THE ANATOMY OF A TREE

The major parts of a tree are leaves, flowers and fruit, trunk and branches, and roots.

LEAVES

Leaves are basically sheets (or sticks) of spongy living cells connected by tubular conducting cells to the "plumbing system" of the tree. They are connected to the air around them by openings called stomates, and protected from dehydration by external wax layers. They frequently have hairs, bristles, scales, and other modifications that help adapt them to their environment.

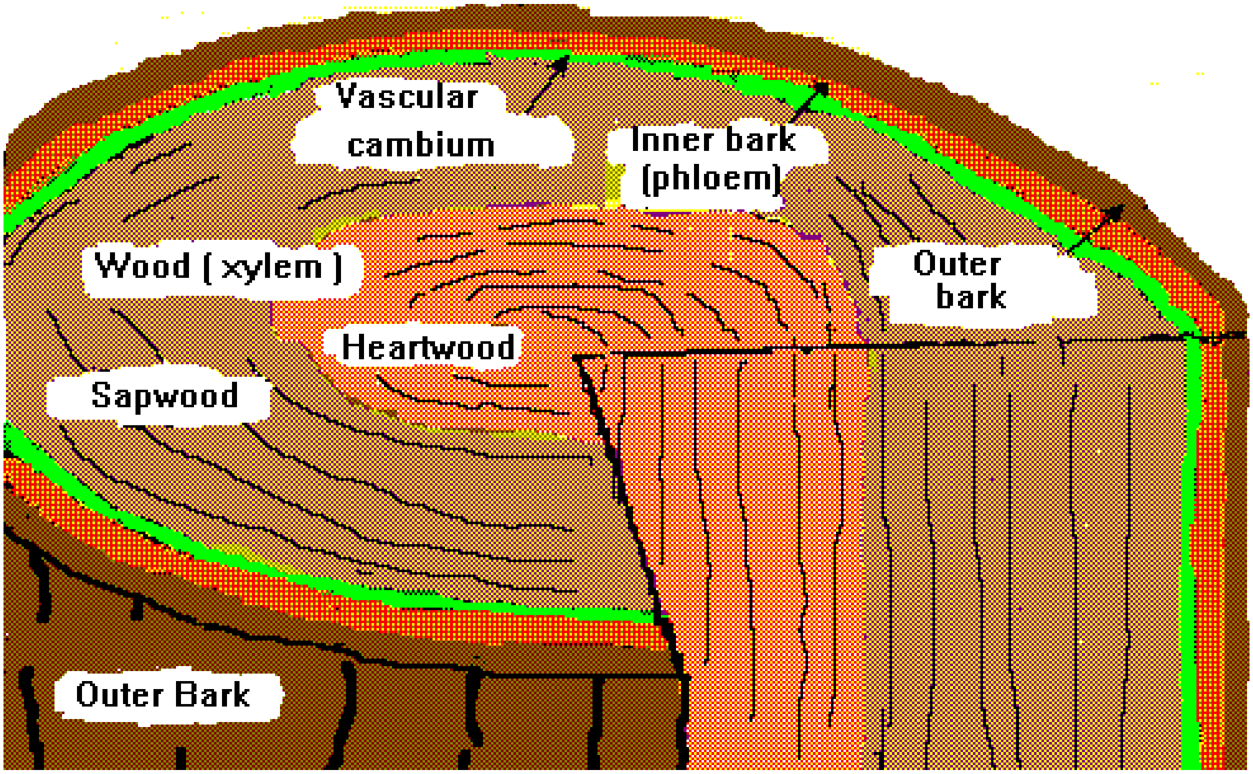
TRUNK AND BRANCHES

While branches and trunks may seem to be "just made of wood," this material (and the bark around it) consists of many types of cells adapted for strength, resistance to injury and decay, transport of liquids, and storage of starch and other materials.

The bark consists mostly of two zones: The inner bark or phloem actively contributes to the tree's life processes: its tubular cells form the "plumbing system" through which sugar and growth regulators, dissolved in water, are distributed to other parts of the tree from the leaves and buds where they are made. The outer bark consists of layers of inner bark cells that have died and cracked as they have been pushed outward by the tree's growth; outer bark forms the tree's first line of defense against damage by insects, people, heat and cold, and other enemies.

A tree normally has three meristematic zones -- that is, cells that can divide and reproduce themselves. Two of these, the root tips and the buds at the tips of twigs, allow the tree to grow lengthwise. The third, located between the bark and the wood, is the vascular cambium zone, often referred to merely as "the cambium." Its cells divide inward and outward, laying down new wood cells on those already in place and new inner bark cells inside those already existing.

The cambium is one important key to trees' success. Its growth from the outside outward allows the tree to cover over minor wounds and (as we will see later) to wall off and abandon entire columns of rot-infected wood. This is the strongest of all a tree's defenses against decay.



Inside the cambium region is the **xylem** or wood. Xylem includes three principal types of cells. There are numerous tubular conductive cells running parallel to the trunk or branch that they form, and adapted to carry water and minerals upward from the roots. There are also sheets of ray cells -- tubes running from the inner bark inward toward the center of the tree. The third type is **parenchyma** (pa-REN-ki-ma); these cells, while they are still alive, warehouse starch crystals made by the action of enzymes on sugar. This starch, reconverted to sugar by enzymes, is the principal raw material for the natural fungicides made by trees in response to injury, and the principal source of energy for growth after injury. Parenchyma can also become meristematic under some conditions, taking on a role similar to the vascular cambium when a tree has been injured.

Various species of trees also have other types of cells, such as **resin ducts**, **fibers**, and **tracheids**. However, conductive cells, ray cells, and parenchyma, make up the bulk of wood, and perform most of its functions.

In heartwood-forming species such as redcedar, walnut, and oak, there may be a distinction between the newest, living layers of **sapwood** and heartwood. True strong>heartwood is the result of aging in normal compartments of a tree. As sapwood becomes less involved in transporting and storing energy for the use of the tree, its cells become "toxic waste dumps." This gives the wood a distinctive color and sometimes gives it natural resistance to decay. Unlike sapwood, heartwood can not respond to injury by forming anti-microbial substances; however, it can discolor.

"**False Heartwood**" is a central column of discoloration that occurs as a young tree matures, when many branches die and are shed even though there may be no decay. Discoloration that takes place in the early stages of decay after a tree is injured is not true heartwood, but it can keep heartwood from forming.

Inside the earliest wood in a trunk or branch is a column of spongy, styrofoam-like material called **pith**. Eventually covered over by layers of wood, pith is the remains of a primary tissue formed as a twig elongates. In some species it disintegrates or is crushed; however it remains in other species, such as black walnut, whose twigs can be easily recognized by their chambered pith.

BRANCH ATTACHMENT

Until you understand the differences, all branches look pretty much alike. But the differences between forks, true branches, and epicormic sprouts (sometimes called "suckers") are profound and important. Knowing them could save your tree, your house, or your life.

When a tree is young, its goal is to get its head above the competition and catch as much sunlight as possible. In the forest, where trees compete for light and space, the most efficient way to do this is with an "excurrent" growth habit -- that is, a single, undivided stem and lateral branches. As it reaches its mature height, the branching habit becomes "codominant" -- that is, its stem and branches often subdivide with forks instead of true lateral branches.

But when we domesticate trees, we encourage them to make this transition much earlier in life... and closer to the ground. In fact, a standard nursery practice has been to force trees into a codominant branching habit. A fork near the tip of a branch has little effect on the tree's strength; but the lower the fork occurs, the worse the problem if it fails.

True Branches

A true branch is the result of a process that starts with the growth of a bud into a twig. Normally this begins from the axillary buds found where each leaf joins the twig. The meristem (reproducing cells) at the tip of the bud divide, and the newly formed cells become a twig. The meristem just under the bark -- the vascular cambium -- continues to divide so that the twig grows in diameter, forming a branch.

At the base of this twig is a swollen area called the branch collar. In this area the wood fibers of the trunk (or parent branch) veer around the twig on each side and continue toward the trunk or the base of the tree; the "plumbing system" in the branch also turns groundward -- none turns upward or goes around the trunk or parent branch. Since growth occurs at different times in various parts of the tree, the twig and branch fibers tend to form interwoven layers, a little like the laminations in plywood. Together, they create the extra wood thickness of the branch collar, which continues to grow as the twig matures.

If the fibers in the crotch at the base of the twig knit well with those of the trunk or parent branch, a bark ridge emerges to some extent across the crotch. Also, natural fungicidal materials saturate the fibers in the base of the growing twig, forming a protection zone; this does not happen in the fibers of the trunk or parent branch. This has important implications for pruning: if you cut only the protected branch fibers outside the collar, you protect the tree from decay.

Forks

A fork is a place where a stem grew in two or more directions, instead of one. Although one side may be larger than the other, neither side has any natural chemical protection. Most U-shaped forks, with all bark visible, are dependable. The problem is with V-shaped forks, particularly when bark disappears down into the fork from each side, and much of the branch junction consists of two bark faces pressed against each other. Such forks, though graceful, have many potential problems:

- First, there is no bond or strength between the two bark faces.
- Second, as the two sides of the fork grow, the pressure between them tends to spread the fork, increasing the splitting force on its the base.
- Third, this pressure also crushes the living tissues under the bark, starving this area and destroying its defenses.
- Finally, rainwater, fungus spores and other materials seep down into the fork, rotting bark and wood so that the weaker side is likely to split from its own weight or under wind stress.

Here is **a common problem to look out for in trees** that have not been maintained carefully -- a weak fork with what is known as "included bark." This makes a tree very likely to split during high wind, ice load, etc. Many people like the graceful appearance of a forked or multi-stemmed tree. It seems insignificant when a tree is young; but this is when a little preventive pruning can make a lot of difference. If you ignore it, you may find out too late that this is one of the most serious structural problems a tree can have.

There is no way to know how much bark is included in a fork, or how soon it may fail. When rods and cables are used to reinforce weak forks, they must be installed properly, and inspected periodically. Too often, such hardware merely postpones the failure of the tree until it is bigger, heavier, and more dangerous. The only good way to deal with such forks is to prune out the weaker side while the tree is still young. Such preventive pruning pays for itself many times over.

Epicormic Shoots ("**Sprouts**" or "**Suckers**")

As a branch or trunk leader grows, its tip bud manufactures a growth regulator that suppresses buds nearer the base of the tree. But when the tip bud dies or is removed, many axillary buds (in the the angle between each leaf and its parent twig) and dormant buds (in the living wood under the bark) are activated, and the cambium may be stimulated to produce new adventitious buds (usually in response to wounding).

Sometimes, if they are carefully managed, suckers can sometimes be trained to become healthy and useful parts of a tree. As a rule, however, sucker growth that occurs as a distress response when a tree is in trouble is likely to cause further trouble. This is because suckers are superficially attached to the surface layers of wood, and because most rapidly formed wood (such as that typically found in suckers) is weak. Under ice load or strong wind the tall spear-like suckers formed around topping cuts are especially likely to bend over and break; or they may tear out where they are attached to the surface layer of the stub, which has been opened up to serious rot.

People want their trees to "look like trees" -- that is, to have a large, shady crown; and we think of multiple stems as "graceful," not understanding that this beauty often comes at the expense of strength and safety. At first blush, this would seem to force us into a choice between beauty and strength. But the more we understand about trees, the more we appreciate healthy structures. It is difficult to remain enchanted by something that is likely to split open and crush anything in its path.

ROOTS

Myths About Roots

Few people have ever seen the entire root system of a tree. Since roots are mostly out of sight, most of our ideas about them come from glimpses and assumptions. So a great mythology has grown up -- where they are, what they look like, how they work, and how we should manage.

them. Some of those that come up most often include:

- Myth: The root system is more or less a mirror image of the top of the tree.
- Myth: Most tree species have deep taproots; if a tree's taproot is cut, the tree dies.
- Myth: A tree's roots extend to the tips of the branches.
- Myth: Tree species are "deep-rooted" or "shallow-rooted."
- Myth: Roots seek water.

To understand what a tree's roots looks like, think about what they do, and how. Their principal jobs are:

- uptake of water, oxygen and minerals,

- transporting water and minerals inward toward the trunk,
- support, and
- growth.

Their work is powered by sugar received from the leaves; "burning" this sugar requires oxygen, which the roots must find in the small spaces between soil particles.

In all, a large tree may have over 30 miles of roots, with about 5-million root tips, plus many small colonies of beneficial fungus. The actual work of absorbing water and minerals from the soil is done by one-celled projections ("root hairs") from the absorbing roots, along with colonies of beneficial fungi **(mycorrhizae**, pronounced MY-co-RISE-ee) that live on or in the feeder roots.

Absorbing Roots feed into long, thin Conducting Roots, which carry water and minerals back toward the trunk. In undisturbed forest soils the conducting roots may extend outward as much as 2 or more times the height of the tree, mostly in the top 1-2 feet of soil. These conducting roots gradually converge into thick lateral Brace Roots, which provide most of the tree's support.

So roots extend in an ever-widening disk, wherever they find all the things they need -- water, minerals, and oxygen. There is little oxygen deeper than about 18" in clay soils; in sandy soils the oxygen may go deeper, but the water or minerals may be in short supply; a high water table may also limit oxygen penetration; or bedrock may prevent roots from penetrating deeper.

To envision a tree's root system, imagine a wine glass sitting on a tray -- the root system is the tray, and its thickness is determined by some limiting factor. Tree species are not necessarily "deep-rooted" or "shallow-rooted" -- certain species are more or less sensitive to various levels of moisture, oxygen, and minerals. Often roots will "bounce" off a soil hardpan or a high water table, forming surface roots where other species may not be able to live at all.

In undisturbed forest soils, roots may extend well beyond the tips of the branches, but a heavy clay soil will greatly slow down their outward growth. Roots are opportunistic: they do not "seek" either water or minerals, but when they find them, they prosper.

Trees seldom have deep taproots, especially in clay soils. When a seed germinates, a rootlet heads downward into the soil, but it quickly branches to the sides, extending only wherever it encounters the essentials for its growth -- water, minerals, oxygen, and growing space. There is no particular difference between the taproot (if there is one) and any other root -- if you cut it, all other roots attached below the cut are lost, but those attached above it will still function, provided a fungus or other disease organism does not enter through the cut.

In deep sandy soils with wide seasonal variation in rainfall, trees have been known to form "striker roots" -- taproot-like connections between two sets of conducting and absorbing roots, one just above each seasonal water table. However, this is fairly unusual.

There are more similarities than differences between roots and structures in the crown. The connections between roots and parent roots are similar to branch structures, as are mechanisms for dealing with injury and decay -- work that roots are extremely effective in handling. And roots suffer the same loss of stored energy when they must react to injury and contain decay.

Anatomical differences include: (1) Roots do not have pith. (2) Roots usually have more parenchyma (living food-storage cells) and fewer fibers. (3) In roots there is less distinction between growth rings than in trunks and branches. (4) Roots do not produce normal heartwood.

Roots have important functional differences, as well. They are adapted for uptake of water and minerals, so (unlike trunks and branches) their bark withstands moisture and low light conditions.

They also require considerable oxygen, which they must extract from small spaces between soil particles.

Perhaps the most important distinction is that we rarely see roots, so we know little about them, and we tend to ignore them. This is unfortunate, since most problems with trees reflect mismanagement of roots.

Click here for Some Practical Lessons in Tree Management

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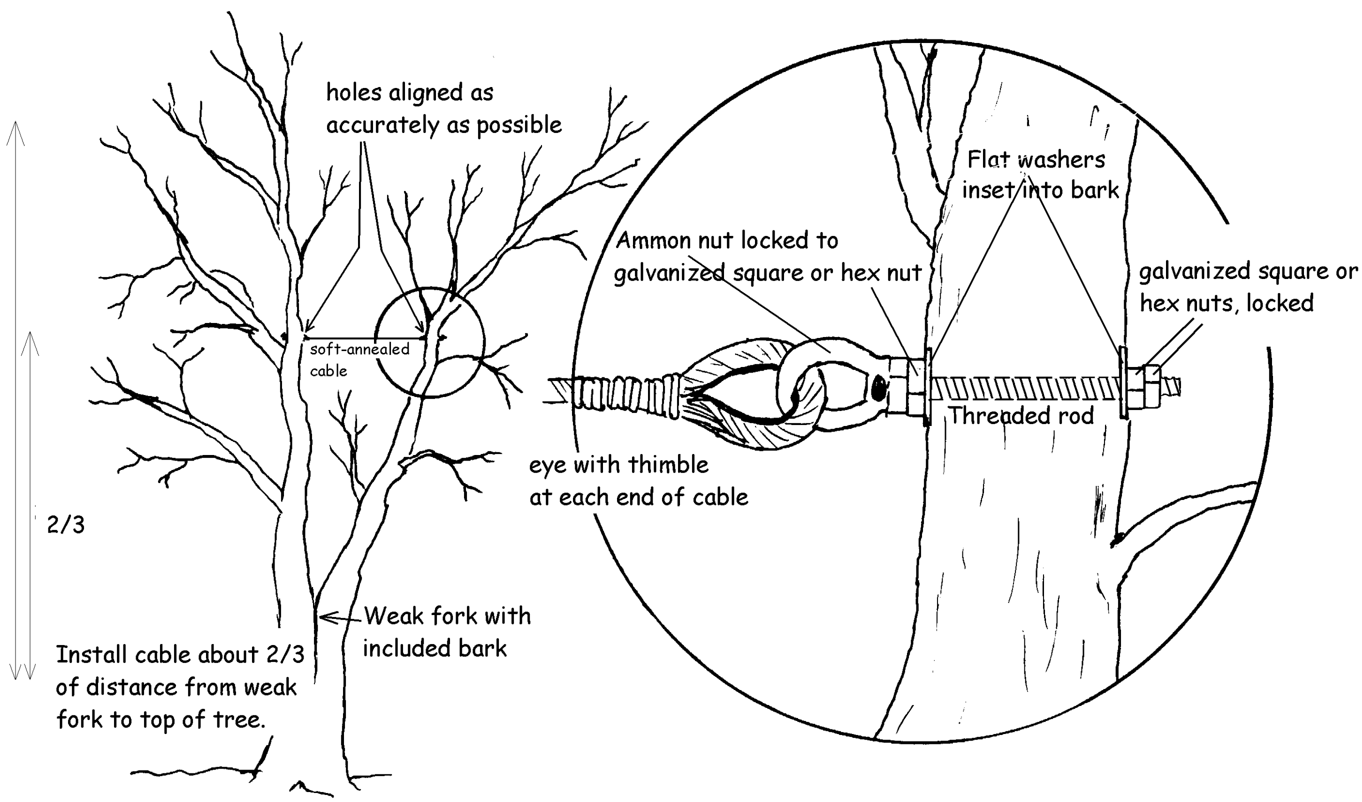
REINFORCING DEFECTIVE TREES WITH CABLES

The decision to cable a tree should never be taken lightly. Cabling is not a permanent "fix" -- it should never be a substitute for good tree management. At best, cabling buys time to get replacement trees started. At worst, improperly installed or deteriorated cable systems can create a false sense of security that can be lead to disaster. **DON'T ATTEMPT TO CABLE "HOPELESS CASES" -- TREES SO SEVERELY DAMAGED THAT THEY SHOULD BE REMOVED.**

Cabling should be done only if thorough inspection indicates that it can be done safely; and it should always be part of a regular program of inspection and care.

Cabling requires experience, a good eye for materials, and an understanding of how trees grow and how they deal with injury and decay. Before deciding to cable a tree, understand forks and "included bark."



Installation of Cable to Reinforce a Weak Fork

Here are the general steps in installing a cable to reinforce a weak fork:

1. Do all needed pruning first.

2. Drill each pair of holes exactly aligned with each other to prevent the fasteners from wallowing, low enough in the tree to involve important, well-attached branches with reliable wood, but high enough for good mechanical advantage. Usually cables should be installed about 2/3 of the distance from the weak fork to the top of the tree, but this is a judgment call that depends on the size and shape of the tree.

3. There will be some decay associated with each drill hole, and to some extent this decay will spread vertically within the tree. DON'T PUT RODS OR CABLE FASTENERS IN VERTICAL ALIGNMENT. The columns of decay are likely to join, resulting in large weak areas where cracks and breakage can occur.

4. Instead of lag screws use threaded rod all the way through the branch or leader. At each end of each hole, use flat washers (round, not pointed) seated flat on bare wood; set square or hex nuts to hold the rod snugly in place, and attach the cable to "Ammon nuts" (commonly used on power pole installations). See the drawing below.

5. Don't paint the hardware or the wounds.

6. Install cables sungly, but not tight enough to prevent the cabled branches from moving somewhat. Cables installed when leaves are absent should be moderately tight, never slack, to prevent the added load of leaves from placing additional stress on the fork.

7. Inspect all cables annually. Remember that bad forks always get worse, not better; and they never "heal." The long-term power of a cable to strengthen a tree comes from the tree's closure of sound wood over the hardware. If decay is advancing faster than the wound is closing, consider removing the cabled parts or the entire tree. When the time comes to remove the tree, don't take chances -- DO IT!

8. Take photographs of the installation, and notes on how and when the work was done.

BOLTING SPLIT BRANCHES

Bolting cracks together doesn't work: the crack will extend at both ends as the branch flexes. Prune out cracked branches.

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Some Practical Lessons in Tree Management

1. Roots needs include:

- **Growing room.** Before planting a tree, assess the area available for root growth; and before building near existing trees, consider how this will affect future root spread.
- **Air, for respiration.** This means choosing planting sites where the soil is not water-saturated; loosening the soil before planting; and avoiding compacting the soil around trees.
- **Water --** enough, but not too much -- to dissolve nutrients and transport them (along with sugars, hormones, etc.), and to cool the tree.
- **Minerals -** nitrogen, phosphorus, and potassium; calcium, iron, boron & other micronutrients; a medium (clay, organic matter) from which they can be extracted from the soil; proper pH (balance of acidity/alkalinity). A SOIL TEST is the only way to determine whether a need for soil amendment, to compensate for needs that the soil can not meet.

2. Problems for roots, and some solutions, include:

- Exposure -- usually caused by soil erosion, or by a high water table or hardpan. Fill with loose, loamy soil; add mulch & exclude traffic. A few shrubs nearby are OK, but don't "garden" regularly in the root zone.
- Compacted soil and oxygen exclusion. Exclude traffic, and don't smother or flood. Mulch and injected air or water may help.
- Girdling roots (wrapped around other roots, constricting them to some extent). The best solution is to use young trees with properly-formed root systems, and plant them properly. Cutting through a girdling root on a mature tree may cause more problems than it cures, and it may not address the worse problems that are out of sight.
- Direct injury, such as:
    - grade change (both cuts & fill)
    - chemicals
    - trenching soil compaction

- lawnmowers, string trimmers, rototillers
- fire flooding
- competition from grasses & weeds

3. Damage control:

When roots must be cut, it is important to minimize the injury to the tree. Cutting them off cleanly maximizes the tree's ability to control decay and generate new roots. The cut should be as far as possible from the base of the tree. Wound dressings won't help the tree.

4. Mulch...

is a substitute for the layer of natural leaf-litter on the forest floor, and it serves many of the same functions:

> * Moisture management: It is easy for rain or irrigation to soak downward through a layer of mulch, but difficult for it to evaporate away, so mulch can be extremely important in moisture conservation. Mulch can also play an important role in slowing down water movement where paving and roofing has increased run-off volumes.
>
> * Most plants require sunlight for early growth, so a layer of mulch can help suppress weed growth; and since mulch helps keep soils moist and loose, weeds and turf runners that do grow into mulched beds are usually easy to pull. Some types of herbicide may be used in conjunction with mulch, but these must be managed carefully to avoid unintended damage to desirable plants and soil organisms.
>
> * Since mulch helps keep weeds and turf are kept out of planting beds, trees and shrubs are less likely to be wounded by mowers and string-trimmers.
>
> * Mulch gradually breaks down and becomes part of the humus near the surface of the soil. Humus holds moisture, holds fertilizer elements where plants can pick them off, and also provides a favorable environment for earthworms, mycorrhizal fungi, and the other soil organisms that benefit plants.
>
> * Less utilitarian, but no less valuable, mulch can be a major contributor to the appearance of a landscape, connecting plants with each other within a bed, and connecting beds to each other by a common surface treatment.

Still, it is important not to overdo mulch. It should be a natural material -- NO PLASTIC! -- applied loosely to a depth of 2-4 inches. Remember that a tree or shrub can be killed by a heap of mulch around its base: insects and decay organisms thrive in such a dark, moist, protected environment.

5. Understand the rules of 'CODIT' (Compartmentalization of Decay In Trees).

Let them guide your pruning and other tree work:

- When a tree is injured, all wood present at the time of wounding may be decayed, depending on how well the tree's defenses work.
- Wood formed after the original injury will not decay, unless the tree's defenses are broken down as a result of further injury or other stress.
- Don't confuse tree wounds with animal wounds. We actually "heal", replacing the injured tissues. Trees simply wall off decay, controlling its spread long enough so that new wood added to the outside of the tree can take over the functions of the wood rotted away.
- All trees work basically alike -- broadleaf and narrowleaf, and trees that form heartwood as well as those that don't.
- The best way to deal with tree problems is by avoiding them. Learn to work with the tree's natural defenses.

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