Wind

Trees, being the tallest organisms, are specially adapted to withstand even strong wind events. When well distributed throughout the tree's crown, wind energy is dissipated by the collective movement of all branches swaying out of synchronization. Long and flexible wood fibers lend amazing flexibility over the length of entire stems and branches, which are quite rigid on shorter scales. As a tree grows, small micro-fractures in the wood caused by light to moderate winds actually result in the strengthening of tissues. But strong winds can be a serious threat to a tree's structural integrity, especially at weak points such as branch unions, sites of previous injury, decay pockets, and at points where maximum tension/compression occur. In forest situations, proper stocking and injury avoidance are the best practices to avoid future wind damage. For urban and landscape trees, proper pruning and tree care are important to minimize the risk of limb or stem breakage. Some tree species are more susceptible to wind damage because of weaker wood or the tendency to develop included bark. Overstocked stands that have been recently thinned may be more severely damaged.

Snow / Ice

Tree structure has evolved to support heavy loads at great heights, but there is a limit to the weight capacity of branches that are periodically tested by snow and ice. Tension and/or compression wood develops during the course of a tree's lifetime at points in the stem and branches where bending occurs most frequently and to the greatest degree. In general, hardwoods tend to react to bending by forming more tension wood, whereas conifers produce more compression wood. Unusually severe snow or ice events can exceed the capacity of compression / tension wood, but more commonly, branch or stem breakage occurs at weak points such as branch unions, old injuries, decay pockets, or in branches with included bark. Branches that have developed from epicormic sprouts (suckers) are weakly attached to the stem and are often the first to fail under heavy loads. When possible, proper stocking and pruning will minimize the risk of limb or stem breakage. Stands that have been recently thinned may be more severely damaged, especially if trees have been suppressed for an extended period of time.

Rain

Normally, rain is considered to be beneficial for trees as opposed to a stress agent, however, too much of anything can be bad. Heavy rains can actually damage leaf tissue or cause minor defoliation. Prolonged periods of leaf wetness can increase susceptibility to certain diseases such as anthracnose or needle cast. Splashing rain is a common mode of pathogen transmission for diseases such as fire blight and sudden oak death. Saturated soils also tend to be conducive to root pathogens such as *Pythium* and *Phytophthora*. Shallow rooted trees are susceptible to wind-throw or root-lifting when the surrounding soil remains saturated for a prolonged period of time, especially when strong winds occur. Soils that remain saturated for long periods may also inhibit a tree's ability to conduct many of the essential oxygen-requiring physiological processes that occur in roots, stressing the tree and making it susceptible to secondary stress agents. Excessive rain in the fall may delay the "hardening off" of succulent tissues before winter, leading to an increased risk of late season frost damage.

Lightning

Lightning is an atmospheric discharge of electricity that can exceed 54,000 ºF (many times hotter than the surface of the sun). Lightning tends to be "attracted" to objects on the ground with a slight positive charge that are nearest to the negatively charged storm clouds above. This makes trees an ideal target for lightning strikes. The type of damage a lightning strike will cause is difficult to predict. In some cases, the damage may be obvious such as the classic vertical stripping of bark (that may be continuous or discontinuous) that may spread straight down the stem or may spiral around the circumference of the tree. In other cases the damage may be more extensive and the tree will appear as if it exploded from the inside. Many lightning strikes go undiagnosed however because they do not cause obvious physical signs. Instead, the tree's vascular system may become super-heated and permanently damaged by the strike. Vascular system damage may be widespread (even extending into the roots) or may occur in relatively localized areas of the tree and can mimic drought or disease symptoms.

Hail

While a relatively uncommon event, hail poses a significant threat to tree health. Hail forms when super-cooled water droplets collide with tiny ice crystals. Strong updrafts produced during severe thunderstorms can keep hail particles suspended in the atmosphere for long periods of time allowing them to grow to sizes in excess of several inches in diameter. The speed at which hailstones fall varies with size; a small stone can reach speeds of around 25 mph, but larger stones can hit the ground at speeds in excess of 200 mph! Even a small, relatively slow moving hailstone can cause severe damage to a tree. Foliage is easily bruised, shredded and/or stripped from trees during hail storms. Hailstone impacts on the stem, branches, and twigs can easily kill the underlying cambium tissue, resulting in a necrotic canker. Widespread cankers can cause branch dieback and severely stress a tree, making it susceptible to attack by secondary insects and pathogens. Wounds caused by hailstone impacts often serve as infection courts for many bacterial and fungal diseases.

Storms

Severe storms expose trees to a combination of many of the most destructive atmospheric stress agents in a short period of time. It is not uncommon for trees to experience heavy rains, saturated soils, strong winds, snow, ice, hail, and/or lightning during a single storm event. Severe damage or mortality often cannot be avoided during the worst storms, but proper tree care starting with the right species selection for the site, appropriate stocking density, and/or pruning when appropriate can minimize damage during less severe events. Large trees should never be “topped”; topping can cause extensive decay pockets and induce epicormic sprouting that gives rise to weakly attached branches that easily break during storms. Care should be taken to regularly examine trees that pose potential hazards to people or structures. Fruiting bodies, holes, or sunken areas on the main stem may indicate areas of decay or weak points that may fail during a storm. After large storm events, trees should be assessed for immediate damage, and be monitored for several years for secondary insects and diseases.

Flooding

Although some tree species are tolerant of periodic or even prolonged flooding, most tree species are severely stressed by flood events. Roots require oxygen for cellular respiration, which is the process of metabolizing sugars to produce energy. The energy produced from respiration is used by trees to power a wide variety of physiological processes necessary to stay alive. During floods, tree roots become starved of oxygen, and therefore cannot undergo cellular respiration. If flooding is prolonged, the entire root system can be severely damaged, eventually leading to decline or death of the tree. Flood tolerant species have evolved mechanisms to transport oxygen from the crown of the tree into the roots, while flood intolerant species lack this oxygen transport mechanism. Flooding while trees are dormant is usually less damaging that flooding that occurs during the growing season. Flood damage symptoms may take years to develop and are difficult to diagnose because they resemble many other root disorders and diseases. Be aware that prolonged soil saturation can have the same effect as floods.

Drought

Water is a critical component of nearly every physiological process in plants; without water, trees will rapidly wilt and die. On average, trees require 1 inch of water per week. A large mature oak can lose nearly 400 gallons of water on a hot summer day through transpiration. Fortunately, trees have vast root systems that, using mychorrizal associations, can access water from the small spaces between soil particles. Trees respond to short term water shortages by closing small pores in the leaf surface called stomata and minimizing transpirational water loss. Longer periods of drought can cause wilting and browning of foliage, embolisms in the tree's vascular system which further inhibit water translocation, dieback of the tree's crown, and eventually death. Drought symptoms will first appear where water is lost at the highest rates (foliage) and at points farthest from the water supply (leaf tips, inter-veinal leaf tissue, and the upper crown). It may take a tree several years to fully recover from prolonged drought. Drought stress can make trees highly susceptible to secondary stress agents.

Salt Damage

Trees can be damaged by salt that sprays or drifts onto foliage or by salt that leaches into the soil. Salt damage is most common in coastal areas, particularly after large storms, and along roadways where de-icing salts are commonly used. Tree species vary in sensitivity to salt in the soil or on foliage, and salt damage severity can vary from year to year depending on temperatures, rainfall, and timing of salt exposure. High levels of salt in the soil can inhibit a trees ability to absorb water and mineral nutrients and may kill fine roots and root hairs. Excessive salt can also cause the soil to break down, leading to poor aeration and permeability. When salt contacts succulent green tissues such as the foliage and buds, water can be drawn out of these tissues. The result is the desiccation and death of leaf cells and common salt injury symptoms such as leaf and needle browning and premature defoliation. Prolonged salt exposure can lead to decline symptoms such as foliage chlorosis, growth reduction, abnormal growth patterns, thin crowns, dieback, and even mortality.

Frost / Freezing

During freezing temperatures, ice crystals form inside of plant cells that rupture the cellular membrane, resulting in death of frozen tissues. Plants have developed many adaptations to avoid freeze damage. For instance, deciduous species shed their leaves and “harden off” succulent tissues before the first frost to avoid damage, and the cells of pine needles expel water into intercellular spaces to avoid intracellular ice crystal formation. However, early frosts in the fall or late frosts in the spring can catch trees off guard and unprepared for freezing temperatures. Newly expanding leaves in the spring are the most susceptible, as are actively growing tissues in the fall such as shoots that have not adequately hardened off. Freeze damaged tissues may appear bruised and water soaked, eventually turning brown or black. Dead tissues may eventually fall out of leaves, giving foliage a “shot-holed” appearance. Excessive rainfall in the fall can encourage trees to continue to put on new growth that may not adequately harden off before the first frost.

Heat

The vascular system of a tree, which is responsible for transporting water and nutrients, and the cambium, which is responsible for diameter growth, lie just beneath the bark. Combined, the vascular system and cambium are usually less than ½ inch thick. Bark is a relatively good insulator, however, intense heat can easily damage this thin layer of vital tissues and cause severe injury or death. Trees with thin bark are more susceptible to heat injury on the stem, but even thick-barked species can be damaged. Avoid placing trees in close proximity to surfaces that absorb and radiate intense heat such as asphalt or dark rocks. Radiant heat from these surfaces can easily "cook" the living cells of the vascular system and cambium on a hot summer day. Succulent tissues such as leaves and young shoots are particularly susceptible to intense heat. The living cells of these tissues can be killed by excessive temperatures, or rapid water loss through transpiration may exceed the trees capacity resulting in wilting or leaf scorch. This is frequently seen on low branches over parking lots.

Air pollution

The foliage of trees, particularly hardwoods, is very susceptible to air pollutants including sulfur dioxide, fluorides, and oxidants such as ozone. These pollutants can be absorbed by leaf tissues, and if concentrations are high enough, will kill cells in a few hours or days. This can stress trees and lower overall tree health. Well defined concentration gradients of pollutants may exist downwind of pollution point sources, and in these cases, injury is most severe near the pollution source and will diminish as distance from the source increases. In other cases, regional sources of these pollutants can result in uniform and widespread distribution of air pollutants over large geographical areas. In broadleaf species, ozone damage will cause leaf stippling or unusual pigmentation patterns. The stippling may be red, purple, brown, or black, and can be restricted to certain areas of the leaf or appear uniformly over the entire leaf surface. Ozone can cause chlorotic mottling and tip burn in conifers. Sulfur and fluoride injury usually results in interveinal and/or marginal necrosis of leaf tissue.

Fire

While some tree species are adapted to survive low to moderate intensity fires, excessively high temperatures can damage even the most fire-adapted trees. Because of the proximity of the vascular system and cambium to the bark surface, these vital tissues can be easily damaged or killed if not protected by a thick layer of insulating bark or if fire temperatures become excessive. In addition, foliage, buds, and near-surface roots can be damaged or killed during fires, further stressing trees and making them susceptible to secondary stress agents. Frequently, secondary insects such as ambrosia beetles will invade damaged tissues shortly after a fire event. If trees are severely stressed, opportunistic insects such as *Ips* engraver beetles or southern pine beetles may move in. Frequent, low intensity burns are less likely to injure or kill trees. Intense fires generated by heavy fuel loads, dry conditions, and strong winds are more likely to exceed the capacity of the bark to insulate. Fire injury may show up immediately, but often the effects are not noticed until many years after the damage occurs.

Mechanical Damage

Mechanical damage refers to the physical injury of a tree and is a term usually reserved for those injuries caused by people or animals. Woodpecker feeding sites, deer rubs, and beaver and rodent feeding are some examples, but people tend to be far more destructive. Examples of human caused mechanical injury include weed-eater and lawnmower damage, root injuries, nailing objects to trees, tying ropes around the stem or branches which eventually girdle the tree, pruning, equipment impacts during logging or construction, and acts of vandalism such as name carving or intentional girdling. Trees do not have the ability to "heal"; they can only compartmentalize injuries such as these. Repeated injuries or severe damage can lead to decay, disease, localized dieback, or even mortality. In most cases, mechanical damage is completely preventable, and requires little more than planning and preparation when using equipment around trees. For instance, mulching around trees eliminates the need to mow up against the stem; and the use of "bumper trees" along skid trails can minimize damage to valuable trees during logging operations.

Root Injury

The vast majority of a tree's root system is present within 24 inches of the soil surface. While frequently forgotten because they are out of sight, roots are critical because they absorb water and mineral nutrients from the soil, store carbohydrates, and anchor and support the tree. Because of their proximity to the soil surface, roots are easily injured by human activities. Often these injuries are accidental such as those caused by lawnmowers and soil compaction. In other cases they may be intentional, such as when roots are cut to install irrigation lines, sidewalks, utility lines, or during construction projects. Small diameter "feeder roots" can be replaced by a tree when they are damaged, however the larger "buttress roots" that emerge from the root collar only develop early in a tree's life. Damage to large roots can seriously impair a tree's ability to obtain adequate water or remain anchored in the ground properly. But even damage to small roots can impair tree health. Root injuries are often invaded by pathogenic organisms and/or insects, and may act as the entry points for decay.

Herbicide Damage

When used correctly, herbicides can be a valuable vegetation management tool. However, improper use or failure to heed all herbicide label instructions and warnings can result in herbicide injury to non-target plants. Symptoms of herbicide damage vary widely with the herbicide and formulation used, time of year the product was applied, and the plant species affected. The most common symptoms of herbicide injury can include chlorosis, dieback, epicormic sprouting, abnormal growth patterns, stunting, wilting, death, and/or the cupping, strapping, curling, or abnormal thickening of foliage. Often, more than one plant species will be affected when herbicides have been used improperly, although some plants can be especially sensitive to certain types of herbicides. Herbicide injury often results when chemicals drift on to non-target plants, are applied to stressed or otherwise unhealthy plants, or when residual chemical in the soil remains present and active for longer than expected. Herbicide injury can often be diagnosed by an expert based on symptoms alone, but positive confirmation can only be achieved through expensive laboratory testing.

Nutrient Imbalances

Nutrient imbalances occur most commonly when there is a macronutrient or micronutrient deficiency in the soil, but may also occur, for example, when excess nutrients are present, when nutrients are unavailable to the tree because of improper soil pH, or when there is a problem with root system structure or function. The most obvious symptoms of a nutrient imbalance are chlorotic foliage, possibly accompanied by growth loss or even deformed growth. Different tree species will react differently to nutrient imbalances, but there are many useful patterns that can be used to narrow down possible problems. For instance, symptoms of deficiencies of mobile nutrients such as N, P, or K will show up in new growth, while deficiencies of immobile nutrients such as Ca, Cu, Mn, or Zn will cause symptoms in older tissues. Color of foliage alone may be enough to determine which nutrient is lacking. Diagnosing specific nutrient imbalances can be difficult using symptoms alone so chemical tests of soil and / or plant tissues are usually recommended.

Frost Cracks

A frost crack is a form of bark damage sometimes found on thin-barked trees. A frost crack is a vertical fracture or crack, usually on the south-facing side of a tree's stem. Frost cracks originate from some sort of weakness in the bark, often an old wound that has since disappeared from the bark surface. During winter months, the inner bark and outer xylem can expand and contract under the widely fluctuating temperatures of cold nights and warm sunny days. Surface bark may cool and contract and / or warm and expand faster than underlying wood, stressing weak points in the stem. Wood that is in some way damaged does not flex to the same degree as healthy wood, resulting in a sudden rupturing of the bark, sometimes with an audible report likened to that of a rifle. These cracks may heal in the summer and reopen again during the winter, so that successive cracking and callus formation over a number of years results in the formation of 'frost ribs' on the sides of affected trees. Frost cracks may act as sites of entry for wood decay organisms and insects.


Sun Scald

Sun scald occurs during the winter months, most frequently on thin-barked trees on the south or southwest facing side of the stem. During warm winter days, sunlight directly contacting the bark may warm the bark enough to bring the living cells of the phloem and cambium out of dormancy. As the sun sets and temperatures rapidly cool, these living cells can freeze suddenly, resulting in the death of large vertical patches of inner bark. During the spring, bark that has been killed by sun scald may slough off, revealing the full extent of the injury. Trees will attempt to form callus tissue over these large open wounds, but frequently these new tissues are killed the following winter, creating perennial open wounds that never fully “heal over.” Commercially available tree wraps or crepe paper can be used to insulate the bark from the warm winter sun, and white paint is often applied to the stems of susceptible tree species in orchards and landscape settings to reflect winter sunlight. Using these protective measures after injury has occurred is the only option available to allow the tree to recover.

Soil Compaction

Soil compaction occurs when heavy loads compress soil particles together causing the loss of natural soil structure and pore space. Compaction can occur over a long period of time by frequent light loads passing over the site (e.g. a walking path), or can occur instantly with a very heavy load. Wet soils are particularly susceptible to soil compaction. Water is not absorbed readily by compacted soils, leading to chronic runoff and erosion issues. Water and oxygen cannot penetrate as deeply into compacted soils, and therefore roots are unable to get the water and oxygen needed for growth and survival. Heavily compacted soils can also inhibit root growth if they are exceedingly dense. Soils vary in their capacity to become compacted and return to a normal state. Clay soils are particularly susceptible to severe compaction and may never fully recover without mechanical assistance. Avoid using heavy machinery within the drip line of trees. In areas with frequent or heavy traffic, a layer of mulch 1-3 inches thick will provide some protection.

Soil Grade Changes

The vast majority of a tree's root system occurs within the upper 24 inches of the soil surface. Within this region water and oxygen are most available. Grade changes occur when soil is either removed from or added to the soil surface. Grade changes can occur naturally (e.g. during flooding), but most often they are a result of grading and excavating by people. When soil is removed around a tree, most of the root system responsible for water, mineral, and oxygen absorption is also removed. The remaining root system is unable to support the tree's needs, and therefore, decline or death can result. Likewise, tree health can be adversely affected when soil is added on top of a tree's root system. Additional soil starves the root system of water and oxygen and may cause soil compaction in the root system region. Usually the affects of grade changes take years to develop in trees. If grade changes are necessary, they should be avoided within the drip line of trees. Use of retaining walls to either keep added soil away from the tree, or to protect the root system when soil is removed is a commonly utilized practice, but walls should be placed as far from the tree as possible.

Improper Pruning

Proper pruning is an important part of tree care in urban, landscape, and ornamental trees. When done properly, pruning wounds are compartmentalized by the tree and can benefit tree health in a variety of ways. However, improper pruning can injure trees, slow compartmentalization, and lead to insect or disease problems. Pruning should be done with the proper tools; use of the three-cut method ensures the cut is made outside the branch collar with no remaining branch stub or bark tearing. Cutting within the branch collar can cause decay in the main stem, and leaving a branch stub can significantly slow compartmentalization. Bark tearing occurs when an undercut is not made on the branch being removed and results in a larger wound that can allow decay fungi to enter. Several important tree diseases are caused by pathogens that can enter the tree through pruning wounds. Care should be taken to sterilize pruning tools and only prune during seasons when the risk of infection is low. Do not apply pruning paint to the wound unless oak wilt is known to occur in the area.

Deep Planting

When planting large-caliper trees such as balled-and-burlapped or containerized saplings, care should be taken to ensure the root flare (the point at which the stem begins to flare out into the root crown zone) is level with the soil surface. Planting trees too deeply can cause a wide variety of problems including disease, bark and stem decay, deformed or girdling roots, and can starve the root system of water, nutrients, and oxygen. Trees planted too deeply can suffer from decline and eventual death. Typically, problems associated with deep planting do not develop for many years, therefore trees usually decline and die just as they reach maturity after years of investment and care. Once a tree has been planted too deep and is established, there is little that can be done to reverse the effects. Follow appropriate tree planting guidelines. Often trees from nurseries will already be planted too deeply in their containers, so be sure to remove soil from containers or the root ball until the root flare is exposed. The root flare should be level with the soil surface when planting is complete.

Improper Mulching

Mulch, when applied properly around trees, can provide many benefits including improved soil moisture retention, reduced soil compaction, reduced competition from weeds and turf, reduced risk of wounding by lawn care equipment, slow release of important nutrients as the mulch decomposes, and improved appearance. Mulch that is applied too thickly or piled high on the tree's stem can have the same effect as deep planting or grade changes. A thin layer of mulch 1-3 inches thick can be applied around the base of a tree at the time of planting, and can be reapplied as needed every few years. Using thick layers of mulch can starve the tree of water and oxygen. Mulch piled high onto the stem can cause disease problems, stem and bark decay, and the formation of abnormal root systems. Extend the mulch zone as far out from the tree as possible. Using natural materials such as bark or shredded wood mulch provide the benefit of some added nutrients, but tend to break down more quickly. Artificial mulches last longer, but can for instance, reflect excessive heat onto the tree's stem. Use local sources of mulch.

Included Bark

Normally stems and branches grow in such a way that bark is confined to the surface of the tree. However, some tree species have a tendency to form multiple stems or develop improper stem/branch unions which can trap bark between adjacent stems and/or branch tissue. This union is relatively weak in strength, and can eventually fail when the tree grows large enough, particularly during storms. Improper pruning can also result in multiple stemmed trees that are prone to included bark formation. Trees that form branches with narrow branch angles are also particularly susceptible. Proper pruning, including the removal of multiple stems, co-dominate leaders, and branches with narrow branch angles, can reduce the risk of included bark formation. Mature trees with large regions of included bark should be inspected frequently for hazard potential. Cable and bracing techniques can be used to strengthen the weak regions in large, valuable trees with included bark.

Girdling Roots

Girdling roots are roots that completely or partially encircle the main stem of a tree. As girdling roots and the stem increase in size, the root tissue can strangle the underlying vascular system of the tree's stem. Eventually, the part of the stem that has been girdled will die. Girdling roots that completely encircle the stem can eventually cause tree death. Girdling roots form for a variety of reasons. Some tree species have a tendency to naturally form girdling roots, but in most cases they result from improper tree care. For instance, trees grown for extended periods in containers may develop girdling roots that can eventually kill the tree many years later. Trees in containers or burlap balls should be inspected for girdling roots before transplanting. Compacted soils, deep planting, grade changes, and root system obstructions can also lead to the formation of girdling roots. Once the effects of girdling are observed, it is usually too late to fix the problem. Girdling roots, when discovered early, can be cut and removed before they completely strangle the stem.

Genetic Disorders

Trees, just like people, are all unique individuals. Occasionally, genetic variations may occur in an individual tree that in some way distinguishes it from the surrounding population. For instance, genetic variations may make trees more disease resistant (or susceptible), possess faster growth rates, or be especially drought resistant. Genetic variations contribute to the evolution of a tree species through natural selection. Sometimes genetic variations arise in a tree that can have a dramatic effect on the tree's appearance or health. For instance, occasionally mutations occur that cause unusual leaf pigmentation called "variegation." Variegated leaves have unique patterns of green and chlorotic foliage, and can even be propagated and resold as unique cultivars. Total lack of pigmentation is called "albinism." While frequently beautiful and always unique, these genetic mutations can negatively impact tree health. Severe variegation or albinism can cause leaves to be intolerant of direct sunlight, or make them more susceptible to foliar insects and pathogens.