MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #611

Tree Growth and Decay

Outline:

As forest scientists observed how trees respond to wounds, pruning techniques changed and pruning objectives were clarified.

This CMG GardenNotes provides background information on how trees grow and decay and therefore the implications of pruning cuts and structural training. For additional information, see CMG GardenNotes #610-617 on *The Science of Pruning*.

Note: In this publication, the term "trunk" refers to a trunk or parent branch, and "side branch" refers to a side branch arising from the trunk (parent branch). The same relationship would exist between a side branch and a secondary side branch.

Developing a Strong Branch Union

In Colorado (and other snowy climates) the most common type of significant storm damage in landscape trees results from failures at the ***branch union*** (crotch), primarily with ***codominant trunks*** (adjacent trunks of similar size). Primary objectives in training young trees are to develop strong branch unions and eliminate structurally weak codominant trunks. [**Figure 1**]

The structural strength of a branch union is based on the development of a ***branch collar***. The branch collar is where the annual growth rings of the trunk overlap the annual growth rings of the side branch, like shuffling a deck of cards. In lumber, the branch collar is called the knot. [**Figures 2** and **3**]

Figure 1. Codominant trunks account for the majority of storm damage in Colorado landscapes.

Figure 2. Structural strength of the branch union (crotch) is based on development of a branch collar.

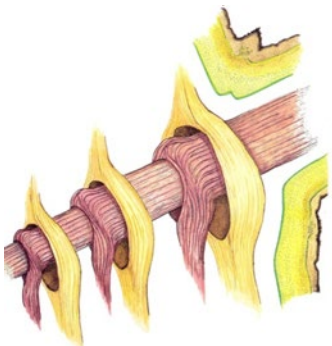

Figure 3. The branch collar is where annual growth rings of the trunk overlap the annual growth rings of the side branch, like shuffling a deck of cards. This creates a very solid section of wood, known as the "knot" in lumber. Line drawing: U.S.D.A.

As the branch collar develops, side branch tissues connect into the trunk in a wedge shape, making a structurally strong unit. **For the branch collar to develop, the side branch must be less than half the diameter of the adjacent trunk. Less than one-third is preferred.**

If the side branch is too large in diameter, prune back the side branch by one-third to two-thirds to slow growth or remove the branch entirely. Over a period of years, a branch collar will develop. [**Figure 4**]

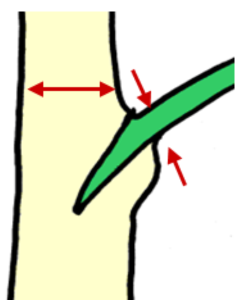

Figure 4. As the branch collar develops, side branch tissues connect into the trunk in a wedge shape making a structurally strong unit. For the branch collar to develop, the diameter of the side branch must be less than half the diameter of the adjacent trunk. Less than one-third is preferred.

The size relationship between the trunk and side branch is called ***aspect ratio***. A branch union with high aspect ratio, like one-to-one (two trunks of the same diameter), is highly prone to failure in wind and snow loading. A branch union with a low aspect ratio, like one-to-three (side branch is one-third the diameter of the adjacent trunk), would not likely fail due to the development of the branch collar.

A branch collar will not develop on codominant trunks (adjoining trunks of similar size), making this branch union structurally weak. [**Figure 5**]

Multiple branches arising at the same location also compromise the branch collar's structural strength. Some tree species, such as elm, maple, and crabapple, naturally develop multiple branches at one location. This predisposes the tree to storm damage if the situation is not corrected by structural training when the tree is young. [**Figure 5**] Choosing structurally correct trees or fixing when young is ideal. Refer to CMG GardenNotes #632, *Tree Selection: Right Plant, Right Place*.

Figure 5.
Left: A branch collar does not develop on co-dominant trunks, making the branch union structurally weak. Tight angled V-shaped branch unions are more prone to decay and storm damage.
Right: Multiple branches arising at the same location are also structurally weak as the branch collars cannot knit together into a strong union.

Spread of Decay. Due to the constriction of xylem cells where the side branch annual growth rings are overlapped by the trunk annual growth rings, the development of a branch collar significantly reduces the potential spread of decay. In addition, branch unions with a right angle of attachment are more effective in preventing the spread of decay.

To reduce the potential for decay, prune to develop branch collars. The side branch must be less than half the diameter of the adjacent trunk. Also select branch unions with a wide angle of attachment. In pruning, remove codominant trunks and narrow branch unions while young (smaller than two inches). If the branch is larger, a heading cut can be made one year, and removal can happen the following year to reduce the percentage of removal as needed. [**Figure 6**]

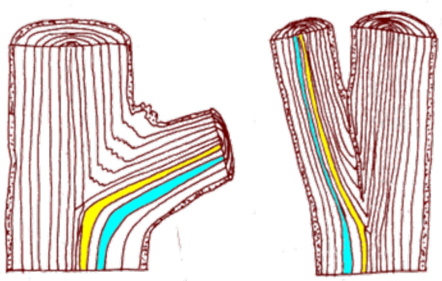

Figure 6. Branch unions that form a right angle are more resistant to decay. A branch union with codominant trunks and a narrow angle of attachment is highly prone to the spread of decay.

How Trees Grow

Xylem Tissues. Each year a tree puts a new outer ring of wood (xylem tissue) under the bark resulting in the increased diameter of a trunk or branch. The number of rings indicates the limb's age, and the width of individual rings indicates that year's growing conditions. [**Figures 7** and **8**]

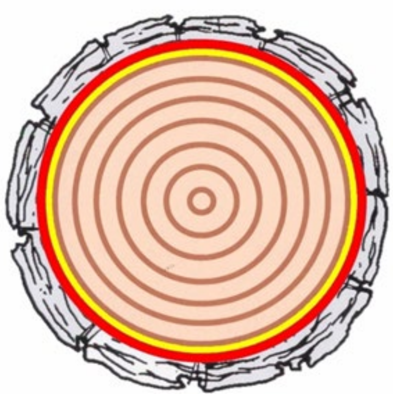

Figure 7. Cross section of a tree.
Bark is the outer protective covering.
Phloem (red in drawing) is the inner bark tissue. Photosynthates (sugars and carbohydrates produced in the leaves by photosynthesis) move throughout the tree in the phloem tissues, including down to feed the roots.
Cambial Zone (yellow in drawing) is the layer of active cell division between bark and xylem.
Xylem (brown layers in drawing) shows each year that the cambium adds a new ring of xylem tissue just under the cambium layer, resulting in a growth in limb diameter. Xylem tissues are the technical name for the "wood."

Figure 8. The “wood” of a tree is the xylem tissue. Xylem tissues that grew in the spring and early summer enlarge and are the tubes in which water with minerals flows from the roots to the leaves. In a cross-section of the log, these are light colored rings. Xylem tissues that grew mid-summer, at the end of the growth cycle, are higher in fiber content, creating a wall to the outside. In a cross-section of a log, these are the darker colored rings.

Younger ***annual growth rings*** (annual rings of xylem tissue) with their living cells active in water transport and storage of photosynthates are called ***sapwood***. Depending on the species and vigor, sapwood comprises approximately the five youngest (outer) annual growth rings. ***Heartwood***, the older annual xylem rings no longer active in water transport, is very susceptible to decay organisms. Due to chemical changes in these non-living cells, heartwood is often darker in color. [**Figure 9**]

Ray cells grow through the annual growth rings, functioning like staples or nails to hold the growth rings together. Ray cells also function as the path to move photosynthates in and out of storage in the xylem tissues. On some species, ray cells are not readily visible. On other species, ray cells create interesting patterns in the wood. [**Figure 10**]

Figure 9. On this Douglas-fir log, the sapwood is the light colored annual growth rings active in water transport and storage of photosynthates. The darker colored heartwood in the center has no resistance to decay.

Figure 10. The cracks on this willow stump show ray cells.

The wood is a series of boxes or “compartments” framed by the ***annual growth rings*** and ***ray cells***. Each compartment is filled with xylem tubes in which water with minerals moves from the roots to the leaves. [**Figures 11** and **12**]

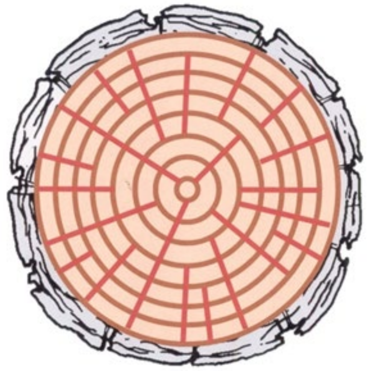

Figure 11. The xylem tissue (wood) is a series of compartments or boxes created by the annual growth rings and ray cells.

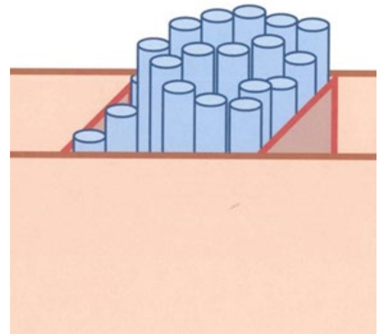

Figure 12. Each compartment or box framed by the annual growth rings and ray cells is filled with xylem tubes. Water moves in the xylem tubes up from the roots.

CODIT: Compartmentalization of Decay in Trees (How Trees Decay)

Unlike animals and people, trees do not replace damaged tissues. Rather, cells in the damaged area undergo a chemical change in a method to seal off or "compartmentalize" the damaged area from the spread of decay. This area of chemical change is called the ***reaction zone***. In most species, a reaction zone appears as darker colored wood.

The spread of decay is related to this compartmentalization of the xylem tubes in a box-like structure created by the annual growth rings and ray cells. In this box-like structure, the four walls differ in their resistance to the spread of decay. [**Figure 11**]

Wall 1 – Resistance to the spread of decay is very weak up and down inside the xylem tubes. Otherwise, the tubes would plug, stopping the flow of water, and kill the plant. From the point of injury, decay moves upwards to a small degree, but readily moves downward. The downward movement may be twenty or more feet and can include the root system.

Wall 2 – The walls into the older xylem tissues (toward the center of the tree) are also rather weak, allowing decay to readily move into <u>older</u> annual growth rings.

Wall 3 – The walls created by the ray cells (being high in photosynthates) are somewhat resistant to decay organisms. This may help suppress the spread of decay <u>around</u> the tree.

Wall 4 – New annual growth rings that grow in years <u>after</u> the injury are highly resistant to the spread of decay.

Resistance to the spread of decay by the new annual growth ring and ray cells creates a pipe-like structure, with a decayed center. This concept of how decay spreads in a tree (as controlled by the annual growth rings and ray cells) is called CODIT, for Compartmentalization of Decay in Trees. [**Figures 13** and **14**]

The spread of decay in trees is suppressed by the four walls created by compartmentalization of the annual growth rings and ray cells.

Figure 13. The heartwood has completely decayed away.

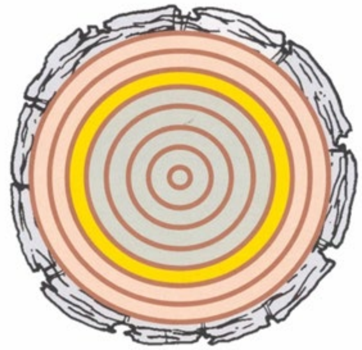

Figure 14. Decay in a tree creates a pipe-like structure with a hollow center. The light colored wood represents new annual growth rings that grew after the year of injury. The darker colored ring is a reaction zone created in the sapwood. The heartwood has completely decayed away.

In the drawing, an injury occurred three years ago when the yellow-colored annual growth ring was the youngest. That year and everything older (grayed annual growth rings) are subject to a reaction zone and decay. The two new annual growth rings (brown color) that grew in years after the injury are highly resistant to decay.

Evaluating Decay

Evaluation of decay and if a tree is hazardous must be done by a **TRAQ (Tree Risk Assessment Qualification) certified arborist**. A commercial arborist or arborists with the Colorado State Forest Service with this TRAQ certification should be the only ones discussing risk! When evaluating risk of the tree, arborists look at tree history, tree vigor, species, crown density, potential targets, consequences of failure, and if there are mitigation steps that can be taken. The following is for knowledge only.

Percent Decay or Hollowness

A trunk or branch with some internal decay is not necessarily at risk for failure. Structural strength is based on the minimum thickness of the healthy wood (xylem tissues) and the structural strength of wood (tree species).

In evaluating potential hazards, arborists (tree care professionals) calculate by dividing the thickness of the healthy wood at the thinnest point (not including bark, reaction wood, or decaying tissue) by the radius of the trunk/branch (not including bark). This healthy wood is sometimes called holding wood and mainly consists of sapwood. A tree with a 33% healthy wood is labelled high risk potential. A tree with a 20% healthy wood is labeled as critical risk potential.

The cottonwood branch above [**Figure 13**] has 25% healthy wood, putting it at “high risk” for potential failure. This *calculation* is valid only when the decay column is centered in the trunk/branch. Other factors are used to evaluate the tree’s health and risk.

On older mature trees, percent holding wood or sapwood (healthy wood) formula standards may overstate the thickness of healthy wood needed to be structurally acceptable. Additional research is needed to better clarify this standard for older/mature trees.

Measuring Decay

So, how thick is the healthy wood in a trunk or branch? Researchers are working to address this big question. Arborists that have specific training in Tree Risk Assessment Qualification (TRAQ) use a Basic Tree Risk Assessment form and certain tools to assess trees. These trained arborists are the ones that should address any question of risk. The following are procedures with limited potential to evaluate the internal structure of trees.

Visual Indicators for Decay

Large pruning wounds suggest the potential for internal decay. Often decay may be observed within the pruning wound. [**Figure 15**]

Figure 15. The black material in the pruning cut is decay fungus. Notice the cracking; it also raises flags of structural integrity.

Cankers suggest the potential for internal decay. If the canker extends down into the soil, decay organisms will always be active.

Valleys, ridges, cracks, and splits along the trunk/branch suggest the potential for decay. Wildlife living inside the tree is a sign of decay.

Abnormal swellings or shapes could be a sign that the tree is growing around a decayed area.

Coring Devices

Note: All coring devices may spread decay since the core is taken through healthy and decayed layers of the wood, so it is only used when evaluating risk potential. Coring devices only indicate the decay potential at the point of drilling and do not represent the entire trunk or branch.

The tools used to measure risk based on decay and health of trees can include an increment borer tool, a drill with a small bit, a Resistograph, digital microprobe, sonic tomograph, electrical impedance tomograph, sonic hammer, tree motion sensors, or chlorophyll fluorimeter.

Listening and Radar Devices
Various methods are used today to predict the risk potential of trees. These methods may include using instruments to measure sound to determine internal decay, visualizing sound waves, measuring the electric field of the wood, or using radar. Some of these methods are financially prohibitive tools for arborists.

Breaks in the Pipe-Like Structure

When a wound or pruning cut breaks the pipe-like structure of a trunk/branch, the tree is especially weak at this location creating a higher potential for tree failure. [**Figure 16**]

Figure 16. Structural strength is significantly compromised when the pipe-like structure of a trunk has a break in the cylinder wall.

Lack of Trunk/Branch Taper

Branch failure (often breaking a few feet to one-third of the branch length out from the branch union) is a common type of storm damage. Branch failures often cause minimal damage to the tree. However, failure of a major branch may create holes in the tree canopy, introduce decay and cracking, and make the tree look unacceptable. ***Trunk failure*** refers to breaking of the lower trunk, above ground level (not at a branch union).

Branch and trunk failures are associated with lack of trunk/branch taper. That is, the trunk/branch does not thicken adequately moving down the trunk/branch. This can be caused by pruning up the trunk too fast and by removing small branches and twigs on the lower trunk or lower interior canopy of the tree.

Very upright branches without a lot of side branches also typically fail to develop adequate taper. For structural integrity, shorten these branches with appropriate reduction or heading cuts.

Authors: David Whiting, CSU Extension, retired, and Carol O’Meara, CSU Extension, retired. Artwork by David Whiting. Used with permission. Reviewed May 2018. Reviewed May 2023 by Susan Carter, CSU Extension.