RESEARCH LABORATORY TECHNICAL REPORT

Wood Decay in Living Trees

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In urban landscapes, trees are subject to damage that predispose them to wood decay. Damage may result from construction activities that cut roots, vehicular injury, or large branch pruning. Wood decay reduces wood strength which can lead to branch or whole tree failures. The likelihood of failure is greater when other defects, such as codominant stems or trunk lean, are present. Many failures occur during high wind, rain, snow, or ice events when there is an increased load on the tree. When a large tree in an urban area fails, there is a potential for property damage or harm to people. To identify structural tree issues and reduce risk and liability, any tree that is suspected of having significant wood decay should be inspected by a qualified tree risk assessor.

Structural components of wood

Wood, or xylem, is made up of complex chains of carbohydrates called cellulose and lignin, which give wood its flexibility, strength, and rigidity. Similar to reinforced concrete, flexible cellulose "rods" are embedded in a matrix of stiff lignin "concrete." The arrangement and combined qualities of cellulose and lignin allow trees to sway in the wind while also bearing loads from the branches and leaves. Sap-conducting vessels and water-conducting tracheids are hollow, like straws, and not living. However, xylem components have living cells adjacent to them in cambial tissues and embedded in them as ray cells that can respond to damage or infection.

The process of wood decay

Wood decay is a process in which fungal organisms degrade the cellulose and lignin structural components. Although wood is difficult to break down, fungi have evolved chemicals and enzymes that actively degrade complex wood carbohydrates. Depending on the decay fungus and tree species, the rate of wood decay and subsequent strength loss can be highly variable, even within the same genus of tree. For example, water oak (*Quercus nigra*) is highly susceptible to decay, while Southern live oak (*Q. virginiana*) is more resistant to decay. Local knowledge of the decay fungi and tree species can be important in understanding the extent of internal decay present in a tree.

Sap rot and heart rot

Wood decay may be called a "rot" and named by the woody tissues affected. When decay fungi are present in the sapwood, the condition may be referred to as sap rot (Figure 1A); conversely, when decay fungi are present in the heartwood, it is referred to as heart rot (Figure 1B). Sapwood is the outermost wood beneath the bark where vascular (water/sap-conducting) tissues are present. Sapwood has active defenses against decay progression from surrounding cells and

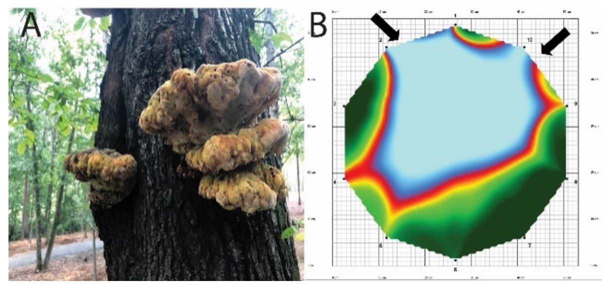
Figure 1: A) Sap-rot fungus *Schizophyllum commune* fruiting on a recently dead Yoshino cherry and B) cross section of a spruce with heart rot

ray cells. Sap rot fungi are inefficient at infecting healthy and functional sapwood. Wounds, droughts, or disease will desiccate sapwood, predisposing it to this type of decay. Sap rot is indicative of dead and dysfunctional sapwood, which can be degraded rapidly. For example, sap rot is often observed on ash (*Fraxinus*) species after emerald ash borer attack due to the desiccation of the vascular tissues from the beetle galleries, resulting in a significant reduction in structural integrity. Similarly, sap rot is common after lightning strikes on trees (Figure 2). Lightning protection systems can help prevent strikes from damaging the sapwood, reducing the likelihood of sap rot decay.

Figure 2: Willow oak struck by lightning resulting in a white rot of the sapwood

Heartwood is the inner wood of trunks, branches, and large diameter roots that no longer conducts water and sap. Though functionally dead, heartwood in some trees contains antimicrobial compounds that passively defend against decay fungi. Heartwood is more resistant to decay than sapwood (due to the chemical deposits embedded in the wood), but many fungi have evolved mechanisms to overcome these defenses. Similar to sap rot entry, heart rot fungi cannot penetrate the wood without wounds or root disease first desiccating tissues. For example, *Inonotus hispidus* will often infect exposed heartwood resulting from pruning wounds or branch failures (Figure 3).

Figure 3: Hispidus canker rot. A) fruiting bodies of *Inonotus hispidus* on swamp white oak stem and B) tomogram taken from the cross mid-section of a stem canker (arrows point to where the fruiting bodies of *I. hispidus* emerge)

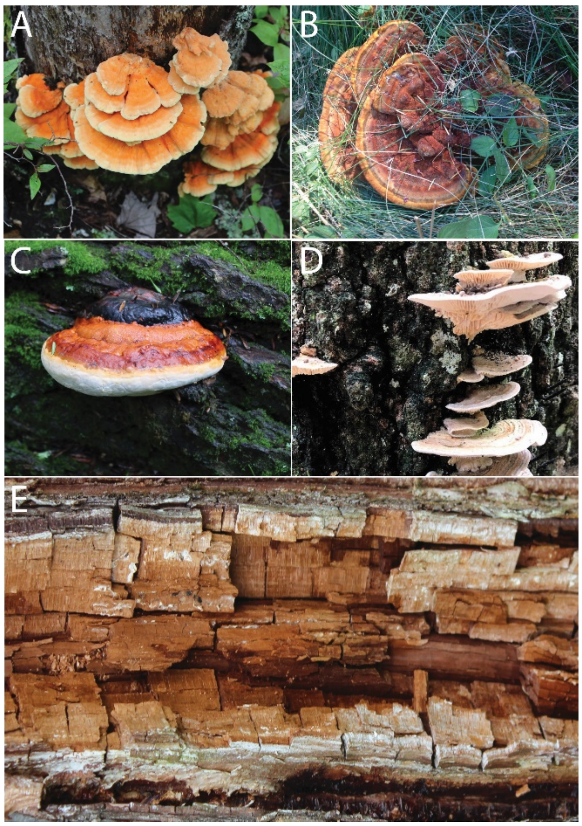


Types of wood decay

If decay advances, naming rots by tree parts affected becomes difficult, so another grouping based on the infected wood's color or texture is used: brown rot, white rot, and soft rot. There are some major differences in how these types of decay can impact the structural integrity of the woody tissues and how they affect the likelihood of failure of a tree or tree part.

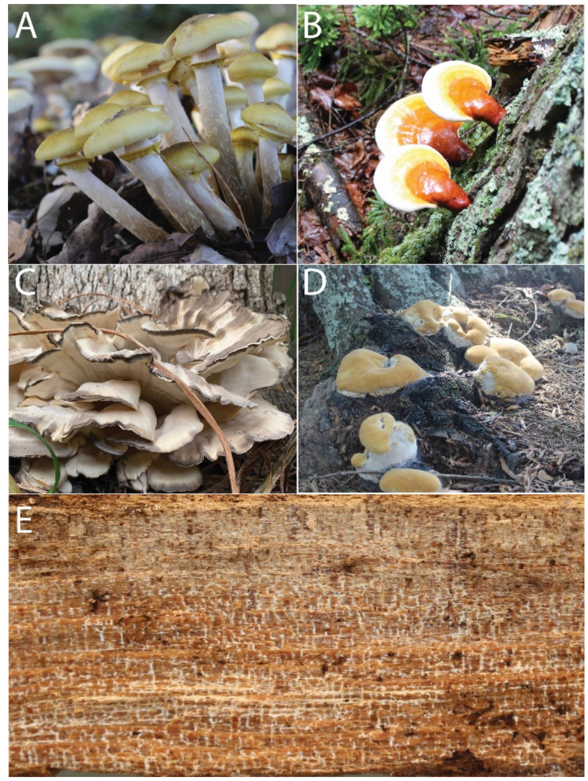
Brown rot decay fungi cause a rapid breakdown of cellulose and hemicellulose, which reduces bending strength. Wood that is decayed by brown rot fungi will be dark in color due to the residual lignin, which is generally brown. In addition, the wood is usually brittle and cracks in a cubical pattern. Due to the rapid degradation of cellulose components, brown rot decay in living trees is usually considered more of an immediate concern compared to white rot. There are more brown rot fungi associated with conifers than hardwoods. Common brown rot fungi genera observed in living trees are *Laetiporus, Phaeolus, Fomitopsis,* and *Daedalea* among others (Figure 4).

Figure 4: Different types of brown rot fungi fruiting bodies and brown rotted wood. A) *Laetiporus sulphureus*, B) *Phaeolus schweinitzii,* C) *Fomitopsis pinicola,* D) *Daedalea quercina,* and E) pine wood that has a cubical brown rot



White rot decay fungi break down all components of wood (cellulose, hemicellulose, and lignin). In many cases this process is more gradual than the decay observed with brown rot fungi. Wood impacted by white rot is commonly white, stringy, fibrous, and often wet. White rot occurs when the fungi simultaneously decay all cellulose and lignin components. Some white rot fungi have evolved to selectively decay lignin (e.g., some *Ganoderma* species) before breaking down the cellulose components, which results in decreased compression strength of the wood. Common white rot fungi genera observed in living trees are *Armillaria, Ganoderma, Meripilus,* and *Pseudoinonotus,* among others (Figure 5).

Figure 5: Different types of white rot fungi fruiting bodies and white rotted wood. A) *Armillaria mellea,* B) *Ganoderma tsugae,* C) *Meripilus sumstinei,* D) *Pseudoinonotus dryadeus,* and E) oak wood with lignin loss visible as pockets of bleached-out wood

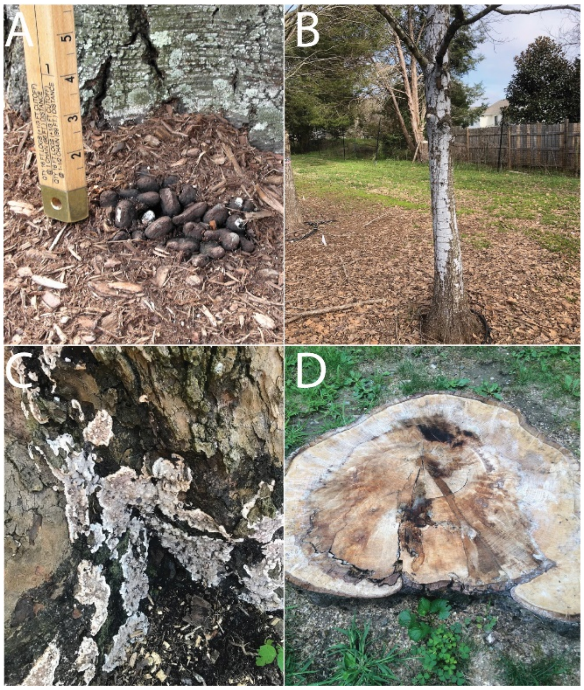


Soft rot fungi cause a more gradual and less common decay in living trees. Soft rot is most akin to brown rot in its impact on the structural properties of wood. These decay fungi cause the wood to become brittle. Fungi that cause a soft rot are often observed fruiting in living trees after decay is present from a previous infection or woody tissue death, and usually indicates significant strength loss. Fungi in the family Xylariaceae are common soft rot fungi in living trees and include *Biscogniauxia, Kretzschmaria,* and *Xylaria* (Figure 6).

How do wood decay fungi enter trees?

Decay fungi require an opening into trees. Infection typically occurs through wounds, diseased tissue, or damaged tissue from some predisposing factor (e.g., girdling roots, large pruning wounds, or construction-damaged roots). While trees have mechanisms in place to seal over wounds, this sometimes occurs slowly and

Figure 6: Different types of soft rot fungi fruiting bodies and a stump of a tree that failed from soft rot. A) *Xylaria polymorpha,* B) *Biscogniauxia atropunctata* (Hypoxylon canker), C) *Kretzschmaria deusta,* D) maple that failed from the decay caused by *Kretzschmaria deusta*
Photo credit: Trevor Hall



is dependent on the size of the wounds, tree species, and vigor of the individual tree. When bark is removed through mechanical wounding, wood tissues are exposed and desiccation occurs, creating a pathway for decay fungi. The best way to prevent decay is to avoid wounding trees, limit the size and number of pruning cuts, and keep trees healthy.

Compartmentalization of decay

If a wood decay fungus gains entry, trees have mechanisms in place to limit the spread of decay, which is the premise of Alex Shigo's CODIT (compartmentalization of decay in trees) model [1]. In this model, four major walls may be formed consisting of active and passive obstructions to the spread of decay. Wall 1, the weakest wall, limits the spread up and down by producing obstructions in vascular tissue such as tyloses—produced by living cells associated with xylem vessels. Thickened latewood cells, seen in growth rings, comprise wall 2 and resist decay's inward spread. Living ray cells of wall 3 confine the spread of decay radially. Lastly, wall 4, the result of response growth and new wood formation, creates a robust physical and chemical barrier and is considered the strongest barrier. Not all trees are equally effective at compartmentalizing decay, but in order to isolate and limit it, a tree must have good vigor. Vigor can be improved or maintained through soil care programs, including Bartlett's Root Invigoration.

Management

Trees can tolerate some level of decay. Knowing the type, extent, and location of decay can help predict the likelihood of failure in a given period of time. Many, if not all, mature trees have some internal decay. Indicators of decay include fruiting bodies on a branch, root, or stem, a swollen base, and internal insect nests. Just because an indicator is present does not signify an imminent likelihood of failure. A qualified tree risk assessor can inspect the tree and provide a risk rating. This assessment should involve determination of the extent of decay with sounding, drilling, resistance drilling, or tomography. (See companion technical reports on "Resistance Recording Drills for Decay Assessment" and "Sonic Tomography.") A risk assessment will help determine the most appropriate mitigation options to lower the residual risks. Trees in urban landscapes that have decay, especially where targets (people, property, etc.) are within 1½ the height of the tree, require special attention. Contact your Bartlett Tree Experts Arborist Representative to discuss specific management options for your tree.

Founded in 1926, The Bartlett Tree Research Laboratories is the research wing of Bartlett Tree Experts.

Reference

[1] Alex Shigo, "Compartmentalization of Decay in Trees," *Scientific American*, no. 252, pp. 96–105, 1985, doi: 10.1038/scientificamerican0485-96.