root growth

A tree's root system grows and responds to stimuli much like its stem and branches, though roots are not seeking the best sunlight but rather the soil where water and nutrients are available (*Picture 14*). Also, because roots do not need to support themselves against gravity they do not expend as much energy as branches or tree stems to develop strength, but rather grow a much larger storage capacity for water and starch. Through genetic selection across thousands to hundreds of thousands of years, every tree species

Picture 14. *A typical tree root system consisting of expansive lateral roots, a taproot and fine feeder roots. Most roots will be found in the upper 1-foot of soil.*

may have specific programming that directs how the roots will grow. Roots are also highly influenced by the soil conditions they are growing in. The most abundant soil nutrients are typically in the upper 1-ft of soil where leaching from surface organic debris occurs, as well as moisture from rain and snow accumulates, thus this is where the majority of the fine feeder tree roots are located. In addition, just like tree branches and stems, root systems do not produce energy but consume it through respiration, and thus they need oxygen which is most abundant near the soil surface and also influenced by soil texture, structure, and water. Tree roots of all tree species will actively grow into the edges of soil zones with good water availability, though most will not grow into water saturated soils due to lack of oxygen. Some species, especially those adapted to grow in soils with high water tables such as willows, cottonwoods, spruces and surprisingly junipers and ponderosa pine, can grow their roots several feet into water saturated soil. This can become a problem when these species are planted near septic drain fields that subsequently get "plugged" by roots causing blockage or backups. Root development and aggressive growth towards water

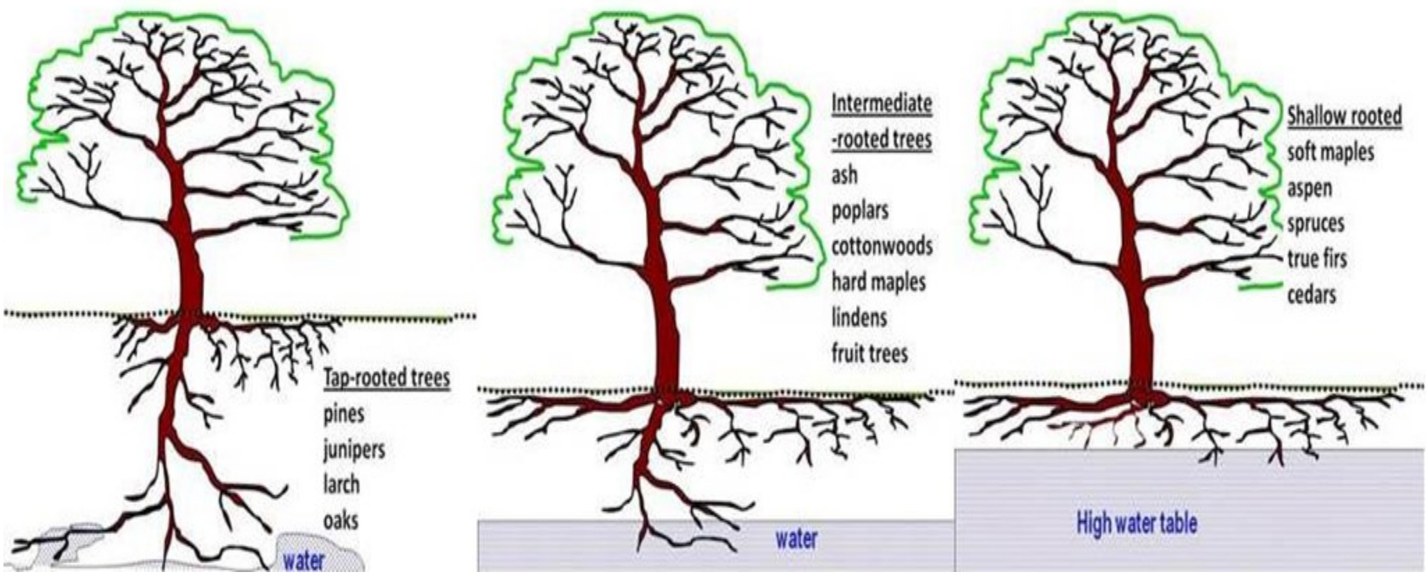


Figure 5. *Different tree species have genetic predispositions for root growth and shape, often to take advantage of specific site conditions where they gain a competitive advantage. Soil conditions can modify the development of root systems such as a high water table or shallow bedrock limiting taproot development. Alternatively trees predisposed to growing shallow root systems typically lack the ability to develop true taproots in deeper or well drained soils.*

will vary by species *(Figure 5)* and this must be taken into account when picking a tree for a specific site, soil, and water table depth. Drought adapted tree species such as pines, oaks or junipers have the capacity to grow tap roots deep into soils or rock fissures (20-30 feet below-ground is not uncommon) to find water, which is why they can survive on dry sites where such deeper water sources exist. Alternatively, when deeper water sources cannot be found such rooting structure may help the root system occupy a greater soil volume which also allows access to more soil water, as well as anchoring these species more firmly against strong winds (*Picture 15*). Previously mentioned species such as cottonwoods, willows and spruces, that have specialized to grow on wetland sites are genetically programmed to develop shallow root systems with specific root physiology that allows roots to survive in periodic flooded soil conditions that would suffocate the roots of many other tree species. Alternatively, this mechanism can also predispose these species, especially cottonwoods and willows, that have not developed water conservative leaf physiology, to suffer from drought stress even in deeper and well-drained soils. The exception to this are junipers,

Picture 15. *Tree species that predominantly develop shallow root systems such as spruces are also highly susceptible to being uprooted by high winds (left picture) as they lack the anchoring tap roots that other species such as pines (right picture and picture 14) develop. No tree is completely resistant to extreme windstorms, though on average for 1 pine that blows over 10 spruces will fail.*

Colorado blue spruces and Russian Olive that also have waxy leaves that limit water loss, allowing them to thrive on both upland and riparian sites (one of the reasons they are popular windbreak species). Regardless of tree species, the majority of roots from most species will grow to where the best soil resources are consistently found. This can become a problem if some event such as severe drought, or ground water disruption causes the water sources or water level to disappear or move below the rooting depth. This can also make planting trees around reservoirs very difficult because a spring high water table will cause deeper roots to die-back, and the surviving shallow root system is then left high and dry if the reservoir pool recedes for more than a month later in the summer. Any time the root aeration or water source that has served a tree root system for a decade or more suddenly changes, whether it is a sprinkler system, irrigation ditch, drip irrigation or a shallow water table, the tree will suffer (*Picture 16*) as it cannot quickly adapt or change its root systems. Although trees are constantly growing new roots, larger and older trees require much more water and thus require several years for enough new roots to find and exploit a new water source, if one exists. Often older trees will die before their root system can adjust. Many tree defenses require ample water to function, and a drought stressed tree is much more susceptible to pests and pathogens. This can lead to a misdiagnosis of the problem where an insect infestation is blamed, though the real culprit was chronic drought stress.

Picture 16. *Any alteration of soils or water supply around a mature tree can have deadly consequences. Trees in the Jordan MT city park (left) lost their irrigation water supply that caused the top 1/3 of trees to die-back. An asphalt layer was installed around a ponderosa pine (right) that sealed off air exchange with the soil suffocating the root system. This tree died 2-years later.*

A good root system is influenced by how a tree is cultivated in a nursery and planted in the field. For this reason it is important that planted tree roots are "trained" to grow expansively through the local soil in order to find reliable sources of water and nutrients. Watering newly planted trees the first several years is very important for their survival as they only have a fraction of the root system that a natural seeded tree has. Gradually increasing the watering distance from the main stem to the edge of the tree canopy as the tree grows will stimulate root expansion.

Root development may also depend on the conditions of the roots of planted trees. Nursery stock should have been recently excavated for best results. Trees that have been kept in containers or root balls for longer than one season will grow new roots that spiral around the inside container wall until the root system becomes what is called "root bound" where new roots have difficulty growing into surrounding soils (*Picture 17*) and spiraling roots may actually choke each other off. This phenomenon seems particularly disruptive for broadleaf trees. Such root systems are incapable of capturing enough water and nutrients for the tree canopy to grow and often results in stunted growth and after several years or more, tree top dieback and death. Good nursery stock and proper planting procedures are essential for transplant trees to grow well and survive some of the harsher sites across Montana (*Figure 6*). Poor nursery stock or improperly planted trees are often diagnosed with insect, disease and soil

Picture 17. *This maple tree was kept (a year or longer) in a container too long before being planted. New root growth had grown into a spiral around the container walls and even after 3 years in normal soil maintained this constricted root ball, indicated by annual and chronic crown dieback.*

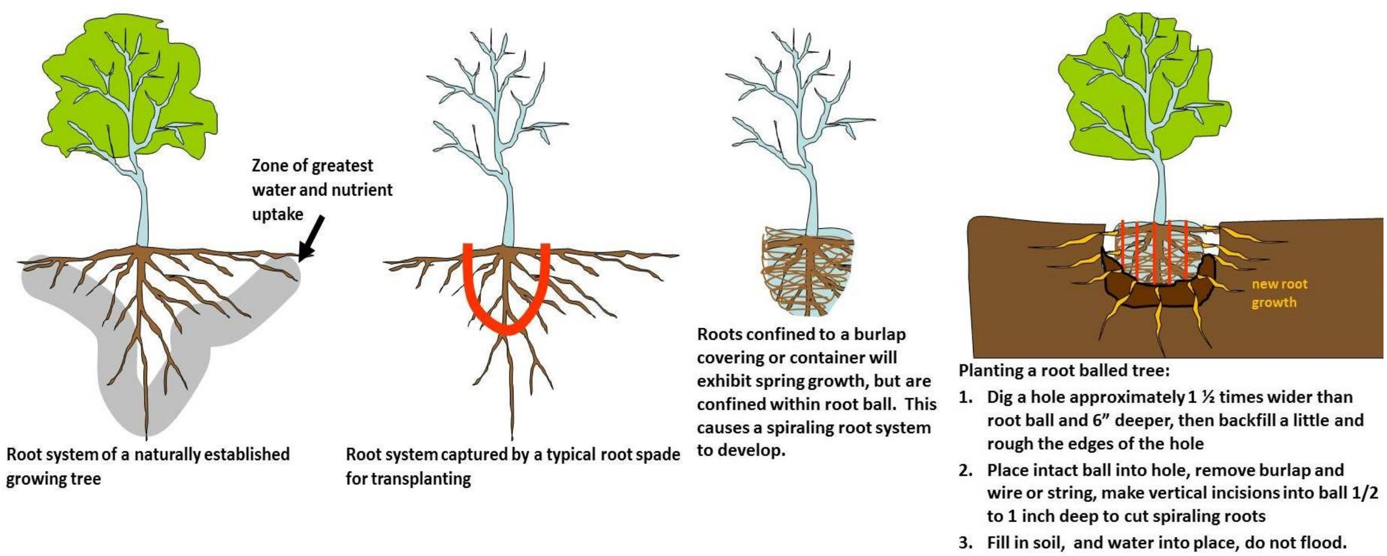


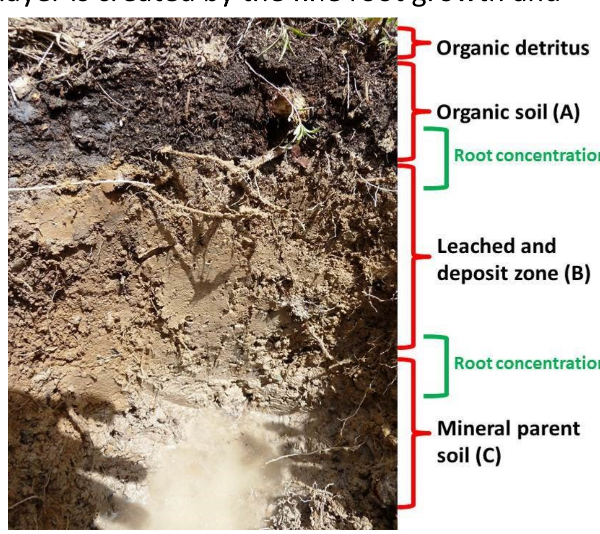
Figure 6. *Ideally larger nursery trees are "lifted" and balled and burlaped in early spring as soon as the soil thaws. They are then transported to nurseries and planted as soon as possible while the tree is still dormant. Although many nurseries recommend not to remove the burlap, dry soils in Montana do not allow for quick burlap decay, which makes it an obstruction to new root growth. Alternatively, exposing roots to air and sunlight is harmful to them, thus remove the covering after the root ball is in the new soil hole. Often trees remain in burlap or containers much longer which leads to root bound trees where new root growth has spiraled around the container or burlap. If planted in this way, these spiraling roots can interfere with new root growth outside the planting space, and even eventually choke new roots, leading to drought stress symptoms and death.*

nutrient deficiencies (*Picture 18*) though the main issue is a poorly developed root system. Poor root systems might be a result of cultural practices that create root bound trees, but can also be the result of heavily compacted or clay soils that impede good root growth. Always check soils and roots of trees that have symptoms of insect, animal or disease damage, especially if they are transplanted trees.

Picture 18. *Trees that are planted in a root bound condition may survive for many years but do not grow well and develop symptoms such as small leaves, insect attack, and dead branch tips, especially on the top of the tree. This maple (left) had been kept alive in a container for several years where roots continued to grow and spiral inside the container. When planted its roots were unable to grow out of their "trained" spiral and extract nutrients and adequate water from the surrounding soil. When the upper soil was gently removed (center) symptoms of a spiraling roots were uncovered. The fully excavated root system is shown in picture 17. Such severe root binding is typically not reversible in broadleaf trees and will eventually kill the tree. Conifers are more resilient to such root binding as they can allow their roots to graft together and remain functional, though stunted growth may also be a symptom (right). These ponderosa pines in the front row where planted in their burlap covered roots whereas the trees in the background had the burlap removed. Although planted at the same time, the burlap intact trees are less than half the size of the burlap removed trees.*

Soil

Soils may be grossly defined as a mineral medium that contains nutrients, water and air necessary to sustain microbial and plant life. For most soils, the most biologically active zone is in the upper 12 inches, and can be observed as a dark brown to black layer overlaying a tan to brown or even reddish layer, which then overlays broken down rock or original mineral parent materials (*Picture 19*). For those studying soils these layers are defined as the "A", "B", and "C" horizons. The dark color of the surface layer is due to decomposed organic matter concentrations that also holds the majority of soil nutrients, especially nitrogen. For most western soils this layer is created by the fine root growth and death of grasses or forbs. Conifer forest soils, alternatively, only have an inch or less of an organic soil layer because trees do not turn over their root system as much, and there is little earthworm activity that pulls the thick surface organic materials into the soil. Soils originating from fill material associated with in construction sites (houses) will often have no organic layer. Tree roots prefer to grow into organic soils because this is where the best nutrient loading and water holding capacity exists. Oxygen is an additional essential component for most soil roots and microrganisms. Soil texture and structure influence how a soil functions as it determines how well water, air, nutrients and roots can move through soil. Clay is the most finely textured soil medium and can impede air and water movement as well as root penetration. Some clays shrink when they dry out and become very hard and impermeable to air and water (why pots are made out of clay). Compaction of wet clay by equipment, vibration or even animal or human trampling



Picture 19. *Typical soil profile showing organic soil "A" horizon as upper layer over weathered mineral "B" horizon and parent mineral "C" horizon. Note root concentrations in organic layer an near water.*

turns it into a medium in which few plant roots can survive, thus stunting or killing trees. Sand is the opposite of clay, and is loose textured allowing for easy air and water movement. Unfortunately the coarse texture does not hold onto water or nutrients very well, usually resulting in a dry and nutrient deficient soil that also limits tree growth. Compacting sand, though difficult, will actually improve its characteristics as a growth medium. Because these two soil textures represent opposite extremes, some people have tried to mix the two to develop a happy medium. Unfortunately the effect is much like adding gravel to cement: the clay coats the sand particles and soil conditions are minimally improved until more than twice the sand by volume is added to the clay. Addition of organic matter is often the most effective amendment to clay, and though lesser amounts than sand are needed a 1:1 mixture is usually required to make a significant impact. The best soil textures for plant growth are "silts" and "loams", where the soil particles are large enough to create adequate gaps for air and water movement, though still small enough to hold onto water and nutrients.

Decomposed organic matter is an important component for any soil as this material resembles a fine sponge under a microscope and adds considerably to a soils capacity to hold water, air and soil nutrients. It also acts as a glue that holds soil particles together into irregular shaped blocks or "clods". These larger structures create larger soil fissures called "macropores" that in turn allow for better air and water movement into the soil. Soil structure takes years to decades to develop, and is the basic concept behind "no till" farming where a structured soil is actually more productive than a finely tilled one. Soil organic matter is also typically acid and can help neutralize the typical alkaline soils found across central and eastern Montana. Even mild alkalinity strongly ties up most soil nutrients that a tree needs, and soil chemistry is extremely difficult to change. Nutrients (fertilizer), watering and soil surface aeration must accompany a good soil to make it productive. A soil organic matter content of 5 to 6% by weight is generally considered optimal for silt and

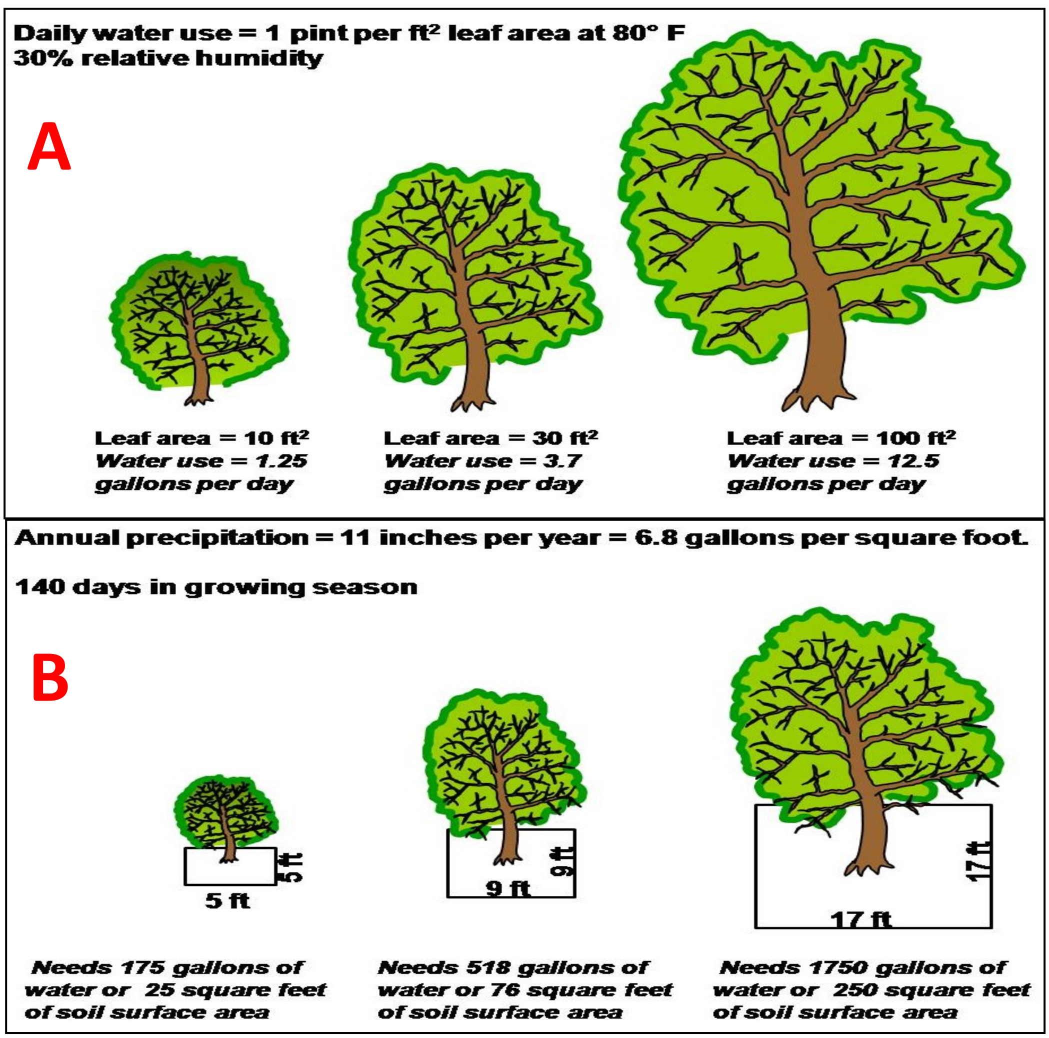


***Figure 7**. Tree water use will vary based on the air temperature and humidity as well as soil water availability and tree species leaf physiology. As a general example, potential water use of a healthy green ash tree is illustrated for the average conditions of a Montana summer day. **Illustration A** depicts how daily water use will increase with increasing leaf area for a tree as it grows from 6-feet, to 12-feet to 24-feet in height. **Illustration B** shows how soil water storage capacity must increase in response to increasing leaf area in order to supply the tree with adequate water from rain or snowmelt across the growing season. The broad simplified assumptions here are that the soil will absorb and hold all rainfall and that tree water-use will not vary, both of which would be factually incorrect. However – the concepts and "average" water uses fall within realistic expectations for conditions found across rural settings and windbreaks across Montana.*

loam soils though higher percentages (10 - 20%) might be required to improve sandy soils nutrient and water holding capacity, and (20-50%) required to amend clay soils.

The balancing act: growth and longevity versus resource availability

The more leaf area a tree has, the more sugar can potentially be produced through photosynthesis to grow a bigger tree, however, the more water is required and lost *(Figure 7)*. Thus the local climate and soil are strongly correlated to tree rate of growth, size and longevity. Each tree species physiological adaptations allow it to balance its needs with the local environmental inputs with different advantages and tradeoffs. The soil in which a tree is growing can moderate many climate driven impacts by buffering extreme water loss with stored water, provide nitrogen to boost sugar production during periods of low photosynthesis rates from drought stress, and increase pest and pathogen resistance by providing essential macro and micro nutrients that boost defense capabilities. A deep well drained and aerated soil with adequate organic matter and neutral to slightly acid pH can store water and nutrients as well as provide a density and texture that allows a tree's roots to expand to their maximum potential for stability, energy storage and water and nutrient absorption. Alternatively, an alkaline, and/or shallow or compacted clay soil will physically limit root penetration and growth, resist water and air absorption and thus exacerbate any local drought and high temperature effects resulting in limited height growth and tree survival. As a tree grows taller, it not only requires more water and nutrients, moving resources longer distances between roots and shoots decreases overall tree efficiency and may limit a tree's overall vigor, growth and pest resistance.

Pruning Deciduous Trees

Pruning branches for tree health can be somewhat different than pruning off branches for tree shape. Proper pruning usually allows for effective removal of branches that have grown too long or in the wrong place, but also should take into consideration that the created pruning wounds must heal completely to prevent unintended consequences such as stem decay and subsequent structural weaknesses. Pruning involves two steps, the first is selecting the correct branches to prune, and second is making the correct type of cut at the right location to ensure good healing potential.

Selecting Branches

Most broadleaf deciduous trees can modify their leaf development to accommodate two different conditions: as sun leaves or shade leaves *(Figure 8)*. The sun leaves develop on the outside of the tree and produce the most sugar for the tree (some measurements indicate about 90%). They are thicker and depending on the species more deeply lobed leaves to absorb and process full sunlight while maintaining cool temperatures. They also can develop more water-loss resistance mechanisms. Shade leaves are structurally thinner, but often wider as they have to absorb and process only about 10% of full sunlight, and as a result may even cost the tree energy as the sugar they produce (photosynthesis) may be less than what they consume (respiration) to stay alive. At the same time they also lose water that can exacerbate drought conditions. When pruning trees, keep in mind that all trees must maintain a balance between leaf area for energy production and root area for water and nutrient acquisition. The healthier the tree, the more reserve sugar it has to regrow branches, twigs and leaves, and for that reason a deciduous tree can typically survive complete summer defoliation from pests or

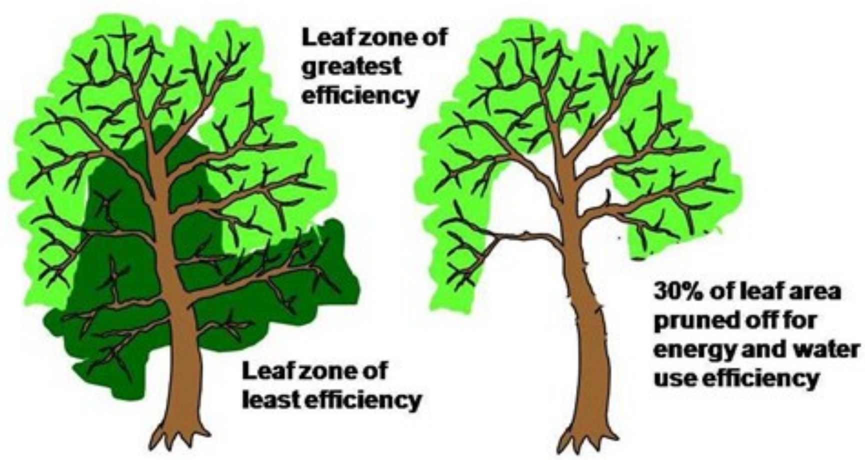


Figure 8. *Sun versus shade leaves on a deciduous tree and pruning for efficiency.*

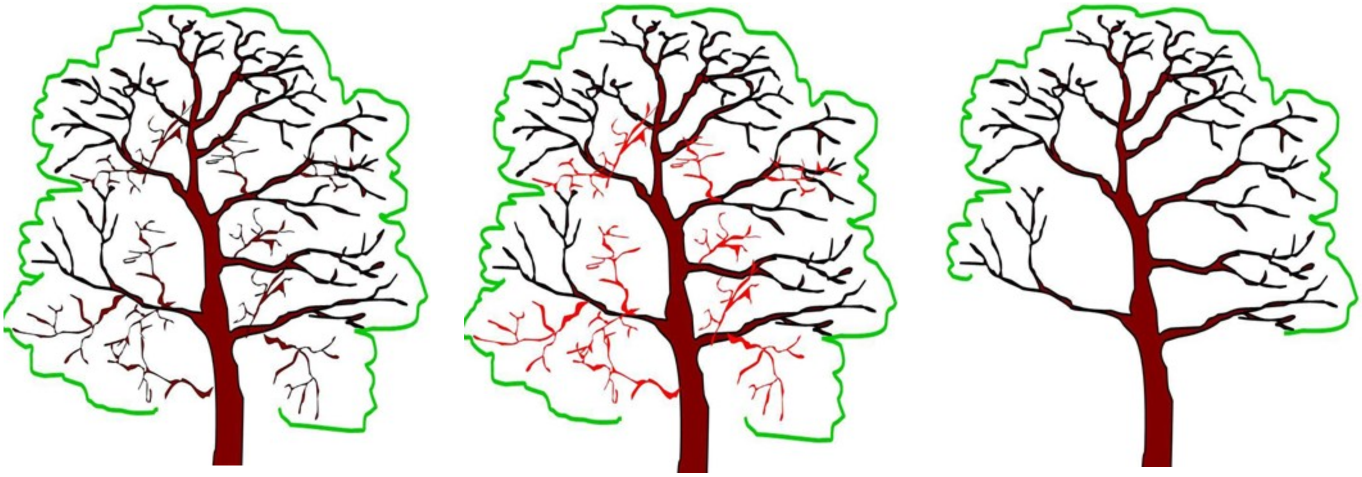


Figure 9. *An example of live branches that can be removed with no negative impacts to a tree and potentially increased energy capture, water use efficiency and thus overall tree health.*

once or twice. Pruning that removes 1/3 of the leaf area at any given time should not harm a healthy tree, though removing branches with shade leaves may actually increase the efficiency of the tree. An extreme example might be storm damage or bad pruning that removed more than 75% of the tree's top and yet the tree survived and grew back. There are, however, also numerous examples where trees weakened by over-pruning resulted in their increased susceptibility to pests and pathogens that eventually led to tree death. A good pruning should help a tree and not weaken it. Pruning for tree health and vigor means removing less efficient branches and leaves that occur at the inner portion of the tree, or that duplicate or interfere with the function of already existing tree branches *(Figure 9, 10)*. This type of pruning can result in a "tree cathedral" look that most people find very pleasing and that also decreases unnecessary water loss and increases the efficiency of light capture for photosynthesis. It is important to note that this basic concept of pruning

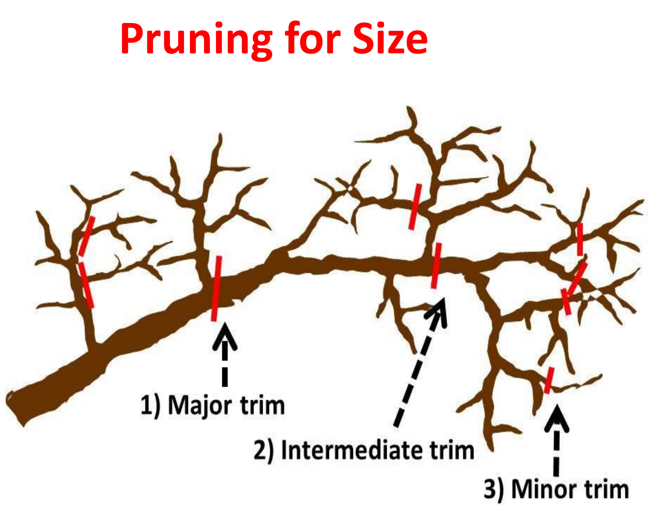


Figure 10a. *How to prune back a branch.*

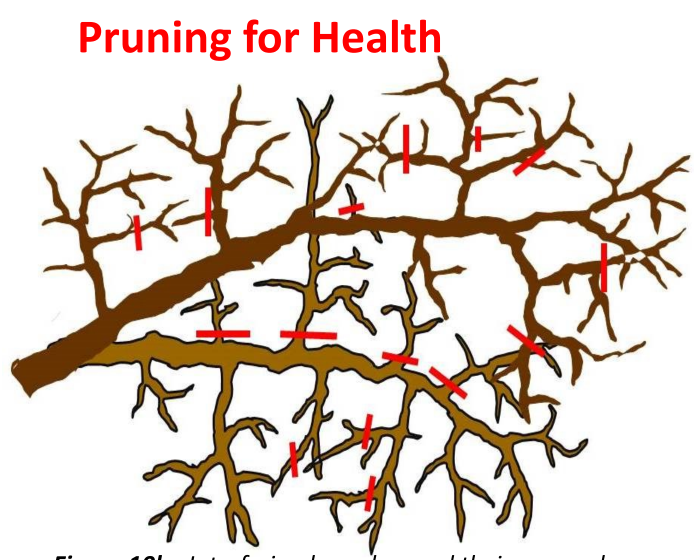


Figure 10b. *Interfering branches and their removal*

for health applies primarily to deciduous broadleaf trees and not evergreen conifers, which will be discussed in a subsequent section.

More often than not, trees are pruned to reduce their size or to shape them into something pleasing to the landowner. This may be because they have overgrown a garden, other trees, into power-lines or even into a house, or because someone wants a perfectly round canopy (or in some cases even a cube). The tendency for an inexperienced pruner is to cut branches or tops back in a straight line, or prune based on convenience versus branch architecture. Although this may work temporarily, it can also cause injuries to a tree that promotes stem decay and a structurally unsound tree. *Figure 10a* shows examples of different levels of pruning severity on an individual branch. In each case, a branch is always pruned back to the junction of another branch. *Figure 10b* shows an example of pruning out interfering branches that will improve overall tree health. If there are two branches trying to capture that light in the same location, they interfere with each other, reducing each others efficiency and thus vigor of the tree. In addition, branches that touch each other create abrasions during wind that result in open wounds that are more prone to pest and pathogen infection. Removing such interfering branches is helpful to the tree by guiding it to grow a more efficient structure. Leaving the healthiest and stoutest branch that has the potential to best fill the space is typically best. Picking which branches to remove is an exercise in aesthetics, functionality (easily picked fruit) as well as figuring out which one helps the tree more (which may be somewhat subjective to the pruners personal biases and experience). An important consideration is how the tree wants to and how you can guide it to grow into the shape best for the tree, its location and still meet your needs. If you desire the tree to grow taller, keep the upper branches. If you want the tree to stay smaller, keep the lower and lateral branches and trim back the upper branches. There are tradeoffs for each scenario, and both take skill, an artists eye, and practice to complete and maintain correctly. Pruning trees “up” is perhaps the easiest because removing lower and internal branches is relatively straightforward. However, if balance is not considered a tree may develop into a broomstick or “lions tail” where branches are too long with tufts of leaves on the ends (*Picture 20*). This can create a structural deficiency where too much torque on the branch from a heavy wet snowfall or windstorm can cause it to break off. Correcting this scenario is possible but difficult, and all too often leads to a method referred to as “topping”.

For trees that have grown too tall and either interfere with house roofs, powerlines, other trees, or have developed drought stress and/or insect and disease issues that resulted in dead or weakend tops, specialized pruning is required. Although typically “topping” a deciduous tree is not a good way to improve health or vigor, there are ways to reduce a trees overall size that is less damaging than the typical

Picture 20. *The opposite of topping is trimming and training branches to grow too long (left), which creates excessively long branches that are prone to breaking in wind and heavy snow storms. Corrective pruning (right) requires that branches are pruned back from the outside in to stimulate new twig formation (suckering) and a more compact crown. Crown shape and maximum desired crown width should be considered before pruning takes place.*

“straight line” top removal abundantly seen along power lines (*Picture 21, 22*) or where unskilled tree trimmers have worked. The practical basis for this type of pruning probably originated from the observation that trees that lost branches and crowns resprouted and reformed smaller dense crowns, and thus was seen as a practical solution for rejuvenating older damaged crowns or reducing the shading, interference with utilities, or failure risk of tree crowns that had grown larger than what the landowner or utility

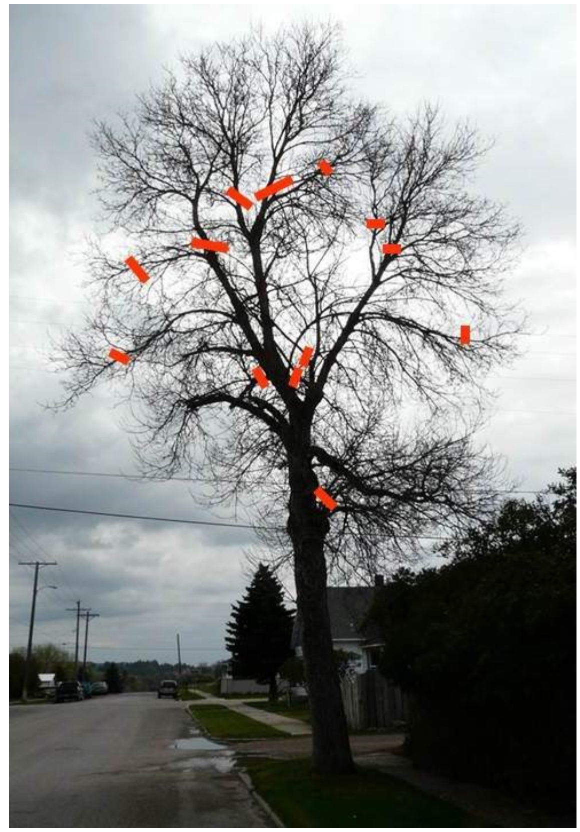
Picture 21. *These Siberian elms were topped by a power company contractor who arbitrarily cut back branches to shorten the trees. Compare to intact trees in background. This is a very poor practice as it will result in either the trees dying or prolific re-sprouting from dormant buds. Such sprouts quickly regrow into larger branches that are poorly attached and often supported by decayed main branches that had large non-healing pruning cuts. Often 10-20 years later such topped trees will have major structural failures during a wind or snowstorm resulting in catastrophic branch failure and severe damage to property under the tree.*

crew desired. Since topping typically results in rapid sprouting from cut branches, the ends of which often decay rather than heal (*Picture 23*), it is at best a short term solution for a hazard tree and creates a much greater long-term hazard when new sprouts, that have poor structural attachments to the main trunk or branch, reach an appreciable size and weight, and break off. Once topping is started it should be reworked every 4-6 years to keep new branches from getting too heavy, developing too much leverage and breaking off. In addition, topping may impact the main stem as wood decay grows from branch ends into the main tree trunk (*Picture 22*) weakening the entire tree. Such trees become significant hazards in wind, ice or snow storms and should be removed before they fail and cause severe damage to structures, other trees, cars or injury to people.

Picture 22. *This large cottonwood had serious heartwood decay that entered through topping to create a structurally unsound hazard.*

Picture 23. *Topping often is a short term solution for a tree that is either perceived to be too large or has dangerously heavy and brittle wood such as cottonwood trees (left, center). Each topping-cut leaves behind a dead stob (right) that is a potential entry point for decay fungi and insect wood borers. Resulting sprouts are poorly attached to a decayed stem and can grow large and heavy quickly creating an even more dangerous tree where wind or wet snow can cause these weak areas to fail.*

Depending on the tree size and structure there are pruning techniques that can be used to reduce the overall size of a tree with less visual disruption and decay potential than topping. This requires that the overall architecture of the tree is assessed and branches removed at nodes where multiple branches fork from the main stem (*Picture 24, Figure 11*). This type of pruning to maintain a smaller tree crown is best initiated when the tree is young and branch diameters small enough where pruning cuts will heal quickly. The larger a tree gets the more difficult it is to dramatically reduce the tree size, and the more dependent it is on tree species with regard to branch regrowth and wound recovery. Trees with dense and multiple branching architecture offer greater potential for size reduction, whereas trees with tall single stems and limited branching can only be reduced in size using topping techniques, and the consequences of future branch and stem failure.



Picture 24. *This large cash has multiple branch nodes (red lines) that would allow for a crown reduction to occur with reasonable chances for the tree to heal the pruning cuts and maintain its overall health and structural soundness. Maintaining overall crown balance is important.*

Topping should not to be confused with "pollarding" that is still commonly practiced in Europe and some places in the United States. Whereas "topping" is a poor practice and refers to the shortening or reduction of a tree's size by simply cutting back major branches regardless of existing branch structure, pollarding (*Pictures 25, 26, 27*) refers to the cultivation of a short statured tree by annual pruning and shaping, typically starting when the tree is young. This practice in general does not harm the tree as the annual removal of sprouts creates only small wounds that heal and does not allow for the development of large heavy branches that are poorly connected to the overall tree structure. Once started, pollarding should be an annual practice to keep the tree healthy and to prevent larger branches from regrowing from sprouts. Not all tree species are capable of tolerating pollarding. The most common trees that seem to tolerate the practice are willows, ash, soft maples, sycamore, and fruit trees. Poplar and cottonwood trees could be cultivated using pollarding, though such pruning may make them more susceptible to disease and insect pests.

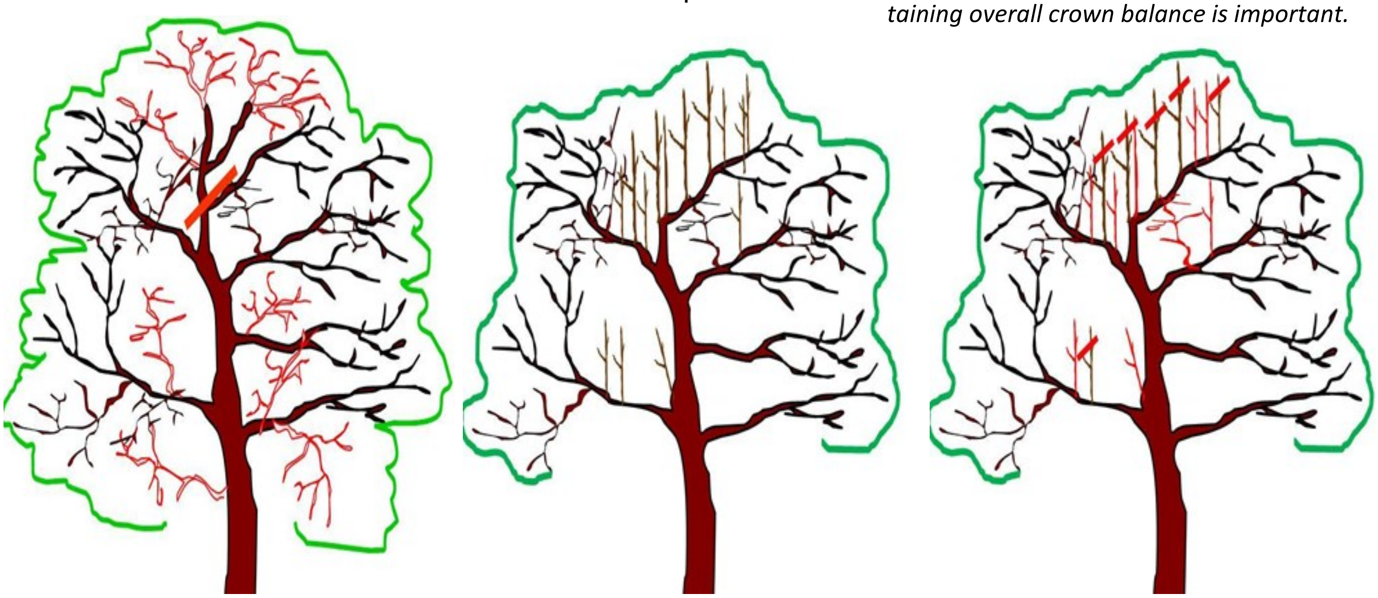


Figure 11. *An example of how a tree is properly pruned back. Often such pruning will stimulate dormant buds and water-sprouts or "suckers" will develop. These need to be selectively pruned and shaped to promote lateral growth versus height growth.*

Picture 25. *Pollarding is usually implemented every year in late winter. Left picture shows sycamore trees in Frankfurt Germany before and after pruning in the spring before bud burst. This practice is used to keep trees that normally grow tall in a shorter stature. Right picture shows pollarded trees in foreground and natural unpruned trees in the background. In some cases pollarding is done to provide an annual feedstock (sprouts) for animals or basket crafting.*

There is one form of "topping" that can be used to rapidly regenerate a tree after a serious injury or pest attack has severely dmaged the tree crown. Although technically referred to as "stump sprouting" this technique (*Picture 27*) removes the entire tree down to a 6-inch or shorter stump. This creates the same effect as topping, except the resulting sprouts appear to have the capacity to fuse with the existing root system with less risk if developing stem decay. The advantages to stump sprouting is that tree species capable of such sprout regrowth can regrow larger, healthy trees in

Picture 26. *Picture on left shows pollarding that started when branches were smaller and sprouts where repeatedly pruned off allowing bark to seal off vascular tissue in a "club" shape resilient to insect and disease entry. Improper pollarding (right) leaves sprout stubs which dieback and do not allow for good healing, which provide an entry for diseases and insects.*

Picture 27. *An ash (left) that had been attacked by bark beetles, canker, or severe weather changes resulted in dieback of most of the tree crown. New sprouts formed at the tree base and stem. If the dead main tree stem is removed to ground level, existing epicormic sprouts, or new ones that develop the subsequent spring should be left to support the root system. The following winter the strongest sprout (center) is retained and the others pruned off. The stored energy of the root system of the previous large tree will allow for rapid growth of the remaining sprout resulting in the development of a larger tree (right) in less than half the time required from a planted seedling. Continued pruning of new emerging stump sprouts is typically required for several years.*

an intact mature root system and a supply of stored starches and sugars.   A new tree can thus be cultivated in a fraction of the time required by a planted seedling and sapling. This technique has been used successfully on willows, ash trees, box elders and some poplars, and a version is used to regenerate quaking aspens only for the later, sprouts will emerge from shallow roots versus the stump. How often this practice can be implemented on an individual tree remains unkown, however examples exist where this type of regeneration has been successfully implemented on the same tree or root system 3 times before a notable decline in reprouting or regrowth of a larger tree was noticed.

Making the Proper Pruning Cut

During springtime and abundant available water, sugar demands for the growth of new leaves and flowers is typically the only time a tree's vascular system will operate under a "positive" pressure. The affinity for water of large quantities of mobilized sugar within the vascular system creates what is called "osmotic pressure". This pressure helps move sugar against gravity and both phloem and xylem tissue may move liquids upwards. Pruning at this time will often result in excessive stem/branch bleeding of sugar rich sap, which can be medium for pathogen infection. This is also why the bird group known as "sapsuckers" purposely drill holes into tree stems in order to feed on the sugar rich sap (*Picture 28*). In addition, the growing cambium under the bark is very susceptible this time of year to bruising injury from ladders or the friction and weight of someone climbing on branches. For these reasons pruning trees during this time of year is not advised.

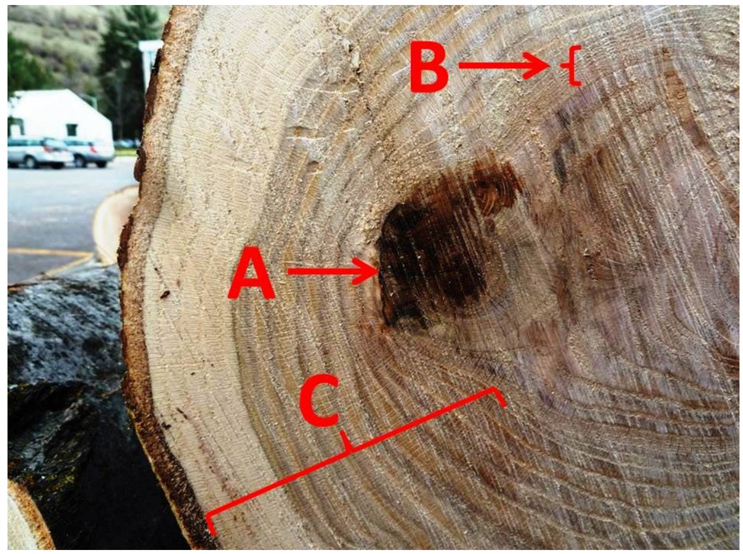
Picture 28. *Evenly spaced Sapsucker feeding holes on a pine during spring sugar flow (keys are only for scale).*

When pruning branches, each removal should be made such that the cut area retains a connection with a part of the tree that maintains a reasonable vascular flow between leaves, stem and roots. If a branch is small enough that you can support the weight with one hand while snipping or cutting with the other, only one cut needs to be made. On deciduous trees this cut should be made on the outside edge of the slight swelling that occurs where the branch enters the stem (*Picture 29*). This swelling is well connected to the main stem and will retain good water and sugar flow when the branch is removed. If the cut is made "flush" with the stem, the injury created is much larger than needed, will impact more of the sapwood, and will therefore take much longer to heal. The purpose of making a proper cut is to allow for the most rapid healing across the wound from what is called "callous" tissue, which is actually a wound

Picture 29. *Removing branches should be made with a cut near the outside of the swelling where a branch attaches to the main stem (left). Trees respond by growing callous tissue over the cut (center-left), that after several years (center-right) will completely heal over the injury (right), and seal off the wound and start growing sapwood over the old injury.*

Picture 30. *An uneven cut resulted in a "stairsep" irregular surface that impedes new callouse growth from growing over the wound.*

response from the cambium next to the cut. Such new tissue grows best over an obstruction free, smooth flat surface that is flush with the surrounding living cambium. Any cut that results in a "stairstep" or torn wood cavity presents a more difficult obstacle for the new callouse tissue to grow over (*Picture 30*). When such unintended irregular cuts are made it is best to recut the surface to provide a smooth flat surface over which new growth can develop more quickly. Proper cuts should heal within 3-6 years and new sapwood will develop over the old wound (*Picture 31*) and seal off any infection from wood pathogens or pests.



Picture 31. *A proper pruning cut made more than a decade ago (A) shows minor decay that healed over and allowed functional sapwood to form over it. Note that the pruning was followed by slow wood growth (B) perhaps from loss of leaf area associated with pruning or injury, which was then followed by rapid growth once the tree crown regrew (C).*

To ensure a good final cut is made when removing larger branches, a 2-3 step cutting practice is recommended (*Figure 12*) . This allows for the removal of the main weight and torque that a large branch exerts on the connection to the main stem before the final cut is initiated. Failure to follow this procedure can result in the last connecting wood fibers left at the bottom of the branch ,as it is being cut, to "rip" a large gash in the side of a tree before the saw severs them. Such wounds are slow to heal and can result in openings for pests and pathogens to attack the tree's living sapwood . Similarly, pruning off branches in a way that leaves a portion of the branch sticking out (*Picture 32*) will often result in a dead branch-end that acts as an entry portal for fungal and bacterial pathogens. Among pruning professionals these stobs are referred to as "coat hangers" because enough woody stem sticks out for a convenient place to hang a coat or hat (pruning can be hard work!). Although some trees can initiate new branch sprouts from such cut branch ends, the exposed sapwood rarely heals and often decays (*Picture 33*), allowing further wood decay to progress into the tree's heartwood which weakens the entire tree structure and can eventually either kill the tree by attacking the sapwood from the inside, or cause it to break off in a wind.

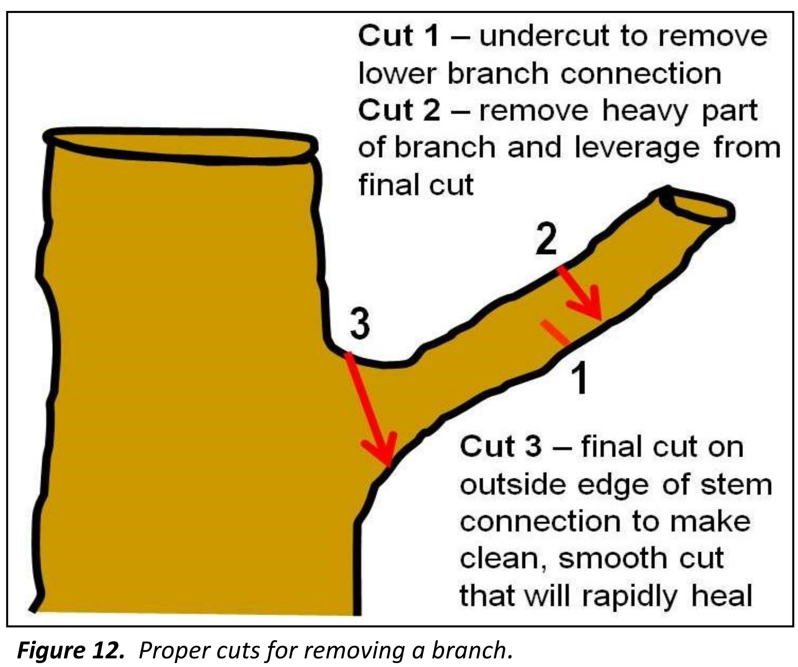


Figure 12. *Proper cuts for removing a branch.*

Picture 32. *Improper pruning leaves stobs sticking out (left—dotted line shows where cut should be) or at the ends of branches (right) that die back and become entrances for decay or pathogens. Such cuts can also stimulate prolific suckering that creates a "rats nest" structure of dense interfering and weak branches that cause structure and disease issues as the tree gets bigger.*

How a tree responds to pruning is species and situation dependent. Several decades ago tree pathologist Dr. Alex Shigo demonstrated that many tree species are able to "compartmentalize" wood decay fungi and pathogens by creating a biological seal around wounds and other stem intrusions as seen in Picture 31. How well trees are able to defend themselves is however highly species and situation dependent. Trees in the populus and salix genus (cottonwood, poplar, aspen, and willows) as well as what are considered "soft hardwoods" (Norway, silver and red maple, green ash, boxelder, linden, Siberian and Chinese elms), and most native conifers (evergreen needle trees) are highly susceptible to decay organisms infecting entire stems though smaller wounds. Compartmentalization of wounds with these species typically does not often occur. Proper pruning cuts that heal quickly are thus the best mechanism to ensure prolonged tree health and longevity. Aside from impacting wood structure, decay organisms can also attack living sapwood from the inside or prevent new sapwood from forming over the pruning cut, which restricts water flow to the leaves (see page 9), which in turn reduces a trees ability to

Picture 33*. Proper pruning cuts on this Norway maple (left) healed within 5 years (A) whereas a poor cut rotted and created a decay cavity (B). Such decay pockets (center) collect water and create conditions where fungi , yeast, bacteria and other organisms can attack the heartwood and sapwood of the stem eventually rotting out the core of the tree and causing it to structurally fail or decline.*

photosynthesize, produce sugar and allow for the tree to grow new tissue and recover from its injuries. In addition, decay pockets within the tree collect water, which freezes in the winter and expands, which further injures a tree by splitting the trunk apart creating what is known as a "frost crack" (*Picture 34*). As such cracks open and close they collect debris, water and more pests and pathogens that further harm the tree. Correcting frost cracks and the stem decay that comes with them is very difficult to remedy and requires placement of drain tubes and annual treatments with fungicides and insecticides that may or may not be successful in remedying the problem. Prevention is worth a lot and for this reason tree pruning cut should be monitored for pest and decay issues until they are completely healed.

Picture 34. *Decay pockets created by poor pruning often are saturated with water, that freezes in the winter and splits the tree stem creating frost cracks. Such cracks allow for more water entry, more decay and eventual tree failure. This process, one started is very difficult to remedy.*

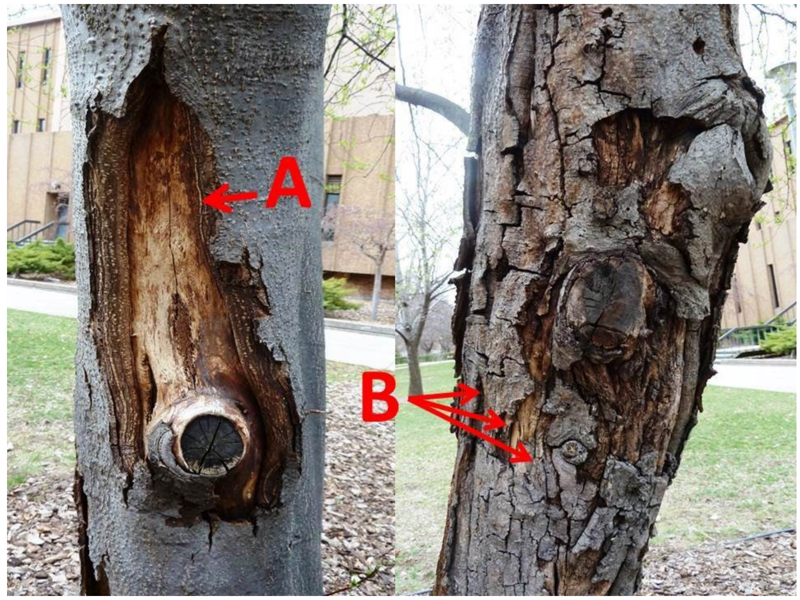
After Pruning – to Paint Cuts or Not to Paint?

During any seminar or workshop about pruning trees the question always arises: Should a person paint pruning cuts with pruning paint? Years ago studies in the Midwest indicated that the use of pruning paint showed no appreciable positive benefit to trees and in some cases actually seemed to promote more rapid wood decay by trapping moisture and decay fungi in the wood. This study led to the general recommendation that pruning paint is not worth the time and money. Alternatively, observations of tree wounds across the much drier climate of Montana (*Picture 35, 36*) has indicated that there may be much more to this issue. The timing of a pruning cut might be an important consideration for deciding on the use of pruning paint. During the low humidity of summer and winter across Montana, a tree's largest stress is typically water deficit. More specifically, an opening into the sapwood (xylem tissue) during dry weather may cause air embolisms to form that can cause irreparable loss of water transport within the

Picture 35. *A large and poorly made pruning wound (note tearing of live wood tissue near top left) resulted in drying of sapwood, cracking and cambium tissue death, thus there is no callous formation which will lead to eventual wood decay and total branch failure.*

Picture 36. *A proper application of pruning paint shown here slows sapwood drying and may reduce pruning related sapwood dieback.*

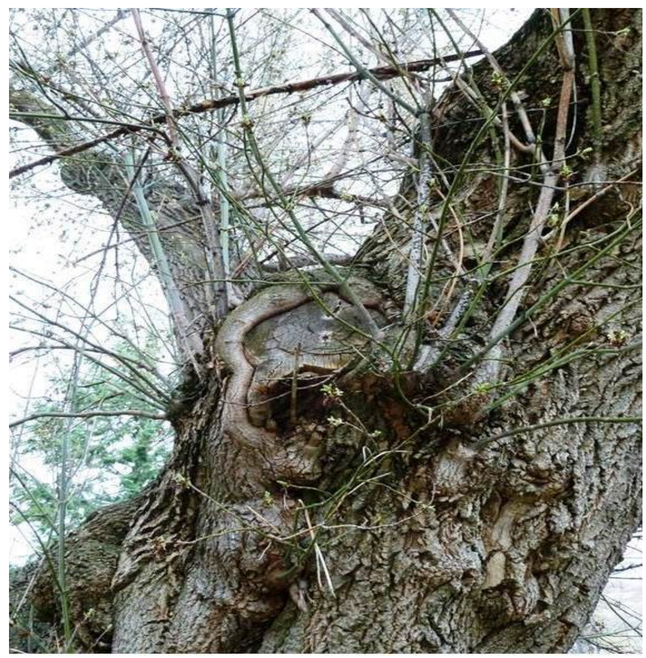
vicinity of the opening, sapwood death and poor wound healing. Treating pruning cuts with fungicides and pruning paint has been observed to slow down drying of the sapwood and result in less dieback, which in turn may facilitate better callous formation and healing. The larger the pruning-wound, the longer it will take for the callous to heal over the injury and thus repeated applications of pruning paint/fungicide might be warranted. Not all trees react the same to pruning cuts or heal at the same rate, and for this reason pruning paint may or may not help pruning wounds heal depending on the species and circumstances. It is very important to note that actual pruning paint is not toxic to living tree tissue, as opposed to roofing tar or similar looking products that will kill back live tree tissue creating a larger wound and prevent healing. Along the same line of thought is the importance of cleaning pruning saws and lopping shears between uses as these can transmit diseases, especially canker forming funguses and bacteria (*Picture 37*). A strong bleach bleach cleaning solution (20%) or alcohol is recommended as a wipe or rinse. Alcohol does not kill fungal pathogens as well as bleach does, and it is important to thoroughly wipe and brush off cutting edges to remove any residue.



Picture 37 . Pruning cuts can be invaded by canker diseases that kill back the cambium (A). Trees may try to grow over such invasions by forming new callous tissue only to have it killed back every season creating "wave" or target shaped cankers (B). Occasionally a topical application of a fungicide will help solve such problems, though some tree's are genetically predisposed to this type of pathogen and little can be done to help cure the problem other than replacing the tree.

Prolific Sprouting

Tree pruning can stimulate many small sprouts (suckers) to develop next to or near the pruning cut (*Picture 38*). Some species (plum, apple, pear, crabapple, boxelder, ash) naturally produce many sprouts even without pruning, whereas other species (maples, elms, ash, oaks, basswood, locust, cottonwood, willow, poplar) are stimulated to produce sprouts by an injury or pruning. Often the more severe the pruning the greater the suckering response tree wide, and sometimes this response does not turn itself off for several years, creating trees that become overgrown by these secondary branches. All trees have dormant buds just under the bark that are stimulated by sunlight and/or a hormonal wounding response. Although this can be a great asset to a tree because it can regrow after injury, it can also become a maintenance nightmare to prune every year. Sprouts are often weaker than normal branches and more prone to disease infection, and unless there is space to select one sprout to develop into a branch they should be removed. Timing of pruning may also impact sprouting with most prolific sprouting occurring after a late winter/spring pruning and least sprouting occurring after a mid to late summer pruning.



Picture 38. *This ash has responded to a pruning cut by producing many suckers near the pruning cut for several years. Unless these are pruned, leaving 1-2 of the strongest suckers to become branches and eventually shade to site, this will continue and become a problem area on the tree for infection. Note the poor pruning cut that is hindering good callous growth.*

Pruning Conifers

Conifers or “evergreen” needle trees require slightly different pruning than deciduous trees. Most ornamental species that grow in Montana do not have needles that function well in shade, or the ability to resprout branches on their lower main stem once these lower branches are pruned off or die off due to shading. Across NW Montana, the very shade tolerant pacific Yew, grand fir and western red cedar naturally grow and are very shade tolerant, however they are intolerant of drought and low humidity and do not grow well where 100˚F summer heat is combined with relative humidity less than 30%, which excludes them as preferred ornamental or conservation trees across most of central and southern parts of the state. Conifers will typically hold onto their needles for 3-7 years (*Figure 13*) depending on the species. The older the needles get the less efficient they are at photosynthesis as wax starts to plug their stomates, limiting carbon dioxide absorption and lessening the energy they produce for the tree. Older 3-5 year old less-efficient needles naturally start to drop mid to late summer. Occasionally conifers may drop several years of older needles in one season, which may be

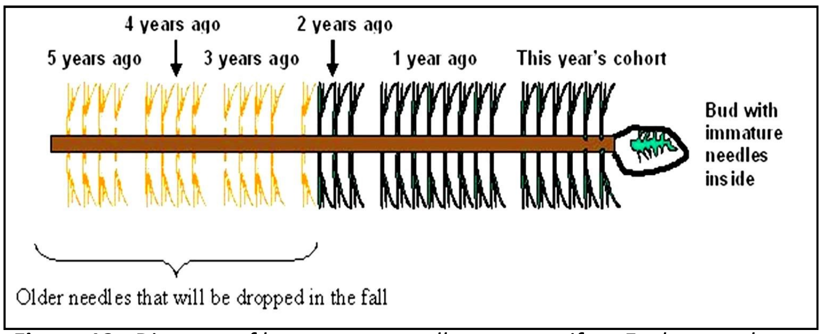
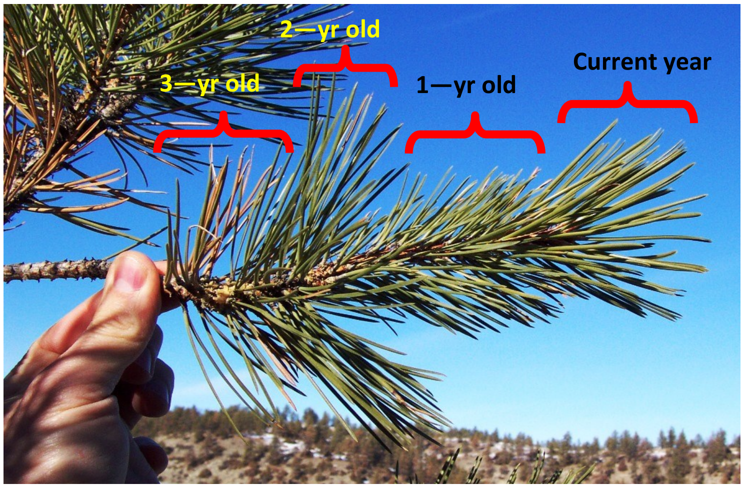


Figure 13. *Diagram of how to age needles on a conifer. Each annual cohort is separated by a small gap—easiest to see on pines and hardest to see on true firs or scale leafed conifers such as arborvitae, juniper and cedar. Each years new needles develop the previous late summer and fall inside the terminal bud.*

Picture 39. *Heavy seasonal drop of older needles*

caused by momentary drought stress following several wet seasons (*Picture 39*). Normal older needle drop that occurs in mid to late summer should not be confused with a variety of fungal needle cast diseases, most of which affect the newest needle growth at the branch tips, or winter wind or extreme cold impacts (also referred to as winter burn) that also mostly impact younger needle cohorts (*Picture 40*. Distinguishing between these impacts can typically be done by examining the timing as old needle drop occurs in late summer and fall, winter-burn occurs in the winter and early spring, and most needle cast diseases become an issue in early summer, especially after a warm humid spring. In most of these situations pruning should be pursued cautiously as there is a good potential that new buds will develop at branch tips and new needles will emerge the next spring. A careful examination of the buds should show juicy green centers if they are alive. Alternatively an evergreen branch that has no needles or all the needles are completely

Picture 40. *Winter burn where extreme unseasonable cold and/or wind desiccated branch tips and newer growth. Many needle cast diseases can also exhibit symptoms such as this.*



Picture 41. This ponderosa pine branch holds onto almost 4 years of needles indicating a relatively healthy tree. Stunted needles developed due to drought stress the previous year, which resulted in a fewer number of needles being produced the current year.

brown can be a good indication the branch is dead and should be removed. If disease is suspected it should be removed from the vicinity of the tree and like species.

As a rule, if an evergreen tree is holding the most recent 3-5 years of needles it can be considered as growing healthy. Needle number for any given year is determined by the previous years growth, where good growth helps predispose buds to develop many needles, and poor growth predisposes buds to develop fewer needles. On the other hand, the length of the needles is determined by the growing conditions and energy of the tree as the needles are elongating in spring and early summer. *Picture 41* shows a ponderosa pine with 4 years of needles, and the results of the tree being water stressed in the spring and early summer of the previous year (1-year old needles) that resulted in short stunted needles. Such stress resulted in less available energy and the tree response of producing fewer needles the following year (current year). Since current year needles are longer again, they indicate that the drought stress is not as pronounced, though since the needles are not as long as they should be (see 3-year old needle length) the tree is still somewhat stressed. Although harder to see on species with shorter needles such as spruces, the same indicators hold true.

For most conifers the new years needles are the best energy producers for the tree, and the older the needles get, the less productive they are as the waxy coating on the needles get thicker and starts to interfere with absorption of CO_2 for photosynthesis. For this reason, pruning off a branch tip with new needles and leaving only 4-5 year-old needles can result in branch die-off. Dormant buds under the bark of most conifer species branches lose their ability to sprout as they get older, which is also typically in the zone of older needles. Some spruce trees will develop sprouts on the main stem or older branches after severe pruning but these are inconsistent and rarely develop into quality full sized branches again. Pines rarely sprout new branches from older stem or branch tissue. When pruning for shape consider that most pines, spruce and juniper species are shade intolerant and thus needles need full sunlight to function and stimulate new growth. Their ideal shape is that of a cone (Picture 42). True fir, yew, hemlock and some cedars grow well in

Picture 42. Annual trimming or shearing of spruces can create very dense foliage for either privacy (left), shape (center left), or to maintain a smaller size (right). A consequence of such pruning might be poor multi-year needle retention that can predispose the tree to severe impacts from needle diseases and insect attack as young needles tend to be more susceptible than older needles. In addition, top shaping can result in multiple leaders to develop (far right) that without corrective subsequent pruning can allow a large multiple top tree to grow that may be structurally weaker.

the shade, but their greater requirements for water limits them to wetter sites found in NW Montana. To promote vigorous healthy evergreens the following guidelines for pruning conifers might be considered:

1. Shade intolerant species such as pines and spruces require full sunlight, and if branches are in the shade they will decline and eventually die off.
2. If you prune a branch back past green needles the branch will typically die.
3. Pruning back older branches or removing them can be done any time of year.
4. Pruning for shaping (for increasing branch density and maintaining a smaller tree) is best done in late spring/early summer immediately after new needle shoots have elongated (*Picture 42*).
5. Branches that are removed should be cut as close or flush to the stem as possible because unlike deciduous trees most conifers do not develop a "swelling" where the branch attaches to the stem.
6. When conifers such as spruces and pines get taller in wind prone areas their tops can become susceptible to breaking off and in the case of spruces that are very shallow rooted, they become very prone to tipping over with their roots pulled out of the ground (*Picture 43*) .
7. Topping, which is not a preferred pruning method on broadleaf trees, can work on spruces and pines with minimal negative impacts (*Pictures 44, 45, Figure 14)*. When removing a top make the initial removal cut 10+ inches above the final cut, which should be within about 1-inch of a healthy whorl of branches. Removing too much height from a conifer will result in a squat round looking tree – thus keeping a conifer short works best when the tree is pruned young and maintained this way by periodic trimming as opposed to drastic topping.
8. Once lower branches are removed they will rarely if ever grow back, especially if shaded by a taller canopy (*Picture 45*). Occasionally severe trimming of the top, storm breakage or disease will result in "suckering" (epicormic branching) to develop along the main trunk of the tree giving the tree a "fuzzy" appearance. These sprouts rarely develop into full sized branches or new crown. This is opposed to situations where the top of a younger tree is removed leaving the bottom whorl of green branches intact. Each lateral branch can develop into a separate tree crown and grow into a multiple topped tree. Christmas tree growers can use this technique to quickly regrow multiple Christmas trees from the same stem after harvesting the original main stem.

Picture 43. Conifers with shallow root systems and heavy dense tops such as spruces are very prone to blowing over in high winds.

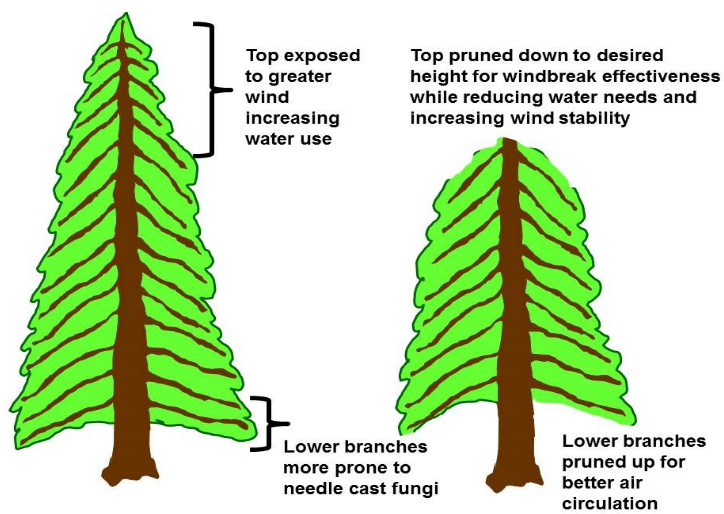
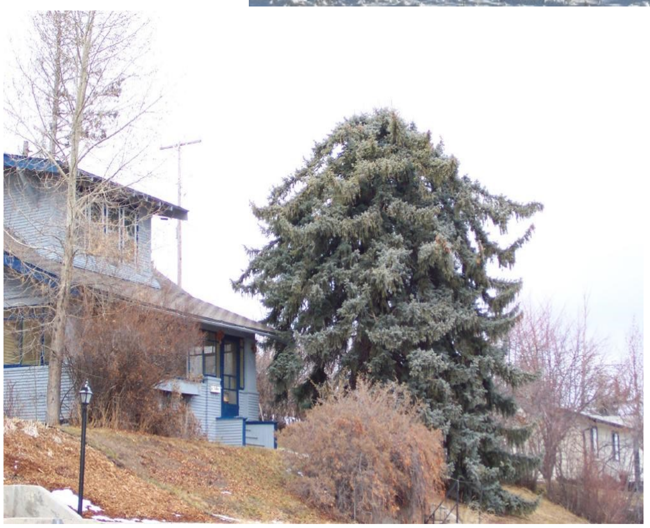


***Figure 14**. Diagram of common issues with larger and older conifers and possible pruning solutions.*

Evergreen conifers produce "pitch" as a defense mechanism to combat disease and insect attack. Most injuries are rapidly coated by this sticky material (*Picture 47*). For this reason using pruning paint on conifers has little value other than cosmetically minimizing any visual impact that fresh cut pruning wounds might create. Pitch should be a clear honey colored material that can turn an orange brown as it hardens and ages. If pitch is white or a milky color it is an indicator that it is the result of a pest or pathogen attack such as bark beetles or fungal infection such as cytospora canker (*Picture 47*) .

__Picture 44__. Pines (taller) and spruces (shorter) that are periodically topped to maintain a shorter and denser shelterbelt. Topping should be done every 5-10 years if the goal is to maintain bushy and densely needled structure.



__Picture 45__. In general conifers tolerate topping better than broadleaf trees because pitch helps seal wounds and slows down wood decay. However, just like broadleaf trees, multiple tops can regrow that are prone to breaking off.

***Picture 46.** Lower branches that die or are pruned off will rarely grow back (left). Occasionally when the tree crown is damaged, sunlight will stimulate sprouts (right), though these usually don't develop into normal sized branches or a crown. Alternatively, if the bottom whorl of branches remains alive after the top breaks off these can be cultivated back into a multi-topped tree.*

__Picture 47__. Pitch that is produced by a tree to seal off an injury (left) is a clear yellow color. Pitch that is milky in color is the result of a pest or pathogen such as bark beetles (center) or fungal pathogen (right) such as cytospora canker on spruce. Clear pitch is no reason for worry whereas milky pitch is an indicator of a pest or pathogen.

Pruning Storm or Disease Damage

Windstorms strong enough to tear limbs off trees or break off tops, as well as a variety of insect pests and diseases can be a problem across Montana. Deciduous tree species such as cottonwoods, poplars, willows, box elders, green ash and Chinese or Siberian elms, and evergreens such as spruces and pines are particularly susceptible to storm damage because they have soft and brittle wood. With high enough wind speeds, however, no tree species are risk free. The tremendous leverage that wind exerts on tree limbs causes various types of damage from broken tops out of conifers (*Picture 48*) to torn and twisted limbs on deciduous trees. Trees that have had poor pruning imposed on them in the past *(Picture 49*) or that grew with poor structure (*Picture 50*) are particularly susceptible to storm damage. This type of damage rarely heals well by itself, which makes immediate pruning essential for minimizing further damage to the tree by pests and pathogens. Although a severely damaged tree will have a different appearance, it can recover into an attractive tree and can continue to grow for many more decades (*Figure 14, Picture 51*). Tree damage and recovery will vary by tree species, and in each situation it is important to assess and properly treat the different types of mechanical damage a storm can cause (*Figure 15*). The first goal of pruning injured branches or stems is to minimize the amount of woody tissue exposed to the air. Open wood that traps water and debris is an invitation to pests and pathogens to enter the tree and further damage it. Injuries caused by twisted and broken branches need to be trimmed in such a way that the tree is able to heal over the wound as quickly as possible. The jagged injury created by a broken branch will heal very slowly since new bark has to grow over the injured area from the surrounding healthy bark. Much like a pruning cut, any kind of irregular surface will act as a barrier to this new callous (bark) growth. A smooth surface made by a proper saw cut will allow new bark to cover the exposed wound

***Picture 48**. A tornado blew through Lewistown Montana in 1999 breaking off numerous large spruce trees (left). Without proper pruning such broken ends (right) are open doors for decay and ultimate tree decline.*

***Picture 49.** Past topping resulted in a dangerous tree such as this Norway maple 15 years after topping. Wind and wet spring snowfalls will exert enough torque to cause weak limbs to fail. Note heartwood decay in previously topped stem that broke off.*

***Picture 50.** Multiple topped scotch pine damaged by wind storm because such forks on conifers are structurally weak.*

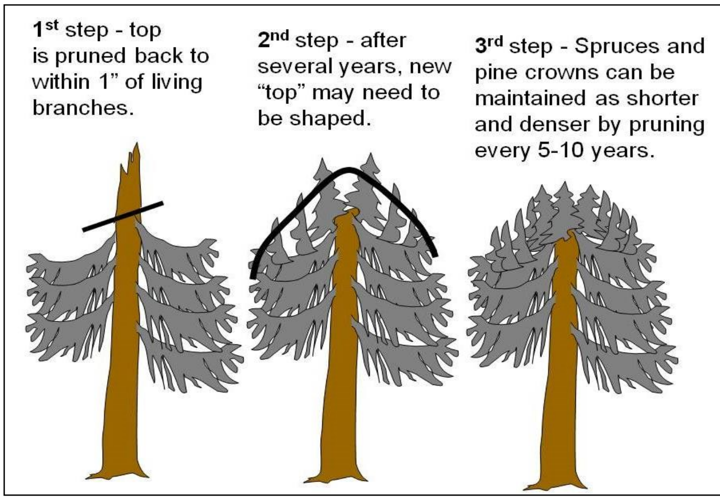


Figure 15. *Proper post-storm pruning to help conifers recover.*

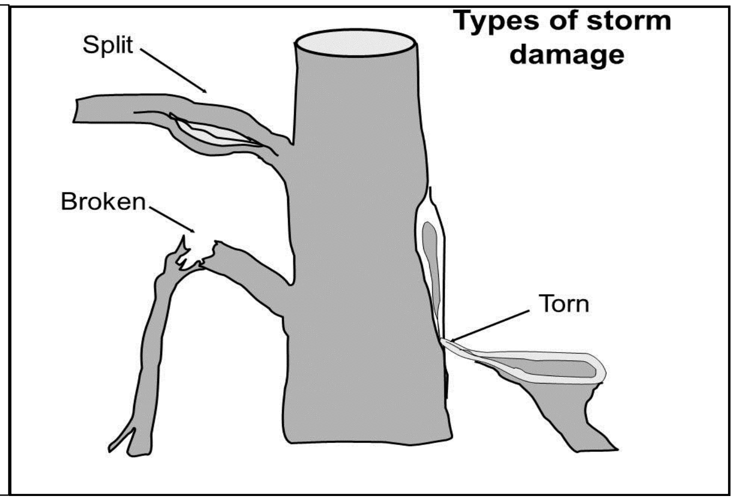
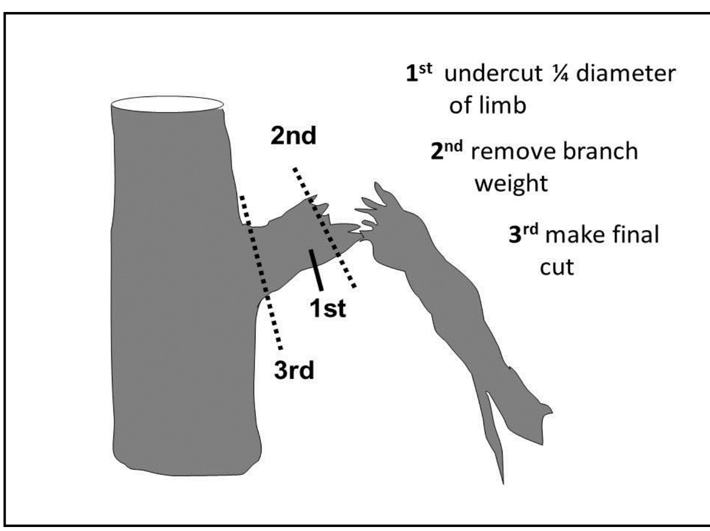


Figure 16 *Types of mechanical damage that depending on tree species may each require a different approach.*



Picture 51. *With proper pruning this spruce (left) that had its top broken off by a tornado in 2000 has started to recover and still provides shade and privacy to the same home 10 years later (center). Loss of a top makes a tree look different (right) but also often causes an increase in the density of the crown and with pruning can regain a lot of its original beauty.*

much more quickly and for the surrounding living tissue to remain healthy. For a broken top or branch (*Picture 52*) it is important to prune the damaged area back to an area of healthy tissue that can remain alive. If a break occurs near the main tree stem or close to a larger branch, the broken branch should first be removed (*Figure 17*) to reduce the weight and leverage on the healthy wood. Next, the branch should be



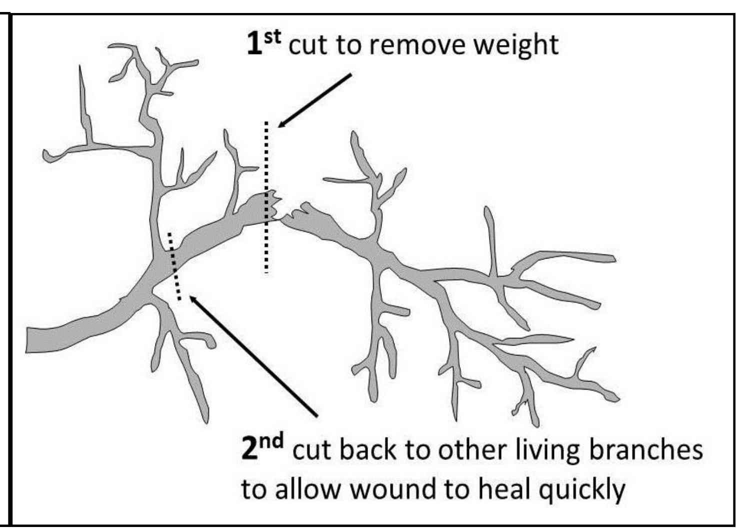


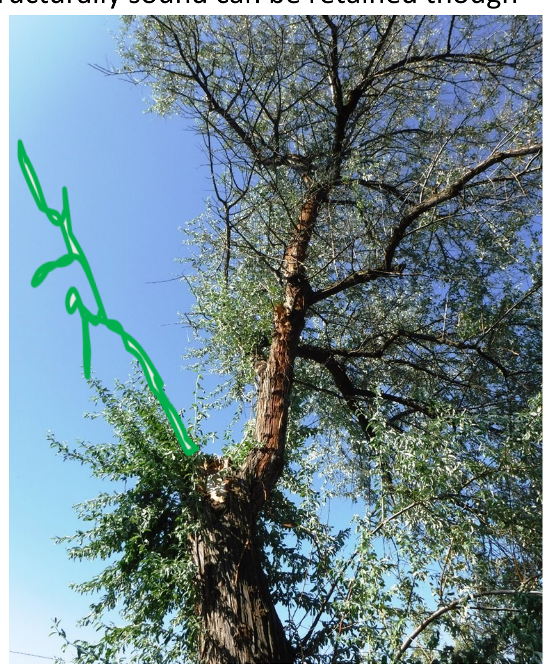
Figure 17. *Techniques for removing broken branches attached to main stem (left) or adjoining branch (right).*

trimmed back close to the main stem at a slight outward angle (as in previous section on pruning) to ensure that enough healthy tissue surrounds the cut to promote healing. If a break occurs far enough along a branch so that healthy branches with leaves or needles exist between the break and the main stem, it is possible to leave the healthy portion of the branch intact. The branch should be pruned back to where the healthy secondary branches protrude. Leaving a short section of branch on either a branch or along the main stem that is long enough to "hang a coat on" can either result in a site where prolific sprouting occurs or a dead stob that will act as an entryway for pests and pathogens (*Picture 31*. Often where multiple branches developed large and multiple pruning cuts cannot be avoided and prolific sprouting or some level of wood decay will result (*Picture 53*). Such problem sites need to be periodically monitored and secondary sprouts selected for cultivation into needed branches and the excess pruned off. Damaged trees might need 2 or three corrective pruning's spaced approximately 5 years apart to help guide the tree back into a structurally sound and aesthetically pleasing shape (*Picture 54*). Likewise cuts should be monitored for wood borer activity or decay fungi and treated accordingly. Insecticides, fungicides can be applied any time to exposed wood and followed up with pruning paint to protect inner wood until they have healed over with healthy bark.

Picture 52. *Torn and split branches are common injuries to trees following extreme storms. It is essential to remove dangling branches as they are extreme hazards that will drop on something or someone.*

Another type of injury is referred to as a "split" limb (*Figure 18*). This is caused by wind or snow pressure on the end of the branch causing an uneven twisting motion. Severe splits will result in the loss of branch stability and causing to easily swing back an forth with wind or pressure. Such splits rarely heal and it is best that the branch is removed. Branches with a split that appear structurally sound can be retained though

Picture 53. *Severe storm damage has the same impact as severe pruning and prolific sprouting can occur. Without further pruning such sprouts will compete and weaken each other. With pruning selected sprouts can be left and trained to grow into branches to fill the crown back into a pleasing shape.*



Picture 54. *Where a major limb was torn off one or two new sprouts can be selected and trained to regrow into the missing branch.*

should be monitored over time because the split can start to decay, resulting in a dangerous hazard. To help diagnose if this type of injury requires branch removal consider:

1) Is the twisted limb in a place on the tree where its removal will severely affect the shape of the tree? If not, it may be best to remove the branch.

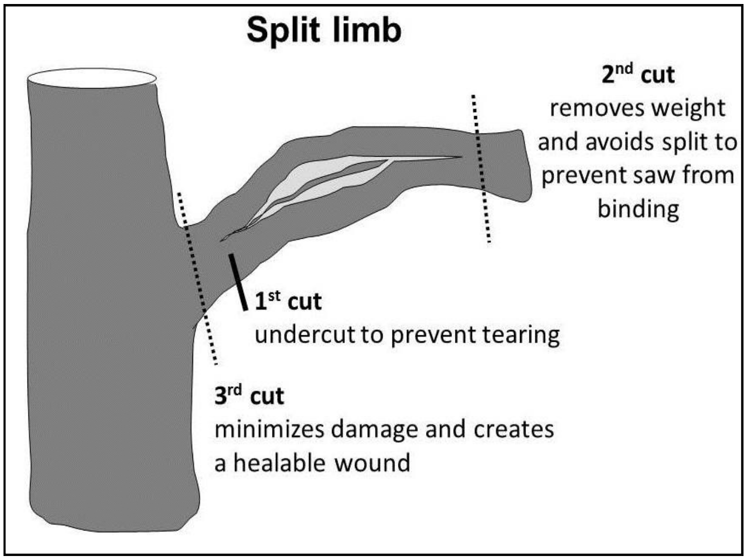


Figure 18. *Split limb and how to remove.*

2) Does the branch easily moved side to side at the split, either from wind or by hand pressure, or does it appear to be fairly secure? If the branch seems fairly secure and the split does not flex noticeable the branch will more than likely recover though the split should be monitored to ensure it heals versus starts to decay.
3) Is the branch greater than 3 inches in diameter and extend approximately 10 feet or more? If so, there is a risk that the weight of the branch and the split represents a dangerous hazard to anything or anyone underneath.
4) Is the split greater than 1 inch wide? Splits larger than this rarely heal well, eventually wood decay fungi will rot out the center.
5) Finally, if there is no immediate danger of the branch falling off in a heavily traveled area, wait and see if the branch recovers – this should only apply to a branch that is split but has not changed its structural position (not hanging or crooked).

When removing a split limb, it is important to follow the proper cutting procedure. Since the limb is already split, improper cutting can cause the split to enlarge and potentially cause much more serious damage to the tree. Also, cutting directly through split will often bind your saw creating a dangerous situation.

The final type of injury is created when the torque of the wind causes a branch to be torn out of the main stem of a tree or from a larger branch. This usually creates a large gaping injury where a strip of bark has been pulled away from the remaining tree along with the branch (*Figure 19, Picture 55*). Although there is little that can be done to "fix" this type of injury, proper treatment can help this injury heal more quickly. Much like a broken branch, the remaining living bark will slowly grow over the injured area it is free of obstructions The smoother the exposed woody tissue, the faster the new bark will grow over it. Using a sharp wood chisel or saw where necessary, trim off any wood splinters protruding from the injury. Likewise, any bark that has been pulled loose from the stem will die, therefore loose bark should be trimmed

Picture 55. *Damage from an object hitting the side of a stem (left) or a fork or limb splitting off (right) creates an elongated wound. Creating a smooth surface that remains dry is essential for these wounds to heal over.*

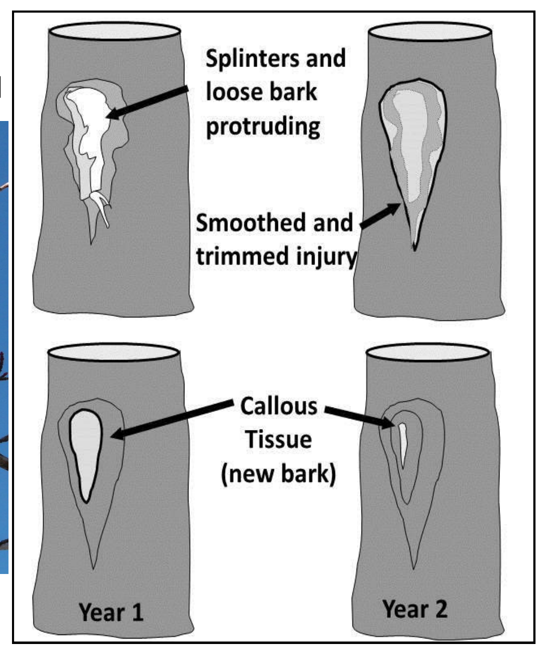


Figure 19. *Torn off branch or bark.*

Picture 56. *The bark was scraped off this quaking aspen (left) by a whitetail deer buck and over the next 4 years new callous slowly grew over the exposed wood. A dissection of the stem (center) shows how water pooled at the bottom of the scrape which allowed for fungal pathogens to gain a foothold and start to decay into the stem. Most trees (right) can sustain an injury such as this over 1/3 to 1/2 of their stem diameter and over time heal it as long as the exposed wood stays sound and decay free. Keeping exposed wood dry is very important so the callous growth has a smooth surface to grow on.*

back to where it connects with the solid wood of the stem. Caution and good judgement must be used when doing this to avoid creating a larger injury. Since water from the roots and sugars from the leaves travel in an upward/downward direction, try to leave the injury in a teardrop or elliptical shape to promote the quickest healing. Pruning paint can also be helpful here to prevent water from seeping into the wood and fungal decay from entering and causing further damage (*Picture 56*).

Special problems

Similar to a split limb is a tree that has a weak fork in the stem that has split apart. A weak fork resembles a "V" shape versus a "U" shape (*Picture 57*). If the V fork is high in the tree there are few corrections that can be implemented to stabilize this weakness. If the fork is low enough and occurring in a tree that has considerable value and sound wood various procedures can be implemented to stabilized the fork (*Picture 58, 59, 60*). Although these will never correct the problem, they can add considerable structural strength to the crown for some time. Much like topping, cabling tree crowns together and adding threaded bolts to bind together a split is at best a temporary reprieve from having to remove a tree. As trees grow larger the weight and leverage they exert on a weakness will only increase. At some point the stress will be too great and the now larger tree has the potential to cause even more damage. Thus any corrective measure must be weighed very carefully against the cost of implementing such a measure, the longevity of its safe utilization, and the increased cost of removing a larger and more dangerous tree. Sometimes such

Picture 57. *Two types of tree forks. The "V" shaped fork on the left often results from a double terminal bud that created two leaders. In this case the wood fibers run parallel to each other and create a severe structural weakness that allows a strong wind to split the fork. This type of fork is a dangerous tree in a high wind. Alternatively the "U" shaped fork it the result of the terminal leader dying back and two lateral branches becoming the leader. In this case the wood fibers run across the fork leaving a very stable fork that is very difficult to split and not a hazard.*

***Picture 58**. Split stems (left) resulting from a V shaped fork will ultimately split when subjected to strong winds. This Norway maple (center) has been split for several years and cannot be "fixed", though valuable trees can be stabilized for some time using two threaded rods with end bolts to tighten the split, and a cable attached to strong spots in the stem near the top of the tree (right). The rods should be placed above and below where the split separates, and not directly where the V converges as this can encourage the stems to snap at this point. The cable near the top of the tree prevents crown leverage on the split. This is complicated work and should be implemented by a qualified arborist.*

***Picture 59.** Siberian elms often have bad forks that get infected by yeast and bacteria that result in decay and internal pressure that forces out a viscous smelly liquid. This "slimeflux" is a difficult problem that might be stabilized for a limited time but a replacement tree should be planted nearby as this condition will severely shorten the trees lifespan.*

measures are worth it, but most of the time it is better to remove the tree and plant a new one.

Picture 56 shows the approximate location for threaded rods to be placed as well as a cable holding the tree crown together. A tree with symptoms of decay (*Picture 59*) is a poor candidate for such work as stabilizing the split will not stop the stem decay that may already have created more weakness than can be saved. Threaded rods should be left exposed at least 3 inches (*Picture 60*) so their location is highly visible to future pruners or tree removers. Hitting metal or concrete with a chainsaw is extremely dangerous to the operator and thus anyone working on the tree in the future should be made aware of hidden metal. Some type of endcaps should be added onto the rod ends for the safety.

***Picture 60.** This birch fork split and was stabilized by an enterprising homeowner. A long 1/2" drillbit was used to drill two holes through the fork in good spots and threaded rods tapped through. Large round or diamond washers were added to each side and bolts threaded on and tightened to squeeze the split back together. In this case the rods were well placed to stabilize the split. Leaving such lengths of rods exposed does not hurt the tree but creates a hazard for humans walking near the tree.*

Attaching cables or ropes to a tree is a common problem area as a natural instinct is to simply wrap the rope around the tree stem or branch. However this can cause real problems for the tree as this will restrict growth of the cambium and the phloem tissue that conducts sugar to the root system of the tree. Over time such restrictions on growth and sapflow can result in stunted root growth, top dieback, or in some cases

Picture 61. *When anchoring a tree or attaching a cable or rope to a tree never wrap around the stem or limb. Pressure on the cambium layer under the bark can kill it, or it will grow around the obstruction hiding it from view. In the case of wire or a cable (left) a tree wrap will constrict sugar flow to the roots limiting their growth and creating an injury where diseases and insects can attack the tree. For younger trees a "wrap" will work as long as it is cushioned with foam or innertube and loose on the stem, not tight as in the center picture. For any tree or branch larger than 3" in diameter a drilled hole and a lag bolt (right) is the best way to anchor to a tree. The hole should be drilled and immediately threaded with the bolt to avoid any air embolisms from forming in the sap wood. For annual use the bolt should be turned out every spring or the new annual growth will eventually bury the bold (right) as happened on only one year in this example.*

if the tree stem is large enough it will grow around and over the obstruction (*Picture 61*). This can lead to buried metal in a tree stem that can cause all sorts of problems to a anyone who eventually needs to cut up the stem. In addition, such aggravated injuries are where pests or pathogens gain enter the tree. For younger tress that have stem diameters less than 3 inches a loose noose cushioned with a soft flexible material such as foam or even innertube will prevent the rope from abrading into the soft cambium. However, rope should never be wrapped tightly around a tree stem for any period of time. For larger stems a drilled hole and screwed in lag bolt is the best way to attach a rope or cable with minimal damage to the tree. The quicker the timing between drilling the hole and inserting the bolt the less chance of air pockets or pathogens entering the tree and disrupting water flow. If possible, the lag bolts should be turned out one turn every year as rapid stem growth can quickly bury the bolt.

Picture 62. *Typical lawnmower and grass trimmer damage to a tree stem. Such damage can be deadly to the tree.*

A similar very common problem that yard and park trees suffer from is bruising damage from lawn mowers and string trimmers (*Picture 62*). Especially young trees are relatively thin barked and bumping the stem base with a mower or string trimmer is enough to bruise and kill the cambium and sapwood underneath. Often such afflicted trees will exhibit top dieback as if they were water stressed, which is in essence the case as such injury restricts water flow up the stem to the tree crown.

How Much Injury Can a Tree Survive?

Sometimes trees are injured to such an extent that tree removal and replacement are the best options. Making such a decision will be based upon the tree species involved and what you the landowner desire. Some tree species such as willows, cottonwoods, green ash, and Siberian or Chinese elms can relatively quickly grow new trees from a stump because of the stored energy in their root system. The advantage of such a process is that you will have a tree back fairly quickly (*Figure 20, Picture 63*). The disadvantage is that larger pruning cuts can become entry points for pests and pathogens that will weaken the trees structural integrity over time. As a general rule, good pruning implemented as quickly as possible with periodic follow up pruning every year or two will yield the best results.

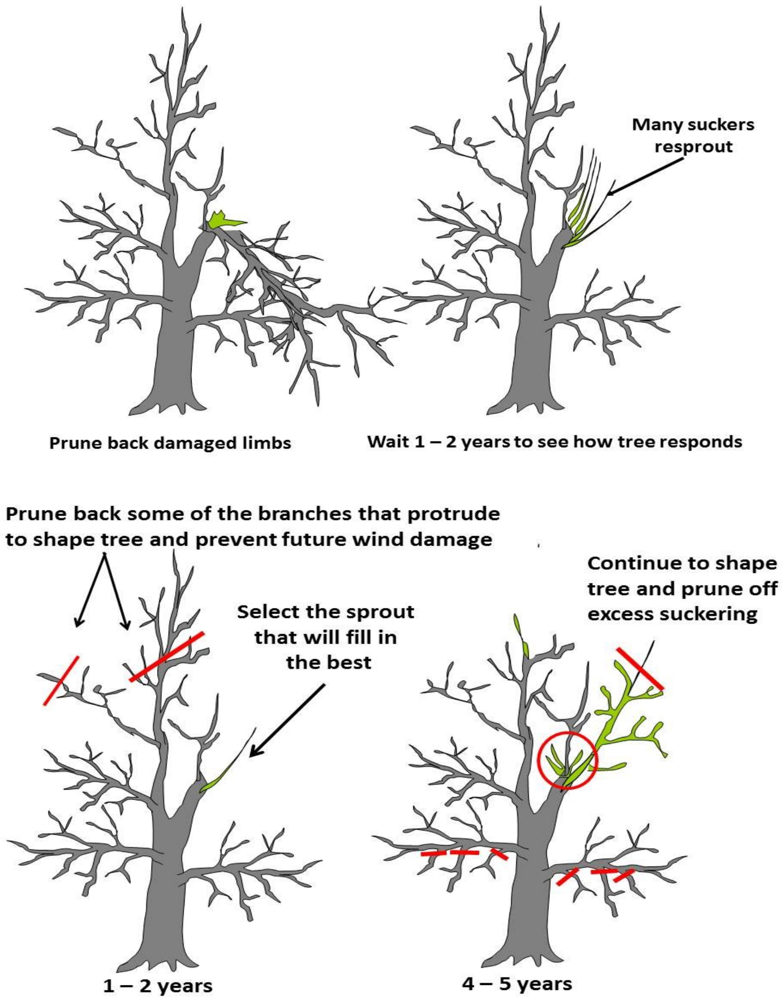


Figure 20. *Illustrated steps of how to 1) remove damaged limbs and broken areas, 2) culture and guide certain sprouts and remove the excess, 3) continue to prune and shape the tree . A well balanced spring fertilizer such as (10-10-10) along with adequate watering during summer drought will speed up the process. Some insect and fungus control might be needed as especially insects are attracted to wounded trees, and fungi grow well on sugary sap that leaks from wounded surfaces. Growing trees from seedlings in central and eastern Montana is a difficult and slow process. Cultivating a new tree from a storm damaged tree can be a much faster process if done correctly. Leaving a tree to its own devices may work, though bad breaks will never heal and allow pests and pathogens to turn a tree that has potential to regrow, into a hazard tree.*

Picture 63. *Although different trees, the picture sequence from left to right shows how a tree can recover from severe damage. Most trees that grow well In Montana, with proper initial pruning and periodic follow-up to guide and shape new branch growth can result in a remarkably fast recovery to former beauty and health from severe damage. An intact root system allows for much faster new shoot growth.*