IDENTIFYING Wood Decay and Wood Decay Fungi in URBAN TREES

By Christopher J. Luley

CEU

LEARNING OBJECTIVES

The arborist will be able to

- name and describe the three basic types of wood decay.
- explain the difference between positive indicators and potential indicators of decay.
- demonstrate an understanding of the life cycle of wood decay fungi.
- identify and distinguish between signs and symptoms of decay.

This article is based on the book Wood Decay Fungi Common to Urban Living Trees in the Northeast and Central United States *by Christopher J. Luley. The publication is available from ISA.*

Wood decay is one of the most common types of diseases of urban trees, and because decay weakens wood and may cause tree failures, it is one of the most important diseases. Decay is considered a disease because it causes a progressive deterioration in cell walls and wood strength and can disrupt sapwood function when living cells are killed or react to advancing decay. Some wood decay fungi are known as canker rots because they can kill bark and cambium as well as decay wood.

Decay, often together with other tree defects, is involved in most tree failures. Decay can affect woody roots, trunks, and branches. Therefore, arborists and urban tree managers should be knowledgeable about decay in urban trees and be able to identify the signs and symptoms. Arborists and tree managers should also understand the important difference between *symptom* and *sign*: A symptom is the effect of the pathogen, or disease-causing agent, on the host; it is what you see that is wrong or different from normal. A sign, on the other hand, is visible evidence of the disease-causing agent, such as wood decay conks, mycelial fans, rhizomorphs, and mushrooms.

Causes of Wood Decay

In 1874, Robert Hartig, the father of forest pathology, proved that decay did not cause fungi, which was a common assumption at the time. In fact, all wood decay of any consequence in living trees is *caused by* fungi.

There are two main groups of wood decay fungi: those in the division Basidiomycota, commonly called basidiomycetes, and those in the division Ascomycota, or ascomycetes.

The basidiomycetes are overwhelmingly the most common cause of wood decay. The fungi in this group are familiar to most arborists as the conks (Figure 1a) and mushrooms (Figure 1b) that sporulate on the trunks, stems, and/or ground attached to roots of trees. The ascomycetes are better known as the cause of foliar cankers, wilts, and blights, but several ascomycetes are very important as wood decays.

Types of Wood Decay

Not all fungi decay wood in the same manner. The three basic types of decay—white, brown, and soft rot—can usually be

Figure 1. Most arborists are familiar with the decay-causing basidiomycetes as (a) conks (*Ganoderma lucidum* in this photo) or (b) mushrooms that fruit or sporulate on woody tissues of trees.

distinguished in the field. These decay types actually represent modes of enzymatic attack of wood. Interestingly, some decay fungi can make more than one type of attack on a single host. There also are different types of white and brown rot, which leave characteristic decay patterns in wood such as pocket rots, stringy rots, or cubical rots.

Enzymatic attack by fungi weakens wood by degrading cellulose and lignin in cell walls and by removing lignin from between cells. Fungal attack on cellulose in cell walls reduces bending strength, while degradation of lignin affects the compressive strength of wood.

Figure 2.
(a) White rot fungi remove lignin before or at the same time they degrade cellulose and hemicellulose, leaving the pale or bleached wood typical of the decay in its advanced stages. (b) The majority of wood decay fungi cause white rot. *Ganoderma applanatum*, the artist's conk, is a common cause of white rot in urban trees.

In general, white rot fungi reduce the compressive strength of wood the most, while brown rot and soft rot diminish its bending strength. A significant amount of this strength loss occurs before the decay is even visible in the wood (Wilcox 1978). A detailed account of how the various types of decay develop in and affect wood was given by Schwarze et al. (2000).

White Rot

The majority of decay fungi on deciduous trees cause white rot. White rot fungi remove lignin before or at the same time they remove the cellulose component of wood. Because lignin is brown or dark colored, its removal leaves the wood pale white or bleached looking in the latter stages of the decay process (Figure 2a). *Ganoderma applanatum*, the artist's conk, is a common, well-known white rot fungus on deciduous trees (Figure 2b).

Brown Rot

Far fewer fungi cause brown rot than white rot, and most of them attack conifers. Brown rot fungi remove the cellulose components of wood and leave behind the brown, modified lignin that gives the decay its characteristic color (Figure 3a). A common brown rot fungus on deciduous and coniferous trees is the sulfur shelf, *Laetiporus sulphureus* (Figure 3b). Another common brown rot on conifers, such as Jeffrey pine and Douglas-fir in the U.S. Pacific Northwest, is *Phaeolus schweinitzii*.

Figure 3.
(a) Brown rot fungi remove cellulose and hemicellulose and leave behind modified brown lignin. The fungi that cause brown rot fungi are much less common than those that cause white rot. (b) The sulfur shelf, *Laetiporus sulphureus*, is a common brown rot fungus of urban trees.

Soft Rot

Soft rot is usually caused by the ascomycete decay fungi, although some basidiomycetes cause decay similar to soft rot. Soft rot fungi use a mode of attack similar to that of brown rot: the cellulose is preferentially degraded. Soft rot fungi attack the cellulose in woody cell walls and often form microscopic cavities in the secondary cell wall (Schwarze et al. 2000).

Soft rot appears straw colored in its advanced stages and can be difficult to distinguish visually from white rot (Figure 4a). Its common name is misleading because soft rot in living trees is not noticeably softer than other decay types. The name refers to decay caused by other ascomycetes that soften the wood but are not common on living urban trees. *Ustulina deusta* is one of the most common wood decay fungi that cause soft rot of living urban trees (Figure 4b).

Significance of Decay Types

In the absence of conks or other visual evidence of decay, the type of decay caused by fungi usually is not apparent until trunk stems or branches are cut. However, brown rot fungi initially cause a more rapid loss in wood strength than white rot fungi. In the advanced stages of decay, the strength of wood is almost totally lost, no matter what the decay type.

Trees affected by structural and strength alterations from white rot are more likely to show adaptive growth, or active localized growth responses to stress, that may result in various degrees of stem swellings or changes in bark characteristics. Bottle butt, which is a unique swelling at the base of trees, has been attributed to white rot (Schwarze et al. 2000).

Figure 4. **(a) Soft rot decay appears similar to white rot but is closer to brown rot in the way the decay fungus attacks wood. (b) A common cause of soft rot is the ascomycete fungus *Ustulina deusta*.**

Indicators of Decay in Living Trees

Most decay in urban trees occurs without the presence of wood decay conks or fruiting. In the absence of conks or mushrooms, arborists often use indicators of decay to help confirm its presence. *Positive* indicators mean that decay is present (Figure 5a). *Potential* indicators mean that decay may be present (Figure 5b).

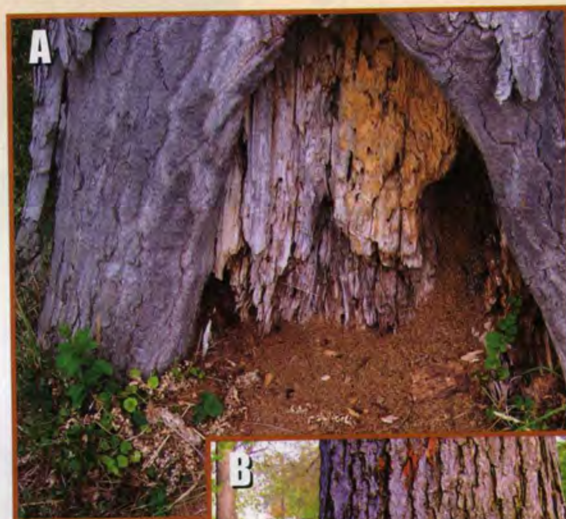


Figure 5. **(a) Positive indicators of decay, such as external cavities, mean decay is present. (b) Potential indicators of decay, which develop as a result of decay or from a tree's reaction to decay, mean that decay might be present. Bulges in stems are a good potential indicator of decay.**

The number of positive indicators of decay is relatively small and includes conks or mushrooms; external cavities; visual evidence of decay in exposed wood; and activity or nesting of carpenter ants, birds, or mammals in decayed wood. The list of potential indicators is longer and includes various breaches in the bark that expose sapwood or heartwood, such as old wounds, topping or heading cuts, and old large cankers. Other potential indicators are the result of decay, such as cracks or seams, or are the result of the tree's reaction to decay, such as stem bulges and swellings or stem flattening.

Indicators of decay are important to arborists because they identify trees that have or may have decay and might require additional inspection. Indicators also help guide where to test for decay in a tree. Indicators of decay are particularly important in risk assessment and for arborists working in trees because failure to recognize their significance can place clients or tree workers at increased risk.

Naming Decay

Once decay is confirmed, a simple convention is to name the decay by the location where it occurs in the tree.

NAMING DECAY IN TREES

Root rot—decay in roots. Root decay develops from the bottom of roots up and may or may not produce visible crown symptoms.

Butt rot—decay in the butt or lower trunk and base of the tree.

Heart rot—decay in the center of the tree.

Trunk rot—decay above the lower trunk.

Branch rot—decay in larger branches.

Sap rot—decay in sapwood after bark and cambium have been extensively damaged or killed. Sap rot is evidenced by the presence of numerous, small fruiting structures.

The naming scheme is simple but far from perfect. For example, some root rot fungi are primarily restricted to roots, but many also decay the base, or butt, of a tree. Many of the butt rot fungi are usually found only in the lower portion of the main trunk of the tree (Figure 6). However, many of those fungi also decay larger buttress roots, and some can decay the trunk higher up in the tree.

Classifying the decay by location can also be somewhat misleading. For example, some heart rot fungi can also decay sapwood. Some sap rot fungi, once they are established (Figure 7), may also kill cambium and decay the wood in living stems. Sap rots also can decay the heartwood of dead stems and are important recyclers of wood in nature.

Despite these ambiguities, determining the location of decay is important to arborists for a number of reasons. For example, the presence of conks or identification of decay in the butt of a tree indicates that the decay may extend into larger buttress roots. Likewise, conks or mushrooms on roots signify decay is present there, but the decay may extend into the base of the trunk. Both possibilities should be considered.

Arborists should never put a rope around or rely on branches with sap rot fruiting structures because these branches may be completely decayed.

Figure 6. Butt rot fungi usually are limited to the lower trunk of the tree and may also decay roots. This decay would also be called a heart rot because it is primarily in the center of the stem.

Figure 7. Sap rot is indicated by the presence of numerous, small fruiting bodies. Sap rot fungi indicate that the bark and cambium are dead—at least where the fruiting bodies are present—and that the branch might be completely decayed.

Nonetheless, the simple naming system has some biological significance and is worth using to facilitate communication among arborists and professionals.

Life Cycle of Wood Decay Fungi

Infection of Wounds

Most wood decay fungi initially enter stems or roots of trees through wounds that expose sapwood or heartwood, but these fungi cannot infect trees through intact, living bark. Wounds come in many forms: scrapes that remove bark and expose or damage sapwood or heartwood; fire scars; exposed sapwood in the face of old cankers; ice damage to branches; or from pruning and other arboricultural treatments such as drilling into stems when cabling, bracing, or injecting trees.

A few fungi can gain entrance into main stems through small-diameter branches. At least one root decay fungus on conifers, *Phaeolus schweinitzii*, can infect roots through dead bark and cambium caused by the root disease fungus *Armillaria*.

Decay of Wood

Fungal invasion and decay of wood occur mostly in the nonliving, structural wood fibers and nonfunctional water-conducting tissues (also known as the apoplastic tree or

CONTINUING EDUCATION UNIT

the part of the tree made up of nonliving cells without protoplasm). Hence, decay may not directly affect the biological health of the tree (also known as the symplastic tree, which is formed by the connection of living cells with protoplasm). Importantly, the health of foliage is usually not a good indicator of the potential structural condition of a tree, because the symplastic tree is not directly dependent on the apoplastic tree for function.

Wood decay fungi grow as microscopic hyphae (single, segmented strands of a fungus) between cells; in the lumen, or center, of woody cells; and within cell walls. Hyphae release enzymes that break down cellulose and lignin.

A few of the wood decay fungi actively infect and kill living cells in sapwood. However, most of the decay fungi do not aggressively attack living ray cells, and they seldom kill healthy bark or cambium.

Tree Reaction to Decay

Most arborists would cite CODIT, or compartmentalization of decay in trees (Shigo 1991), as an instructive model for how trees respond to and contain invasion by decay fungi. However, the controversy over how trees respond or do not respond to decay progression continues in the academic world (Pearce 1996).

Observation of reaction zones that form ahead of advancing decay suggests that a generalized active response to decay occurs in sapwood that is not limited to the defined walls of CODIT (Pearce 1996). Reaction zones are areas of discolored sapwood that might have induced alterations of cell walls, elevated levels of antifungal compounds such as polyphenols, and other chemical changes (Pearce 1996).

Another theory suggests that decay is limited to heartwood and inner sapwood because of the presence of high sapwood moisture. The resulting low oxygen and high carbon dioxide levels are thought to prohibit growth of decay fungi in functional (water-conducting) sapwood (Boddy and Rayner 1983).

Determining the mechanisms of decay response in living trees is important because understanding them is the first step in developing effective decay management strategies. For now, CODIT serves as a good generalized model of the response of trees to wounds and, if it occurs, decay.

Spread of Decay Fungi

Most decay fungi spread via airborne basidiospores or ascospores that are released from fruiting structures produced on living or dead trees. A single conk can release millions of spores (Manion 1981). Removal of conks will eliminate one source of spores but will have no impact on decay inside the tree.

Virtually all the wood decay fungi are also able to survive as saprophytes (that is, they derive their nutrition from nonliving trees and wood). Most all wood decay fungi can also fruit or sporulate on dead trees or down woody tissues. Therefore, removal of dead trees, stumps, and large, woody roots can help reduce the spread of some root decay fungi and can eliminate a source of wood that decay fungi can sporulate on.

Wood decay fungi can also spread by a number of other mechanisms. Some root decay fungi can spread via root contact between adjacent trees. Insects also can spread decay—at least one decay fungus (*Cerrena unicolor*) is spread by a horntail wasp when it oviposits in weakened trees. Spread in soil from infected roots and stumps via vegetative growth of rhizomorphs is also well known with the fungus *Armillaria* (Shaw and Kile 1991).

Significance of Conks on Living Trees

Conks or mushrooms that are attached to woody stems or roots of living trees are positive indicators of decay, meaning that the tree has decay to some degree. Identification of the wood decay fungus present can sometimes help determine the status of decay, along with other characteristics that may be known about an individual wood decay fungus.

Some conks may be a clue as to the amount of decay present. For example, the artist's conk, *Ganoderma applanatum*, is usually associated with extensive internal decay (see Figure 2b). At a minimum, decay is usually advanced where the conk of *G. applanatum* is attached to the tree.

On the other hand, in the northeastern United States, the scaly polypore, *Polyporus squamosus*, is often associated with pruning or other wounds and with limited decay around the wound. However, in Europe, *P. squamosus* is considered an important decay fungus leading to stem breakage (Schwarze et al. 2000). Most conks, however, only indicate that the tree has internal decay that may require additional testing to determine its extent.

Identification of wood decay fungi can also help determine where the decay might be located. For example, decay from the warted polypore *Inonotus dryadeus* usually is found mostly in roots and does not progress substantially into the butt of the tree. Further, trees with root decay from this fungus may not show substantial symptoms of dieback or decline typically associated with root problems or cambial death from other types of root rot.

Identification of conks may also help determine the mode of attack. *Ganoderma lucidum* causes a root and butt rot on a wide range of deciduous species and also attacks the bark and cambium of roots. The fungus is frequently associated with declining trees because of the loss of root function.

Identification of a conk will help identify the type of decay present in a tree. Also, information about which fungi cause which type of wood decay (that is, white, brown, or soft rot) is generally available to assist in identifying a pathogen.

Incidentally, some of the wood decay conks and mushrooms are choice edibles, such as chicken of the woods (*Laetiporus sulphureus*), and some have proven medicinal effects, such as Reishi mushrooms (*G. lucidum*) (see Figure 1a).

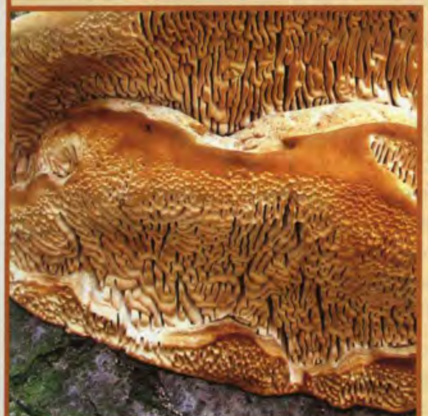
Identifying Wood Decay Fungi

Modern taxonomic identification of wood decay fungi has become increasingly complex and relies on microscopic features of the fruiting body, reactions to selected chemicals, and genetics (Gilbertson and Ryvarden 1986). The older system of identification was more user-friendly and relied on macroscopic features of conks and the spore-producing layer, and on selected microscopic features (Overholts 1977).

Types of Spore Layers

Gills are found on mushrooms of annual and fleshy wood decay fungi.

Pores are a common spore layer and are found on both annual and perennial decay fungi. Perennial wood decay fungi form a new pore layer each year.



The daedaloid, or mazelike, pore layer is found on annual and perennial wood decay fungi.

A toothed spore layer is found on some of the annual wood decay fungi.

Most arborists are familiar with some of the older taxonomic names, such as *Polyporus* (fungi that are primarily annual and have pores) and *Fomes* (fungi that are perennial and have pores). Some of these names are still in use for certain wood decay fungi. However, the names of most wood decay fungi have changed to fit new taxonomic schemes.

Gilbertson and Ryvarden (1986, 1987) identified more than 500 wood decay fungi in North America. Fortunately, most of these fungi are saprophytes and relatively few are common on living urban tree species—at least in the northeastern and central United States, which simplifies the task of identifying common wood decay fungi (Hickman and Perry 1997; Weber and Mattheck 2003; Luley 2005).

It is significant to arborists that the relative importance and distribution of individual wood decay fungi vary considerably by region and continent. Furthermore, host interactions likely change throughout various geographic regions.

Arborists are encouraged to learn the decay fungi that are common to their local area and how these fungi interact with their hosts. Considerable research in Europe has been conducted, and much information is now available, on the interactions of various wood decay fungi and their hosts (Schwarze at al. 2000).

Finally, as Hepting (1971) noted, the frequency of fruiting is not an indicator of which fungi are causing the most decay, at least in forested habitats of the southern United States. However, some fungi are likely to be locally important. For example, 20 percent of declining Norway maple (*Acer platanoides*) in the New York City area were reported as being infected by *G. lucidum* (Sinclair et al. 1987).

Continued study and observations of wood decay fungi of urban trees are needed to help arborists and urban foresters make better judgments in risk assessment and in the development of management strategies. One repository for information on wood decay fungi associated with tree failures is the International Tree Failure Database (ITFD), on-line at http://ftcweb.fs.fed.us/natfdb. Arborists are encouraged to report the type of decay and presence and identification of wood decay fungi to the ITFD. It is one of the few ways that the relative occurrence and importance of these fungi can be determined.

Literature Cited

Boddy, L., and A.D.M Rayner. 1983. Origins of decay in living deciduous trees: The role of moisture content and a re-appraisal of the expanded concept of tree decay. *New Phytology* 94:623–641.

Gilbertson, R. L., and L. Ryvarden. 1986. *North American Polypores*, Volume 1. Fungiflora, Oslo, Norway.

Gilbertson, R. L., and L. Ryvarden. 1987. *North American Polypores*, Volume 2. Fungiflora, Oslo, Norway.

Hepting, G.H. 1971. *Diseases of Forest and Shade Trees of the United States*. Agricultural Handbook No. 386. USDA Forest Service, Washington, DC.

►

Hickman, G.W., and E. Perry. 1997. *Ten Common Wood Decay Fungi on California Landscape Trees*. Western Chapter, International Society of Arboriculture. Sacramento, CA.

Luley, C.J. 2005. *Wood Decay Fungi Common to Urban Living Trees in the Northeast and Central United States*. Urban Forestry LLC. Naples, NY.

Manion, P.D. 1981. *Tree Disease Concepts*. Prentice Hall, Englewood Cliffs, NJ.

Overholts, L.O. 1977. *The Polyporaceae of the United States, Alaska, and Canada*. University of Michigan Press, Ann Arbor, MI.

Pearce, R.B. 1996. Antimicrobial defenses in the wood of living trees (Tansley Review No. 87). *New Phytology* 132:203–233.

Schwarze, F.W.M.R., J. Engels, and C. Mattheck. 2000. *Fungal Strategies of Wood Decay in Trees*. Springer, New York, NY.

Shaw III, C.G., and G. Kile. 1991. *Armillaria Root Disease*. Agricultural Handbook No. 691. USDA Forest Service, Washington, DC.

Shigo, A.L. 1991. *Modern Arboriculture*. Shigo and Trees, Associates. Durham, NH.

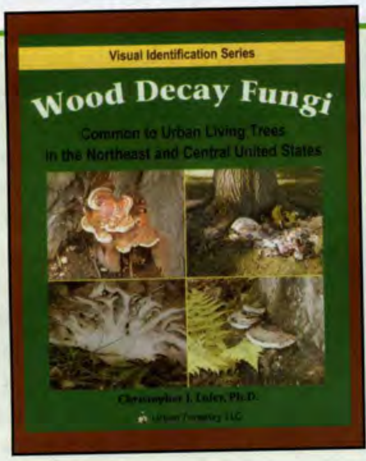
Sinclair, W.A., H.H. Lyon, and W T. Johnson. 1987. *Diseases of Trees and Shrubs*. Cornell University Press. Ithaca, NY.

Weber, K., and C. Mattheck. 2003. *Manual of Wood Decays in Trees*. The Arboricultural Association. Hampshire, UK.

Wilcox, W.W. 1978. Review of the literature on the effects of early stages of decay on wood strength. *Wood and Fiber* 9:252–257.

Christopher J. Luley, Ph.D., is vice president and pathologist for Urban Forestry LLC, an urban forestry consulting company located in the Finger Lakes region of western New York. He recently published a book on the common wood decay fungi of living urban trees in the northeast and central United States.

Photos courtesy of the author.



Wood Decay Fungi

Visual Identification Series

With high-quality color photographs and a straightforward approach to identification, this manual aids the arborist in identifying common decay fungi and types of decay.

Author Christopher Luley introduces readers to the causes and types of decay and explains the characteristics of each type of wood decay fungi.

Wood Decay Fungi is an indispensable resource for all arborists!

ISA

Retail Price: $27.95
ISA Member Price: $24.95
#02033

To order: 888-ISA-TREE • www.isa-arbor.com

CEU TEST QUESTIONS

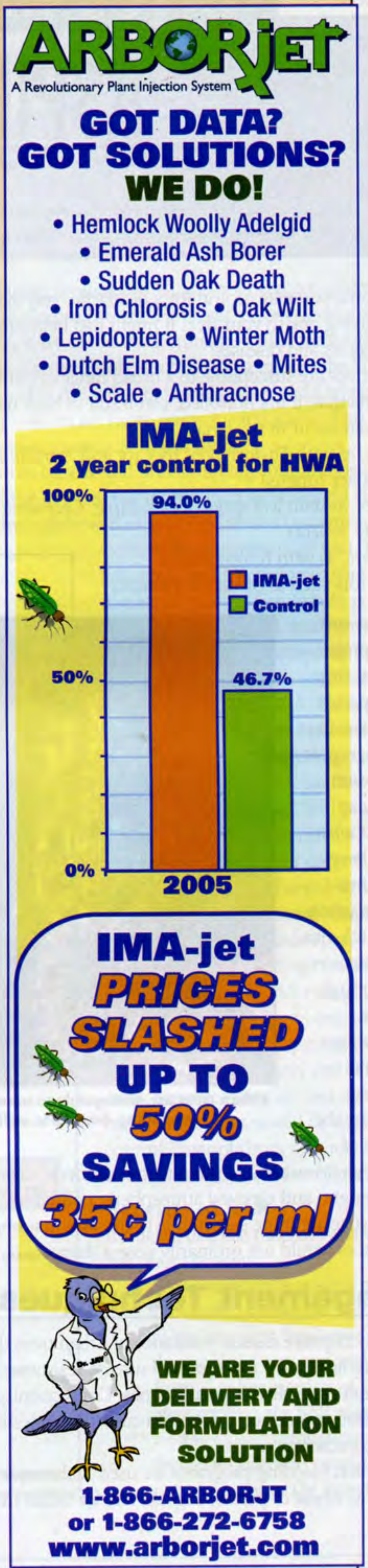
To receive continuing education unit (CEU) credit (1.0 CEU) for home study of this article, after you have read it, darken the appropriate circles on the answer form of the insert card in this issue of *Arborist News*. (A photocopy of the answer form is ***not*** acceptable.) A passing score for this test is 12 correct answers.

Next, complete the registration information, ***including your certification number***, on the answer form and send it to ISA, P.O. Box 3129, Champaign, IL 61826-3129. Answer forms for this test, **Identifying Wood Decay and Woody Decay Fungi in Urban Trees**, may be sent for the next 12 months.

You will be notified only if you do not pass. If you do not pass, ISA gives you the option of re-taking the quiz until you do achieve a passing score.

1. Wood decay is a disease because it
   a. attacks trees
   b. is contagious
   c. is caused by a biotic agent
   d. causes a progressive loss of wood strength
2. Wood decay of living trees is caused by
   a. bacteria
   b. fungi
   c. bacteria and fungi
   d. saturated wood fibers
3. Wood decay organisms can attack
   a. heartwood only
   b. sapwood only
   c. heartwood and sapwood
   d. bark, cambium, sapwood, and heartwood
4. Some wood decay organisms fruit and sporulate as
   a. conks or mushrooms
   b. bacterial ooze from stems
   c. imperfect fungi with conidia
   d. only as conks
5. Decay organisms attack wood by removing cellulose, hemicellulose, and lignin at the same time.
   a. true
   b. false
6. The most common type of wood decay is
   a. brown rot
   b. dry rot
   c. soft rot
   d. white rot

7. In general, soft rot is similar to brown rot because
   a. lignin between cells is removed
   b. bore holes are formed in cell lumens
   c. cellulose is degraded
   d. lignin is degraded
8. Decay reduces the strength of wood by
   a. maceration of rays, vessels, and tracheids
   b. enzymatic digestion of cellulose and lignin
   c. forming bore holes in ray cells
   d. all of the above
9. The compressive strength of wood is reduced most by
   a. brown rot
   b. dry rot
   c. soft rot
   d. white rot
10. Butt rot fungi may be found decaying
    a. the base of a tree
    b. the lower trunk of a tree
    c. the roots of a tree
    d. all of the above
11. The presence of numerous, small fruiting structures of a wood decay organism on tree bark indicates that
    a. sap rot is present
    b. initial invasion of live bark is occurring
    c. initial sporulation of a heart rot fungus has started
    d. epiphytes are on the bark of the tree
12. The presence of a single or a few conks on a living tree means
    a. extensive internal decay
    b. sap rot is present
    c. removal is recommended
    d. decay is present to some degree
13. The health of foliage is not a good indicator of decay because
    a. apoplastic health is not affected by decay
    b. decay mainly affects living wood
    c. symplastic health is not a good indicator of apoplastic health
    d. decay mainly affects living heartwood cells
14. "Potential indicators" of decay mean the tree
    a. has decay, but the extent is unknown
    b. might have decay, but the extent is unknown
    c. has decay and the extent is known
    d. might have decay, and failure is likely
15. In the absence of conks or mushrooms to identify a decay organism, decay symptoms
    a. can be named by the general location of the decay in the tree
    b. can assumed to be present if other positive indicators are found
    c. might be present if potential indicators are found
    d. all of the above
16. Wood decay fungi can be spread by
    a. airborne spores
    b. root contacts
    c. insects
    d. all of the above
17. Compartmentalization of decay in trees (CODIT), high sapwood moisture, and reaction zones are several models and theories that attempt to explain how decay is contained in a tree.
    a. true
    b. false
18. Identification of a wood decay conk or mushroom can help determine
    a. fungicidal treatments for decay
    b. how long to tree failure
    c. how much decay is present
    d. all of the above
19. Which of the following are the different types of spore layers of wood decay fungi?
    a. gills, pores, mazelike, roughened
    b. gills, pores, mazelike, toothed
    c. pores, mazelike, shelflike, toothed
    d. pores, mazelike, shelflike, mushrooms
20. The number of wood decay fungi on living trees
    a. is more than 500 in North America
    b. is relatively small compared to saprophytes
    c. can easily be determined by an autumn survey
    d. all of the above AN



Circle 135 on Reader Service card or go to www.isa-arbor.com/readerresponse/