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report on
PLANT
DISEASE

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WOOD ROTS AND DECAYS

Wood rot diseases, caused by a wide variety of wound colonizing fungi, produce decay of the trunk, large branches, and roots of practically all woody plants. Decay usually develops slowly over a period of many years and may not noticeably shorten the life of an affected tree or shrub, although it causes huge annual losses of timber for building and wood products. The annual loss to wood decay is estimated at 20 billion board feet in the United States (or about one-third of the timber cut annually), an amount more than that caused by fire, insects, and various other natural catastrophes combined. This annual loss represents enough lumber to construct a wooden sidewalk a mile wide, with all its underpinnings, all the way from New York City to San Francisco. Fortunately, this loss is decreasing as we learn to better manage our forests and as we continue to harvest trees at progressively younger ages. Discoloration and decay are much more common and serious in over mature trees and poorly managed stands than in young trees or well managed stands.

Figure 1. Ganoderma Root Rot.

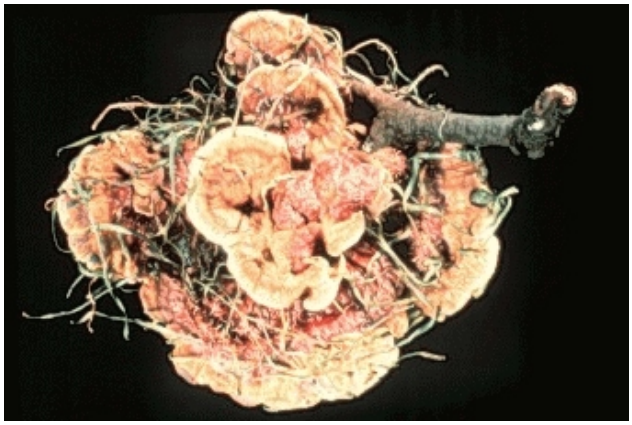

Figure 1a. Ganoderma off Honey Locust (photo Nora Simkus).

In living trees, most of the decay is confined to the older, central wood (heartwood) of roots, trunks, or branches. Once the tree is cut, however, the outer wood or sapwood is also colonized by the wood-decay fungi, as are the wood products made from the tree, if moisture and temperature conditions are favorable for growth of the fungi. When deep wounds or cuts are present, discoloration and decay often spread into the outer wood, and the entire tree, especially if it is a hardwood, loses its economic value.

Symptoms

Trees extensively invaded with a wood-rotting fungus may show a gradual decline in vigor. Twigs and then branches die back with trees becoming structurally weak and more susceptible to ice and wind damage.

For further information contact Nancy R. Pataky, Extension Specialist and Director of the Plant Clinic, Department of Crop Sciences, University of Illinois at Urbana-Champaign.

Most wood-rotting fungi produce fruiting structures or sporophores of the bracket (shelf) or hoof type–called conks (Figures 1, 2, 3, and 4, Plates 1 and 2) – or the mushroom (toadstool) type (Figure 5; Plate 2). Bracket or hoof conks may be corky, leathery, woody, punky, or fleshy in texture. Clusters of mushrooms may form at a trunk base or at wounds. Fruiting structures of decay fungi are unreliable predictors of decay because they commonly do not appear until decay is well advanced.

Figure 2a. Ganoderma root and butt rot of honey locust (Gleditsia triacanthos) caused by Ganoderma applanatum (Il Natural History Survey photo).

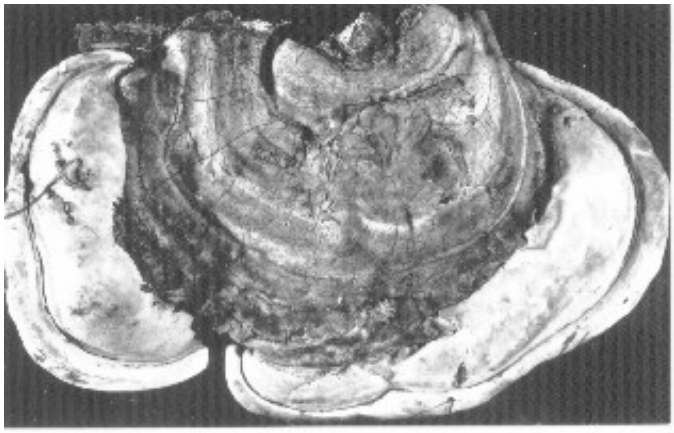

Figure 2b. Perennial conk of Ganoderma applanatum (Fomes) igniarius. The outer white tissue is new; the dark tissue was formed in past years (Purdue University photo).

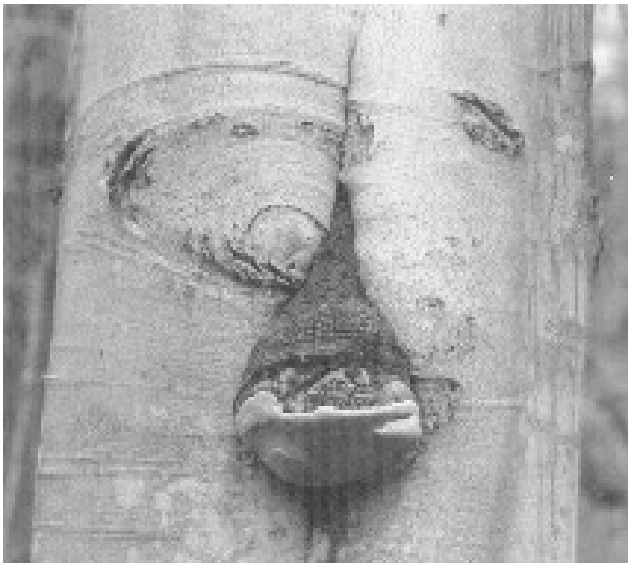

Figure 3a. Hooflike conk of Phellinus (Fomes) igniarius at a seam covering an old branch stub on American beech (USDA Forest Service photo).

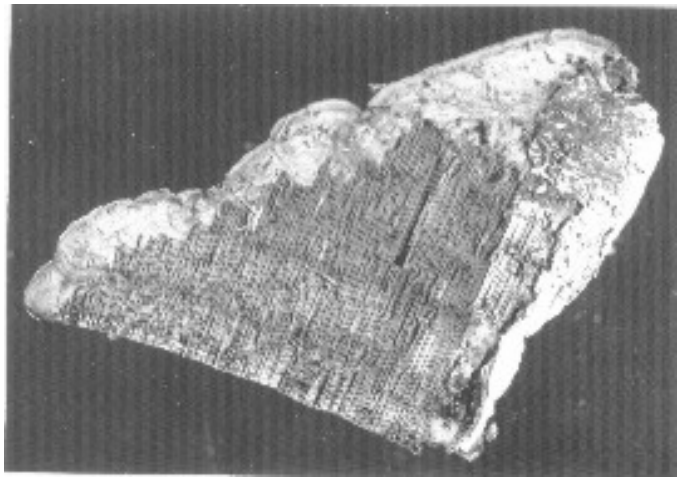

Figure 3b. Cross section of perennial conk of Phellinus (Fomes) igniarius. A number of layers of spore-bearing tissue from past years can be seen (Purdue Univ. photo).

Decay fungi may cause the colonized wood to become watersoaked, spongy, stringy, crumbly, or flaky. Affected wood may also be discolored (Figure 1 and 1a), usually brown, white, yellow, or some shade of red, for several feet or more above and below where a conk or cluster of mushrooms appears.

The development of wood rots varies somewhat with the fungus involved, the woody host that it invades, and the site on which the tree is growing. Thus, some fungi cause mainly root and butt rot, others a top rot, and still others a trunk and/or branch rot. Top rot decay fungi attack the heartwood in the upper part of the tree. These fungi seldom progress very far into the roots and therefore rarely spread from one tree

to another via roots or from the tree stump to the next generation of stump sprouts or root suckers. Root and butt rot fungi colonize the lower stem and roots and can cause serious problems in forest stands generated from sprouts and suckers. Rot in the parent tree and its invasion of cut stumps may serve to infect the new stand with root rot fungi. Fire, logging, lawn mower, and construction scars frequently provide entry points for root- and butt-rotting fungi.

Some species of decay fungi cause root and butt rot in one species of tree and trunk rot in another species. A few fungi cause both top rot and root or butt rot in the same tree species. Fungi that can decay living sapwood and heartwood and cause cankers are called canker rots.

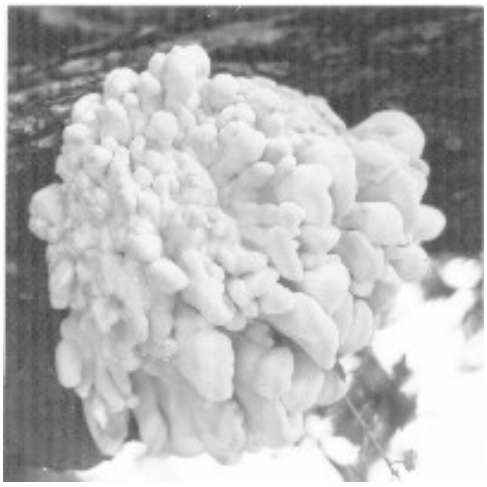

Figure 4. Laetiporus (Polyporus) sulphureus causes a widespread heart rot of living trees, especially oaks. The fruiting structure is a bright sulphur yellow color.

Causes

More than 1,000 species of fungi can cause wood deterioration and decay. Most of the fungi that cause serious wood rot are Basidiomycetes (brown rot and white rot fungi), although some are Ascomycetes (such as *Daldinia, Hypoxylon*, and *Xylaria*). The fungi grow inside the wood cells and produce enzymes that digest the cell wall components for food and energy. The brown rot fungi, which attack mostly softwoods (conifers), produce cellulase enzymes that digest the cellulose and hemicellulose in the cell wall but leave the lignin largely unaffected. The result is decayed wood that is some shade of brown and that, in an advanced stage, may be stringy, have pockets, or may crack into a cubical pattern. The decayed wood then becomes crumbly. The white rot fungi enzymatically digest both cellulose and lignin and reduce the wood to a light-colored, spongy, or stringy mass with white pockets or streaks separated by thin areas of firm wood. White rot fungi commonly attack hardwoods (deciduous trees) that are normally resistant to brown rot fungi. Some Ascomycetes cause a relatively slow white rot with variable black zone lines in and around the rotting wood both in standing hardwood trees and in slash. In standing trees the decay is usually associated with wounds or cankers.

Other causes of decay, especially in wood that contains a high moisture content, include the soft rot fungi and bacteria. Soft rot fungi, usually species of Ascomycetes and Fungi Imperfecti (e.g., *Alternaria, Bisporomyces [Chloridium], Diplodia,* and *Paecilomyces*) digest both lignin and cellulose. Their effects are normally confined to localized pockets in the surface layers of wood commonly exposed to water in moist climates. Bacteria multiply and develop primarily in wood rays, where they feed on the contents and walls of parenchyma cells when the wood is in water or protected with a water spray. The sporophores of many of these fungi, including their spores and spore bearing surfaces, are illustrated in Plates 1 and 2.

Disease Cycle

Infection nearly always occurs through moist, unprotected breaks in the bark where the wood underneath is exposed. These entry wounds include pruning cuts and branch stubs; mowing bruises; cuts made by knives, bicycles, automobiles, snowplows, and logging or construction equipment; summer or winter sunscald; fire scars; lightning strikes; frost or drought cracks; damaged roots; insect wounds; sapsucker

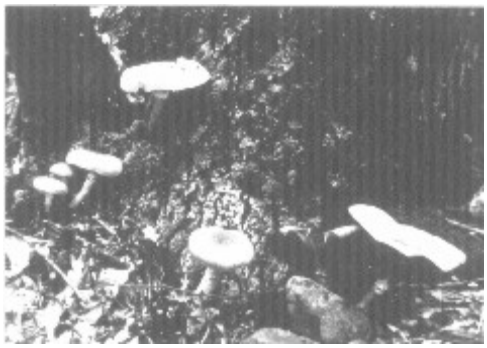

Figure 5. Armillaria (Armilleriella) mellea root and butt rot fungus fruiting at the base of a tree.

punctures; breaks due to ice, snow, and windstorms; and dwarf mistletoe cankers. Other infections may occur through dead branches and tree stumps.

A wide range of microorganisms are borne by air currents, rain droplets, or the wounding agent, or are carried to the wound surface by insects, birds, or other animals. These pioneer invaders (bacteria and non decay fungi) do **not** cause wood rot but grow and feed on the cells of the discolored wood around the wound and break down parts of the cell walls, adding to the discoloration and wetness of the wood and increasing certain mineral elements. Such wood is called wetwood, redheart, or blackheart. Finally, if the moisture content is above fiber saturation, the wood-rotting Basidiomycetes become active, begin to digest the cell walls of the wounded tissue, and grow inside the wood cells that have been discolored by chemical (oxidative) processes and then fed upon by the bacteria, Ascomycetes and Fungi Imperfecti.

If the wound is small and occurs in the spring, a new growth ring forms over the wound, and its cells act as a barrier zone that checks the discoloration and growth of decay fungi. In addition to forming a barrier zone at the cambium, the tree forms a layer of callus tissue at the margins of the wound. If the callus grows rapidly and the wound is completely healed ("compartmentalized"), further development of discoloration is checked, and the process may stop with full closure by the callus.

In large open wounds, especially in hardwoods, the discoloration and subsequent decay may continue to advance slowly toward the center and laterally around the tree. The process occurs much more rapidly – up to a foot (25 cm) per year – in a column upward and downward within the cylinder of barrier cells, but **not** outward into the callus tissues formed by the cambium after wounding. The rotted column, which is never wider than the diameter of the tree at the time of injury, may extend 10 feet or more above and below the area where the pioneer organisms and decay fungus entered the tree or where its fruiting bodies (conks or mushrooms) appear.

Figure 6. Hypoxylon trunk canker and wood rot of quaking aspen (Populus tremuloides) caussed by Hypoxylon mammatum. Entry probably occurred through a mowing bruise at the trunk base.

Wood-rotting Basidiomycetes generally remain confined to the discolored cylinder and are unable to attack the new growth. The decay within the discolored column continues until the wood is completely disintegrated (digested). A succession of microorganisms continues to enter the wound after the initial wood-decay fungus and ceases only when all woody tissues within the cylinder are completely digested. The process of discoloration and decay may take 50 to 100 years to develop, being most common and rapid in older, larger, and overly mature trees.

In other wood rots, particularly of conifers, the rotted cylinder may grow steadily in diameter until the tree is killed or blown over (windthrow). The decay may extend over much of the height of the tree. The

process of discoloration and decay may stop at any stage as a result of compartmentalization of the wound, antagonism among the bacteria and fungi involved, natural wood resistance, or other factors.

Plate 1. Common wood rot or decay fungi: (a) top, side, or bottom view of sporophore; (b) section through sporophore; (c) close-up of pore surface (hymenium) of sporophore; (d) basidiospores. The figures are not drawn to scale. (artwork by Lenore Gray).

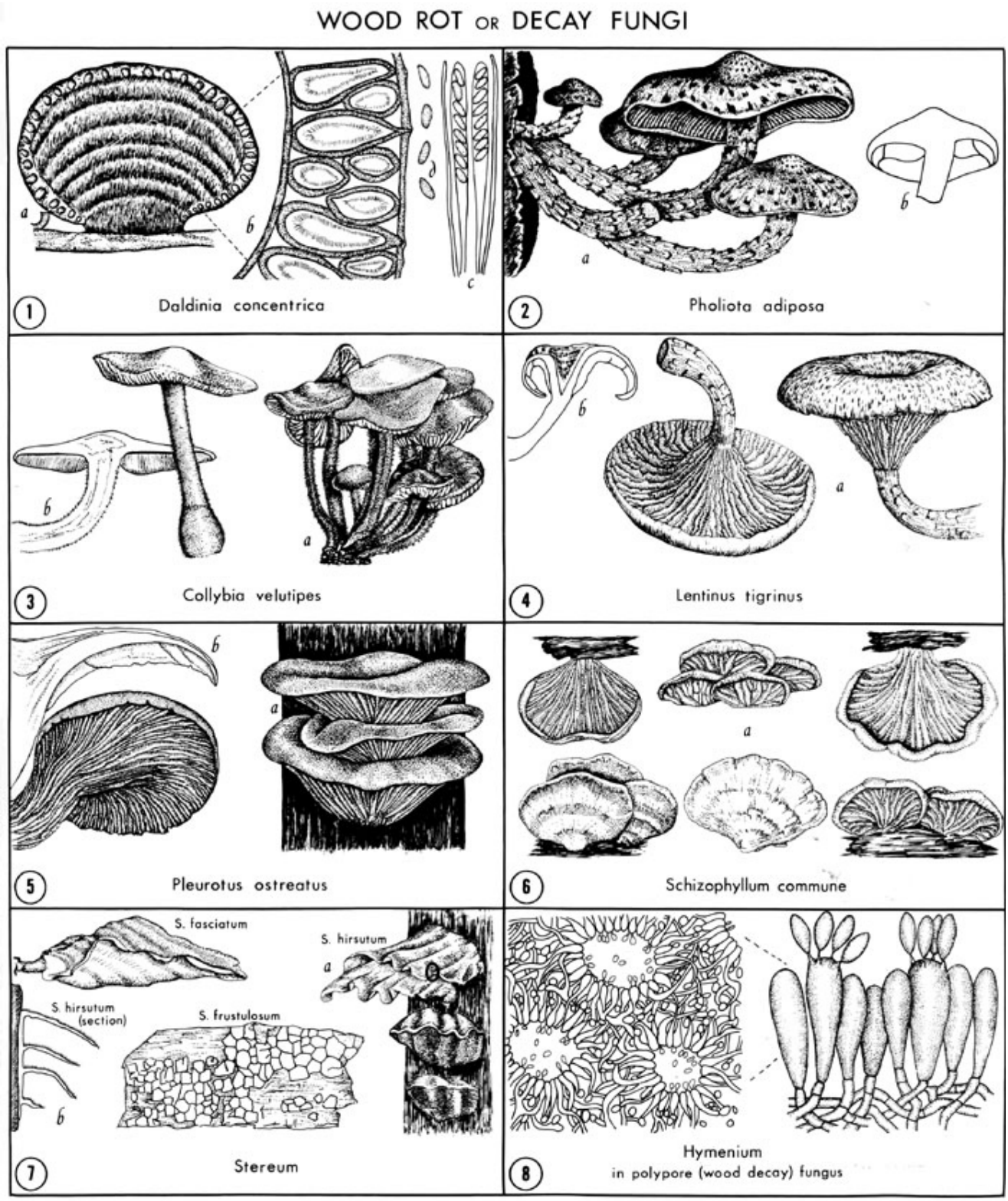

Plate 2. Common wood rot or decay fungi: 1. Daldinia concentrica, (a) section through stroma of fruiting body, (b) enlarged view of perithecia embedded in stroma, (c) asci containing eight ascospores, (d) ascospores; 2-6, (a) sporophores showing gill structure, (b) section through sorophore; 7. (a) sporophores, (b) section through sporophore; 8. (left) microscopic view of pores with basidia and basidiospores, (right) close-up of basidia forming basidiospores. The figures are not drawn to scale (artwork by Lenore Gray).

The sporophores (conks or mushrooms) of wood rotting Basidiomycetes appear at or near where the fungus entered, near the soil line, in cankers, at decayed branch stubs or swollen knots, along the trunk or branch of living trees, or along the length of the trunk following its death. The sporophores of most wood rotting fungi (such as *Armillaria, Bjerkandera, Cerrena, Collybia, Daedaleopsis, Hericium, Hypsizygus, Laetiporus, Lentinus, Lenzites, Pholiota, Piptoporus, Pleurotus, Polyporus, Schizophyllum, Trametes,* and *Trichaptum)* are formed annually and do not produce spores for over a year, while those of *Fomes, Oxyporus,* and *Phellinus* are usually perennial and add a new layer of spore-producing tissue each year (Figure 3b, Plate 1) for 50 years or more.

The sporophores produce basidiospores at the hymenial surface of gills or pores (Figures 5 and 6; Plates 1 and 2) during part or most of the year, and the spores are carried by air currents, rain, insects, birds and other animals, or other agents to nearby tree wounds. A single large conk may shed up to 100 billion basidiospores in a single day.

Typically, the spores are randomly disseminated by the wind. When a spore comes in contact with a wound in a tree and conditions are suitable (proper temperature, the presence of moisture and nutrients, and the lack of inhibitors produced by nondecay organisms), the spore germinates and forms a germ tube that expands into a hypha. The hypha branches and grows into the wood fiber and vessel cells to form a mycelium. Food is obtained by enzymatic digestion of the cell walls. Wood rotting fungi may also enter woody plants as mycelium.

A tree is commonly injured many times during its lifetime. The disease cycle described above may be repeated after each new wound is formed, thus involving more and more wood in the natural and more or less continuous process of discoloration and decay. The end result is one or more cylindrical compartments of discolored and decayed wood that may extend over much of the height of the tree.

Domesticated tree varieties differ greatly in their susceptibility to heartwood decay. Table 1 groups these trees into resistant or very resistant, moderately resistant, and slightly or nonresistant.

Control

1. Select and grow only species and varieties or cultivars of shade, ornamental and fruit trees and shrubs that are well adapted to the area. Plant only vigorous, disease-free nursery stock. Grow somewhat tender species in sheltered locations. Plant at the proper depth in a large hole, well spaced apart, in fertile, well-drained soil of the proper soil reaction (pH).

2. When feasible, keep woody plants vigorous through (a) proper applications of fertilizer in mid- to late-autumn or early spring; (b) thorough soaking of the soil to a 12-inch depth every 10 to 14 days during extended hot, dry periods; and (c) wrapping the trunks of newly transplanted, thin barked trees with sisalkraft paper, special tree-wrapping paper, or other appropriate material prior to winter.

3. Prune periodically to remove all dead, dying, interfering, and broken branches so that they are nearly flush with a major branch or main stem; leave the "collar" that surrounds the base of the branch. Prune broken stems below the damaged portion so that water will drain off and not collect on the wound surface. The severed ends of roots should be made blunt rather than left jagged. Pruning is best done during the dormant season when the weather is dry. Pruning in late spring often leads to separation of wood and bark around pruning wounds.

4. Avoid burning of trash near trees and shrubs.

5. Make as few changes as possible in the soil grade or drainage patterns in the vicinity of trees. Avoid compacting soil over the roots.
6. Follow cultural practices suggested by Extension horticulturists and foresters at the University of Illinois at Urbana. Your local Extension office and a professional arborist or forester can also provide valuable help on general tree care.

7. Control insect borers by spraying the trunk and major branches with a suggested insecticide following recommendations of University of Illinois Extension entomologists. Many wood boring insects infest trees previously weakened by drought, temperature extremes, various diseases, and so forth.

8. Avoid all unnecessary bark wounds. When bark and wood injuries do occur, treat them promptly. Cut away all loose or discolored bark. Remove splintered wood. Clean, shape, and smooth the wound into a streamlined oval or vertical ellipse. Then swab the surface liberally with an antiseptic such as 70 percent alcohol or shellac. The use of a commercial tree wound dressing (tree paint) is of questionable value since it does **NOT** check the invasion of wood by decay fungi. The barrier zone of cells formed by the cambium effectively confines the decay within the tissues present at the time the tree was wounded. The use of tree wound dressings is largely cosmetic and their usefulness in preventing wood decay is questionable.

9. Reduce losses in forests, plantations, and farm woodlots by (a) eliminating, as much as possible, the introduction of wood-rotting fungi into healthy stands by early pruning of lower branches; (b) conducting logging and thinning operations to minimize breakage of branches and the creation of major wounds (top breaking, stripping of bark, butt and trunk damage from heavy equipment) to the stems and roots of the remaining trees (such operations should take place during the dry season or winter to avoid much of the mechanical damage to the root systems of the living trees that remain; (c) harvesting trees **before** they become overly mature and thus increasingly susceptible to wood-rotting fungi; and (d) not letting livestock graze in farm woodlots. Livestock damage trees through soil compaction, butt damage, and root wounds caused by sharp hoofs. All trees that are dead, hazardous, diseased, or pest ridden should be removed.

10. Control discoloration and decay in lumber and other wood products by drying the wood in a kiln or by treating with a recommended wood-preserving fungicide. Wood likely to be in contact with soil or moist surface should be treated with a wood preservative suggested by the Extension forester, University of Illinois at Urbana.

Table 1. Grouping of Some Domestic Trees According to their Resistance to Heartwood Decay[a]

RESISTANT OR VERY RESISTANT	MODERATELY RESISTANT	SLIGHTLY OR NONRESISTANT
bald cypress (old growth)[b]	bald cypress (young growth)[b]	alder
catalpa	Douglas-fir	ash
cedars	honey locust	aspen
cherry, black	larch, western	basswood
chestnut	oak, swamp chestnut	beech
cypress, Arizona	pine, eastern white[b]	birch
junipers	southern pines: long-leaf[b], slash[b]	buckeye
locust, black	tamarack	butternut
mesquite		cottonwood
mulberry, red[c]		elm
oak: bur, chestnut, gambel, Oregon white, post, white		hackberry
osage orange[c]		hemlock
redwood		hickory
sassafras		magnolia
walnut, black		maple
yew, Pacific[c]		oak (red and black species)
		pine (other than long-leaf, slash, and eastern white)
		poplar
		spruce
		sweetgum
		true fir (western and eastern)
		willow
		yellow-poplar

[a] From U.S. Department of Agriculture Handbook No. 72

[b] The southern and eastern pines and bald cypress are now mostly second growth with a large proportion of sapwood. Consequently, substantial quantities of heartwood lumber of these species are not available.

[c] These trees have exceptionally high decay resistance.