The Seven Defect Categories

 Decayed wood

 Cracks

 Root problems

 Weak branch unions

 Cankers

 Poor tree architecture

 Dead trees, tops, or branches

Decayed Wood

Decayed wood = wood that has rotted or is missing.

Advanced decay and cavities always result in less structural strength and reduced stability. Indicators of advanced decay are rotten wood, fungal fruiting bodies, cavities, holes, open cracks or bulges in the wood. See Figure 3.8.

Figure 3.8. *Advanced decay reduces the structural integrity and strength of wood.*

Decayed wood is the result of the long-term interaction between a tree and decay-causing fungi. The decay process takes wood through several stages of degradation; from stain to decay to cavity. The presence of advanced decay or a cavity results in less structural strength and can reduce the stability of the tree. Decay can occur in branches, stems and/or roots. Root decay will be discussed further in the section on Root Problems. Some tree species are resistant to decay; others decay quickly and more extensively (Table 3.1).

Wood decay is an internal process with just a few external indications. Indicators of advanced decay are the fungal fruiting bodies—mushrooms, conks and brackets (see Figure 3.9) and rotten or punky wood, cavities, hollows, holes, inrolled cracks, and bulges in the wood (see Figures 3.10 through 3.14).

Figure 3.9. *Fungal fruiting bodies indicate advanced decay.*

Figure 3.10 - 3.11. *Rotten or punky wood or cavities indicate advanced decay.*

Figure 3.12. *Hole in stem revealing internal column of advanced decay.*

Figure 3.13. *Decay is always associated with inrolled cracks.*

Figure 3.14. *Bulges often indicate decay.*

Wounds start the decay process. See Figures 3.15 through 3.19. Wounds can be caused by storms, vehicles, excavation, improper pruning, vandalism, and by animals and insects.

Figure 3.15. *Wounds start the decay process.*

Figure 3.16. *Old pruning wound with decay.*

Figure 3.17. *Old wound with wood discoloration.*

Figure 3.18. *Lawn mower damage associated with decay.*

Figure 3.19. *Human caused canker with internal decay.*

Wounds expose cambium and wood to air or to soil, if wound is underground (Text Box 2 and Figure 3.20).

BOX 2

What is the cambium?

The cambium is a layer between the bark and wood that sheaths the tree from root tip to branch tip. See Figure 3.20. This is the layer that creates wood and inner bark each year.

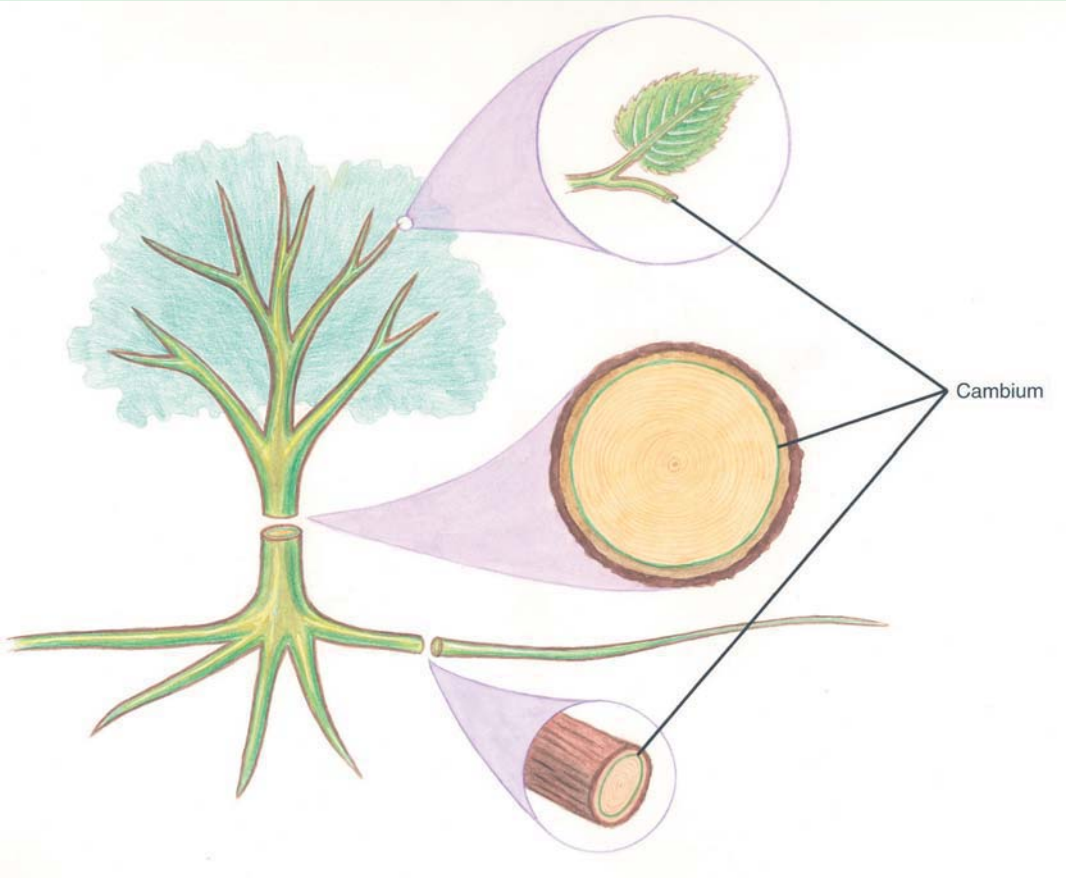

Figure 3.20. *The cambium is a thin layer of cells that sheath the tree.*

Decay-causing fungi infect the wounds and can, in time, cause advanced decay. Trees interact with decay-causing fungi and limit the spread of decay within the tree. See Box 3: Compartmentalization of decay and other defects.

BOX 3

Compartmentalization of decay and other defects.

Compartmentalization explains how wounded trees set boundaries which limit the spread of decay (Shigo 1989). The process of compartmentalization preserves a tree's mechanical strength so that a decaying tree does not fail. Compartmentalization also occurs when wounded trees are infected with canker-causing fungi, mining or boring insects, and other agents.

How does a tree limit decay and other defects?

1. Wounding starts the process. A wound exposes cambium and wood to air (or soil if below ground). See Figure 3.20.

2. The living cells just behind the wound react immediately. If wounding occurs during the dormant season, the cambium reacts very early the next spring.

3. The tree creates a new wall, called the barrier zone, to prevent the invading micro-organisms from spreading out into the new and future wood. It is created by the cambium. It is a continuous barrier, both chemical and physical, which is built right into the current annual ring. The barrier zone persists for the life of the tree in the annual ring in which it was created. See Figure 3.21.

4. A succession of bacteria and fungi are involved in the infection of the wound and they grow into the wood.

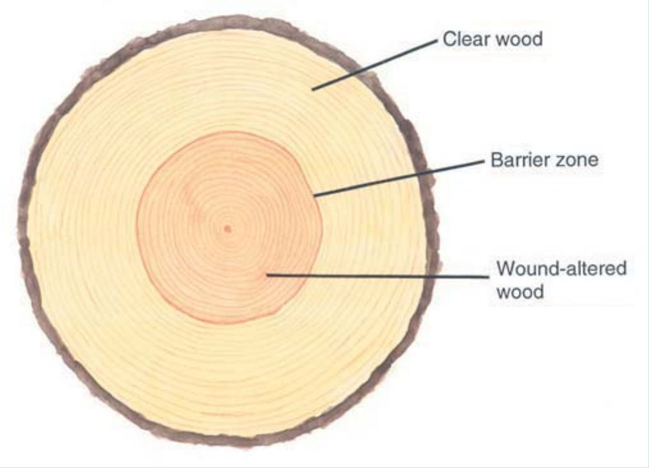

Figure 3.21. *The barrier zone separates wood formed before wounding from wood formed after wounding.*

5. The compartmented tree uses its existing structure to limit the extent and severity of injured and infected tissues.

6. Discolored and sometimes decayed wood results, but it is limited by the barrier zone and other walls. Inside the barrier zone, the tree attmpts to halt or contain the invading fungus. The column of wood is decay-altered, ranging from discolored wood to decayed wood to a cavity. The actual extent and severity of decay within the column is up to the interaction between the tree, the fungi and how long they've been interacting.

7. New wood, laid down in the years after wounding, will be free from decay.

BOX 3 - Compatmentalization *- continued*

The barrier zone separates wood formed before wounding from wood that will form after wounding. The essence of compartmentalization is that trees set the boundaries; trees limit the decay column so that new wood will be free from decay. See Figure 3.22.

Decay will be contained or limited by the barrier zone. If you know the size of the tree when it was wounded, then you know the potential extent of internal decay; all the wood present at the time of wounding.

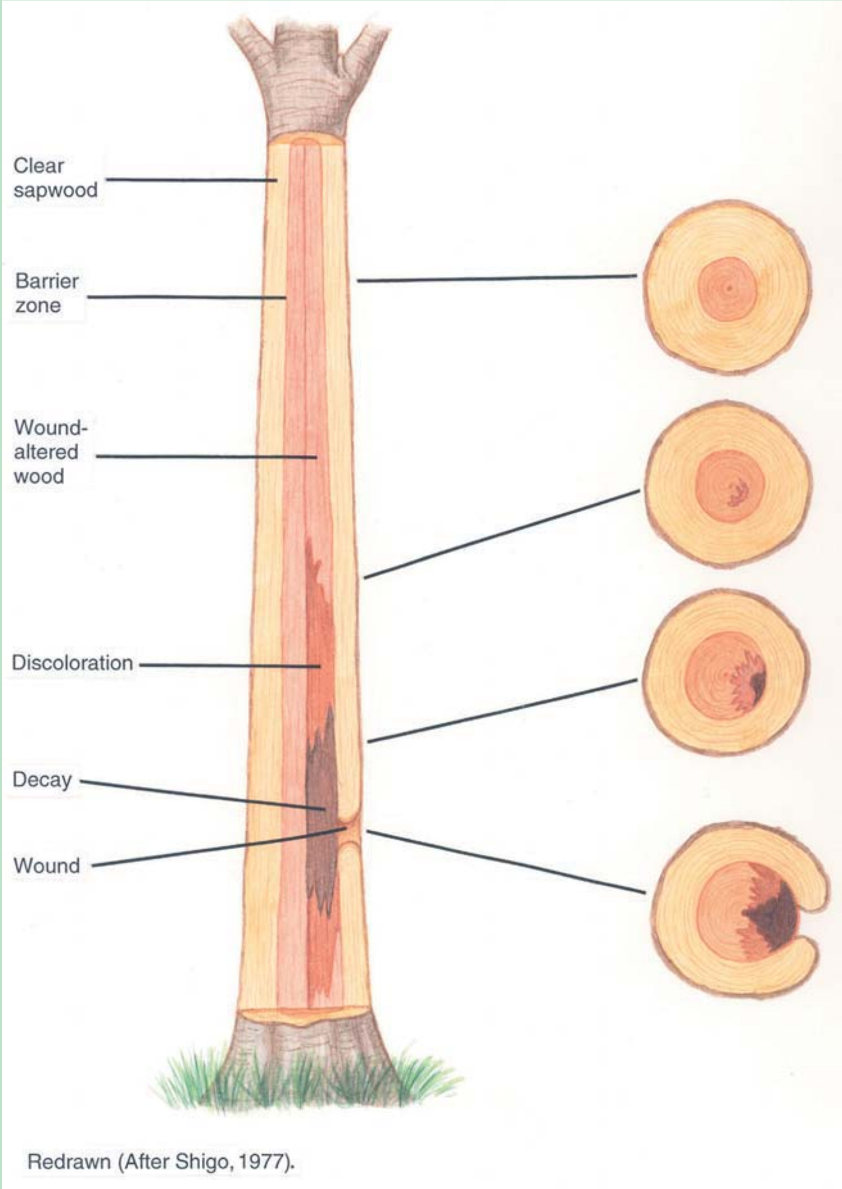

Figure 3.22. *Trees limit the extent of decay so that wood formed after wounding will be free from decay.*

Commonly, the extent of decay is limited to the wood present at the time of wounding. See Figure 23. All wood inside this column could potentially be decayed. In reality, decay is often limited to the location of the wound and only extends a few feet above and below the wound. Wood produced after the year of wounding will not be decayed. However, if a tree wounded a number of times over a period of years, multiple decay columns are created and they often merge. See Figure 24. Only in advanced stages of decay do the fungi produce fruiting bodies.

Figure 3.23. *Decay is usually limited to the wood column present at the time of wounding.*

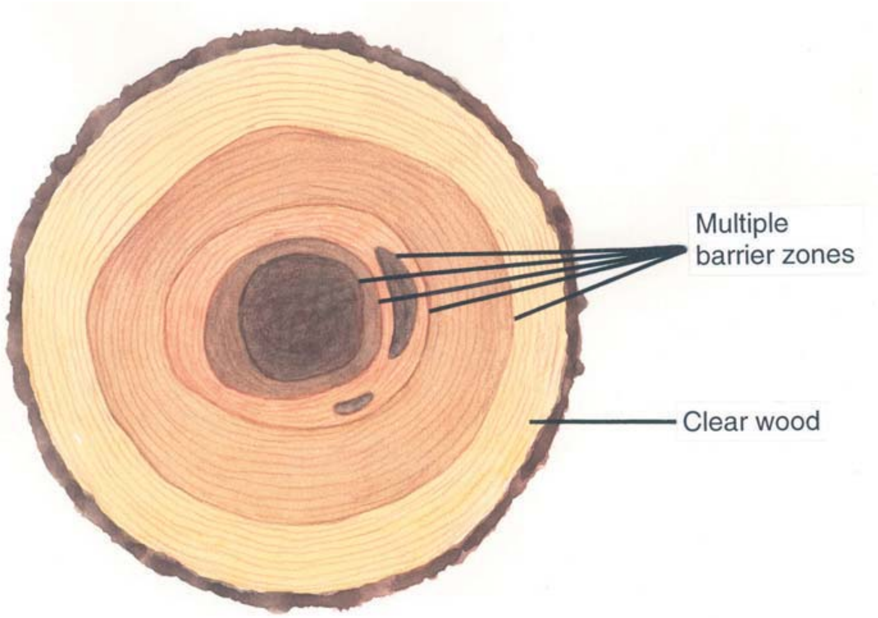

Figure 3.24. *Additional columns of discolored and decayed wood form as the tree suffers additional wounds.*

The undecayed layer surrounding the compartmentalized decay column is called the *shell*. See Figure 3.25. If the shell thickness is thin relative to the size of the tree, the shell is likely to fracture causing the tree to fail. See Figures 3.26. Studies have shown that, if a tree has less than one inch of sound wood in its shell for every six inches of stem diameter, then the tree is very likely to fail (Mattheck 1998). See Figure 3.27 and Table 3.2. Measure stem (or branch) diameter where decay is present. If possible, determine where the shell is the thinnest and take your measurement there because the tree is most likely to fail where the shell is the thinnest.

Figure 3.25. *The outermost layer of undecayed wood is called the "shell."*

Figure. 3.26. *If shell thickness is thin relative to stem diameter, then that area is likely to fail.*

Table 3.2. Shell thickness requirements for closed shell

Closed shells need at least 1 inch of sound shell for each 6 inches of stem diameter	
Stem diameter (inches)	**Shell thickness** (inches)
6	1
12	2
18	3
24	4
48	8

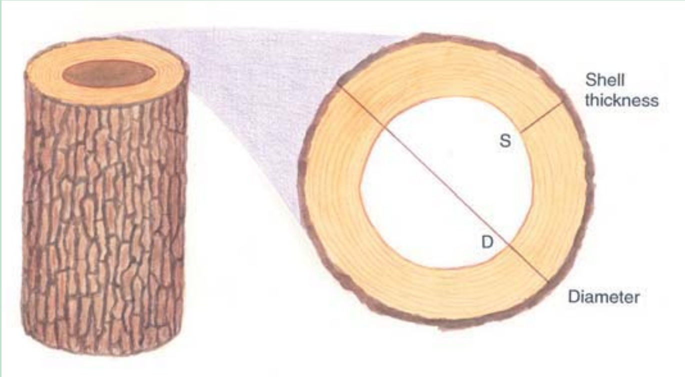

Figure 3.27. *There needs to be at least 1 inch of sound wood in the shell for each 6 inches of stem diameter. Measure in the same location on the tree.*

All trees do not have a sound shell of wood: some have openings in them. See Figures 3.28 and 3.29. An opening can be a hole, and old wound, a fire scar, a cankered area or a wide crack. A tree can have internal decay and an opening and still be structurally sound provided that the shell is thick enough and the openingis not too wide. If an opening in the stem is up to 30 percent of the stem circumference, then the shell needs to have at least 2 inches of sound wood for every six inches of stem diameter (Fraedrich and Smiley 1999). See Figure 3.30 and Table 3.3. Trees with larger openings and/ or thinner shells are likely to fail.

Figure 3.28-3.29. *All trees do not have a solid shell of sound wood. Some trees have cracks or openings in them.*

Table 3.3. Shell thickness requirements for open shell

Open shells need at least 2 inches of sound shell for each 6 inches of stem diameter when the opening is less than 30% of the stem circumference.	
Stem diameter (inches)	**Shell thickness** (inches)
6	2
12	4
18	6
24	8
48	16

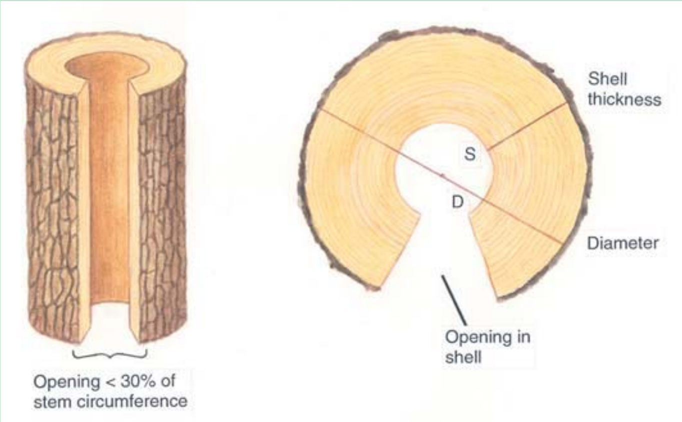

Figure 3.30. *There needs to be at least 2 inches of sound wood in the shell for each 6 inches of diameter when openings occur in the stem. The openings must be smaller than 30% of the stem circumference.*

Shell thickness can be affected by the presence of bulges or swellings on the stem. See Figure 3.31. Bulges in the stem are formed as a reaction to the presence of decay. Bulges and swellings help strengthen the tree and can decrease the likelihood of failure due to the presence of decay. See Box 4: Adaptive growth and decay.

BOX 4

Adaptive growth and decay

Thicker annual rings are created where the risk of breakage is greatest. Where decay fungi are active, the wood's structure is weakened. Each year, as the tree creates a new annual ring, a slightly thicker layer of wood is created in the vicinity of the decayed wood. See Figures 3.31 and 3.32. Over time, the tree creates bulges, swellings, etc. to add wood more quickly to that area, decreasing the likelihood of failure and fracture due to the presence of decay.

Figure 3.31. *Trees create thicker annual rings in the vicinity of decaying wood. Over time, bulges or swellings develop.*

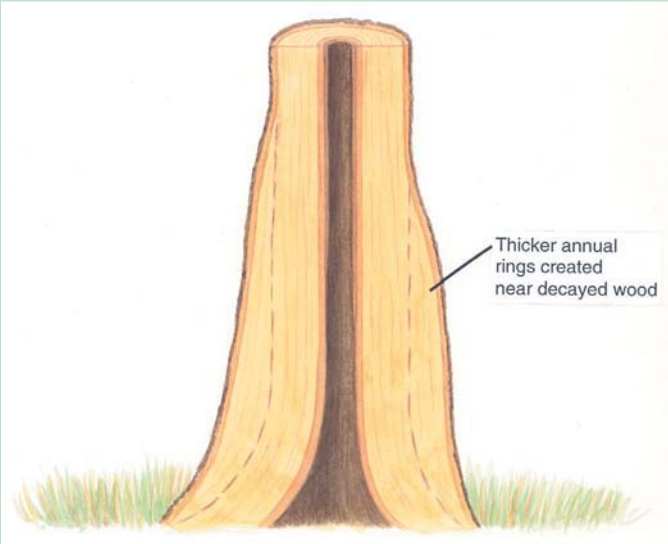

Figure 3.32. *Bulges and swellings indicate advanced decay.*

One group of decay-causing fungi, the brown rotters, do not induce the tree to create extra wood near the location of the decay. Bulges and swellings are not produced. Examples of these fungi are: The velvet-top fungus, *Phaeolus schweintizii*, on conifers, the chicken mushroom, *Laetiporus sulfureus*, and the red-belt fungus, *Fomitopsis pinicola*, on hardwoods and conifers. See Figure 3.33.

Figure 3.33. *Decay caused by a brown rot fungus.*

If a tree is repeatedly wounded by the presence of inrolled cracks, included bark, canker-rot fungi, or equipment (mowers, plows, and weed whips), decay occurs in every annual ring of wood. See Figures 3.34 through 3.36 and Box 5: Canker-rot fungi. These trees should be carefully inspected because their decay is never fully compartmentalized and a sound shell of wood does not form. The tree is likely to fail at or near the location of the crack or wound because a large and ever-expanding column of decay is present there. Again, evaluate shell thickness and opening width to help determine the tree's potential for failure.

Figure 3.34. *Canker rot fungi cause the decay column to constantly enlarge.*

Figure 3.35. *An inrolled crack creates an ever-expanding column of decay.*

Figure 3.36. *Diagram of decay in an inrolled crack.*

BOX 5

Canker-rot fungi

A canker-rot fungus rewounds the tree each year and infects each new annual ring allowing decay to spread. A solid shell of wood cannot be formed at the location of a canker-rot infection. See Figure 3.37.

Some examples of these fungi and their hosts are: *Phellinus pin*i on conifers; *P. everhartii* and *P. robustus* on oaks; *P. spiculosus* on oaks, hickories, and honey locusts; *P. tremulae* on aspens; *Inonotus obliquus* on birches; *I. glomeratus* on maples; and *I. hispidus* and *I. anderson*ii on many hardwood species. See Figure 3.38.

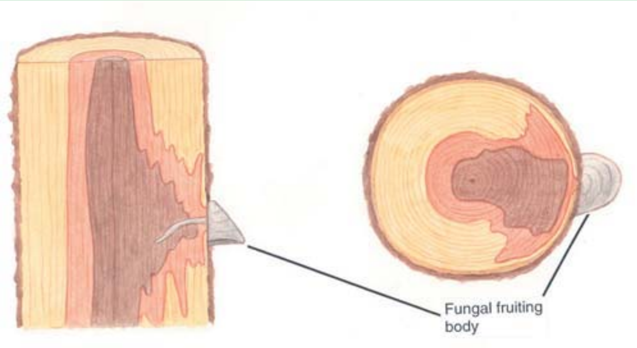

Figure 3.37. *Decay spreads to all new wood layers as they form each year. Decay is not fully compartmentalized.*

Figure 3.38. *Fomes connatus on maple.*

In some situations, wood is missing from one side of the tree due to a combination of causes such as decay, canker, or mechanical wounding. In this case, a tree needs at least 60 percent of its circumference to be sound wood. See Figure 3.39.

Figure 3.39. *A tree needs at least 60 percent of its circumference to be sound.*

All the situations described for stems also apply to branches and root collars.

Visual assessment of the extent of decay can often be a reliable means of predicting potential risk. However, invasive techniques may be needed to quantify the thickness of the sound shell of wood in comparison to the size of the tree. Use a probe or another tool to test several areas in order to find the location of the thinnest shell of sound wood. The shell will be thinnest between root flares, where the defect symptom is most pronounced, or just behind the bulge of an inrolled crack. If possible, use a metal rod to probe existing holes and cracks to determine shell thickness. Use an increment borer, drill, or other invasive techniques only when there are no other means to estimate the extent of sound wood. See Figures 3.40 and 3.41.

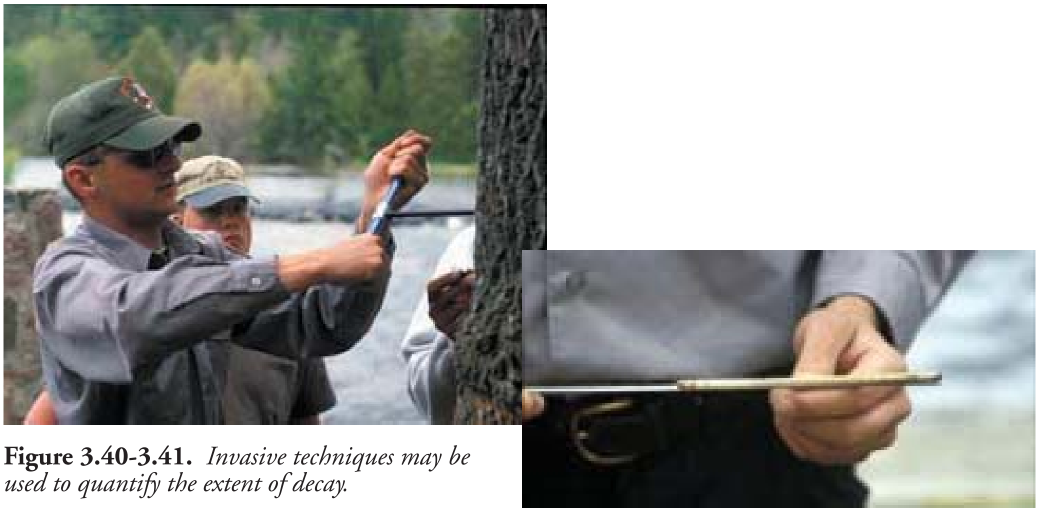

Figure 3.40-3.41. *Invasive techniques may be used to quantify the extent of decay.*

In-depth assessments, using specialized diagnostic tools, may be warranted when additional information about the location and extent of internal decay is critical to assessing the probability of tree failure. See later section in this chapter, Tree risk inspections and the use of specialized diagnostic tools.

Decayed Wood

High risk of failure:

See Figures 3.42 through 3.45.

- Advanced decay affects more than 40 percent of the circumference of any stem, branch, or root collar.

  Note: In order to verify the extent of decay, you may want to use probes, drills, or other diagnostic tools to determine shell thickness.

- Stem has advanced decay and the shell thickness meets the following criteria:

  – Shell thickness is less than 1 inch of sound wood for each 6 inches of stem diameter, or

  – Stem has an opening greater than 30 percent of the stem's circumference, and the shell thickness is less than 2 inches of sound wood for each 6 inches of stem diameter.

- Any large branch with decay.

Moderate risk of failure:

- Indicators of advanced decay are found on 25 to 40 percent of the circumference of any stem, branch or root collar.

  Shell thickness is between 1 and 2 inches of sound wood for each 6 inches of stem diameter, and stem has opening less than 30 percent of the stem's circumference.

Figure 3.43. *High risk of failure: Shell thickness is less than 1 inch of sound wood per each 6 inches of stem diameter.*

Figure 3.44. *High risk of failure: Stem has opening greater than 30% of its circumference and there is less than 2 inches of sound wood for each 6 inches of stem diameter.*

Figure 3.45. *High risk of failure: Large branch with decay.*

Return to Table of Contents | Chapter 3, Next - Section 3