Decay fungi of riparian trees in the Southwestern U.S.

Jessie A. Glaeser and Kevin T. Smith

Introduction: Most of the tree species that characterize riparian woodlands are early or facultative seral species including Fremont cottonwood (*Populus fremontii*), Arizona alder (*Alnus oblongifolia*), Arizona sycamore (*Platanus wrightii*), Modesto ash (*Fraxinus velutina*), boxelder (*Acer negundo*), and narrowleaf poplar (*Populus angustifolia*). Arizona walnut (*Juglans major*) is a riparian species that can persist at a low density in late seral or climax forests.

The Southwest is a harsh environment for trees. The frequent occurrence of early-seral tree species in riparian forests reflect the frequency, severity, and extent of disturbance events. Disturbance from fire, seasonal flooding, and landslides all provide special opportunity for injury and infection by wood decay fungi. Even riparian species can undergo periodic drought conditions as water levels drop during the heat of summer. Human activity can lead to soil compaction and root damage. Stressed trees are more susceptible to agents of mortality, including "opportunistic pathogens" that are only able to cause disease in weakened trees. Infections in a young tree can produce a cascade of processes that result in long-standing decay and cavities in large, mature individuals. As the tree loses structural support to decay, it becomes a potential hazard. The degree of hazard depends on the physical condition of the tree, including the presence of cracks and weak branch attachments, as well as the size and position of decayed wood and cavities. Identification of the fungi responsible for the decay improves prediction of tree performance and the quality of management decisions, including tree pruning or removal. Consequently, the hazard tree specialist needs a working knowledge of the fungi associated with hardwood decay. We present here some of the common fungi responsible for decay of riparian species of the Southwest. Many of these fungi are nonspecialized and will be encountered frequently throughout North America.

Wood decay fungi can be grouped in different ways. Academic mycologists use evolutionary or genetic relationships, largely discerned from DNA sequence analyses, to group fungi. In recent years, improved analytical techniques have greatly increased our understanding of fungal evolution and upended many traditional groupings of fungi that shared morphological similarities. Ecological groupings based on observations of fungal habitat, spatial position, and the appearance of the decayed wood (Tainter and Baker 1996), are also relevant to the hazard tree specialist. White-rot fungi degrade the lignin, cellulose and hemicellulose of wood, leaving behind a white or off-white residue. Some white-rot fungi produce many small pockets of decay throughout the infected volume of wood, a condition known as "pocket rot". Brown-rot fungi, on the other hand, degrade the cellulose and hemicellulose in the wood cell wall, but do not significantly degrade the lignin. Brown-rotted wood in advanced decay is often seen as more or less cubical fragments. Eventually, brown-rotted wood becomes a brown residue, composed largely of lignin, which becomes part of soil humus and resists further degradation. This brown-rot residue is an important component of the carbon sequestered in forest soil. White-rot fungi frequently decay hardwoods, and brown-rot fungi often colonize conifers, but many exceptions occur. The decayed wood within the tree can take different forms described by its appearance and texture, including "stringy rot," "spongy rot," "pocket rot," "cubical rot," and "laminated rot." Each of these decay types has different physical properties that affect the amount of strength remaining in the wood. In brown-rot decay, large amounts of strength loss occur early in the decay process due to the rapid depolymerization of cellulose (Cowling 1961). In white rot, wood strength declines more gradually with time.

...the hazard tree specialist needs a working knowledge of the fungi associated with hardwood decay.

An eco-nutritional approach groups some wood decay fungi as saprotrophs that attack wood in service or as felled logs, slash, or snags (Toupin et al. 2008) or as pathogens that decay wood in living trees. Pathogenic wood decay fungi can be further subdivided based on the type of wood degraded and the position of the fungus within the living tree. Heartrot fungi can decay heartwood in living trees despite the tree's ability to produce protective chemicals and low oxygen conditions in the central cylinder (Highley and Kirk 1979). When sapwood is exposed by

Glossary: Definitions of mycological terms
(Gilberston and Ryvarden, 1987)

Annulus – a ring found on the stipe of certain mushrooms.

Applanate- thin, flattened horizontally. Usually used to describe sessile fruiting bodies or the pileate portion of effused-reflexed fruiting bodies.

Dimidiate – semi-circular in outline when viewed from above.

Effused – flat (resupinate) with no pileus or shelf. Adheres entirely to the substrate.

Effused -reflexed – a fruiting body that is partially resupinate and partially shelving into the pileus.

Mycelium – the vegetative stage of the fungus, usually observable as a mass of individual threads, termed "hyphae."

Ochraceous – a yellowish buff color.

Pileus – the portion of a fruiting body with a sterile upper surface and a fertile lower surface.

Resupinate – flat

Rhizomorph – a macroscopic strand, often resistant to drying, that spreads throughout the soil. Black in Armillaria species.

Sessile – without a stipe [or stalk]

Stipe – stalk-like or stem-like structure that supports the pileus.

Stipitate – with a stipe. The stipe can be central or attached laterally (eccentric).

Ungulate – hoof-shaped.

mechanical injury, many saprot fungi can act as primary pathogens and directly kill living cells in advance of infection. These include canker rot and many root rot fungi (Shortle et al. 1996). Fruiting bodies of saprot fungi around the outer circumference of the stem can indicate structural weakness and increased risk for climbing arborists.

Many decay fungi can be categorized using the above static criteria. However, the great advance in understanding of the biology of wood decay in living trees involves the compartmentalization process (Shigo 1984), a foundation concept in forest pathology (Manion 2003). Prior to the description of the compartmentalization process, heartrot was thought to form by the direct infection of dead heartwood exposed by injury. In the compartmentalization concept, heartrot generally begins with the infection of sapwoodd by a succession of fungi. The spread of those fungi throughout the tree is resisted through the boundaries and barriers of compartmentalization (Smith 2006). As the vascular cambium continues to produce new xylem to the outside of existing wood, and healthy sapwood continues to be converted into heartwood, the infection becomes more or less centered in the middle of the tree. The early-seral tree species in this group do not have a strong compartmentalization response to resist the spread of infection after the wounding of live sapwood. Dead wood, including the dead wood attached to living trees, is generally of low durability and therefore decays readily. The inability of these species to compartmentalize and limit the development of further decay makes them particularly hazardous in highly trafficked areas.

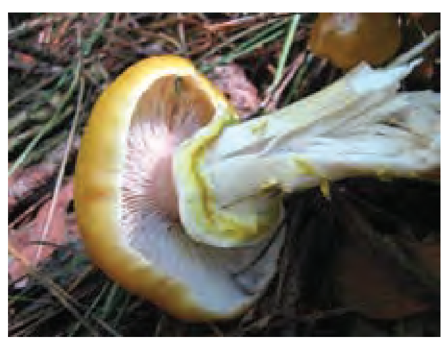
The types of decay, morphological features of the fruiting body, and a short discussion about the impact on hazard tree analysis are presented for some of the major decay fungi associated with riparian trees in the Southwest. A glossary of mycological terms is included.

Armillaria mellea

Although the traditional concept of *A. mellea* has been split into 10 biological species in North America, the name is still valid for the root-rot fungus present on hardwoods and some conifers in California and the Southwest. Fruiting bodies are gilled mushrooms, produced in clusters usually of 8 – 10 but sometimes 30 or more. The cap (pileus) is honey-colored, 3-13 cm wide, generally with a smooth surface, but which may show a few sparse hairs or scales on the upper surface. Gills are attached to the stalk (stipe), which tapers at the base and usually has a persistent ring, or "annulus," at the upper portion. Black rhizomorphs form on the surface of colonized roots and under the bark of infected trees (Burdsall and Volk 1993). Mycelial fans may also form

Armillaria mellea **cluster**

Armillaria mellea **gills**



Armillaria nabsnona **trudell**

beneath the bark of diseased roots and the root crown. *Armillaria mellea* may be the most virulent species of *Armillaria* in California, causing a serious whiterot of roots, especially in overwatered urban trees (Baumgartner and Rizzo 2001 a & b). Infected wood initially appears water-soaked, then becomes light colored and spongy with more advanced decay (Swiecki and Bernhardt 2006). It is also found among oaks in southern Arizona (Gilbertson et al 1974).

Armillaria nabsnona

Armillaria nabsnona is found on many hardwoods in western North America, most commonly on alder. Macroscopic characters that distinguish *A. nabsnona* from other North American species of *Armillaria* include a deeper orange coloration when fresh and a narrower stipe in comparison to the size of the cap. The stipe is darker than other *Armillaria* species, especially when dried. There are no scales, but small black hairs may be present on the surface of the pileus, as for *A. mellea*. *Armillaria nabsnosa* is often associated with dead wood in riparian zones and causes a white rot (Volk et al. 1996). In California, it is restricted to the northwestern redwood forest area and is primarily associated with living and dead red alder (*Alnus rubra*), tanoak (*Lithocarpus densiflorus*) and California laurel (*Umbellularia californica*) (Baumgartner and Rizzo 2001b).

Armillaria solidipes(= *Armillaria ostoyae*)

Armillaria solidipes is the most common species of *Armillaria* in Arizona (M. Fairweather, personal communication). It is usually associated with conifers but will also colonize hardwoods and causes a serious root- and butt-rot. In some areas it seems to be nonpathogenic (Klopfenstein et al. 2008) but may become an opportunistic pathogen on trees stressed by drought, insect attack or other factors. *Armillaria solidipes* can be differentiated from other species of *Armillaria* by its brown cap and stipe, the fairly prominent scales on the cap, and the well-developed ring (annulus). Mushrooms form in clusters at the base of affected trees and on the dead wood of fire scars and other wounds. The wood becomes yellow to brown in color and advanced decay appears water-soaked and stringy.

Bjerkandera adusta

"Smoky Polypore." Fruiting body effused-reflexed (growing flat against the surface, but with a shelflike edge) to sessile (stalkless), or shelf-like, up to 3 cm wide, frequently in large numbers or coalescing to form larger fruiting bodies or even large sheets on the underside of logs. The upper surface is pale yellow-white to pale creamy-buff, becoming grayish-white with age, smooth to finely fuzzy. The pore surface is pale gray to dark gray, sometimes with a brown tint. Pores are 5 – 7 per mm, circular, gray, and become angular with age. This fungus causes a whiterot of fallen wood, slash and standing snags of hardwoods, more rarely on conifers, and is very common in old aspen stands (Gilbertson and Ryvarden 1986). In Arizona, it is reported on Arizona alder, trembling aspen (*Populus tremuloides*), Gambel oak (*Quercus gambelii*), as well as southwestern white pine (*Pinus reflexa*) and Douglas-fir (*Pseudotsuga menziesii*) (Gilbertson et al. 1974).

Bjerkandera adusta

Coniophora puteana

Coniophora species

Fruiting bodies are thin, brown, and resupinate (flattened) with an irregular, wrinkled surface. There are no pores or teeth. The margin of the fruiting body is white and fringed. Mycelial cords may also be seen; these conduct water and allow the fungus to grow in relatively dry areas. Traditionally based on microscopic features, four common species were recognized in North America. Recent molecular studies show a high degree of genetic variability and a large number of cryptic species separable only by DNA sequence (Kaserud et al. 2007). Species of *Coniophora* form root and butt rots of living conifers but are largely saprotrophic on hardwoods. They are brown-rotters and form a brown, cubical rot that sequesters carbon into the soil for long-term storage (USDA Forest Service 2011). In Arizona, *Coniophora* species have been associated with alder, walnut, sycamore, and trembling aspen (Gilbertson et al. 1974).

Daedaelopsis confragosa

"Thin-walled Maze Flat Polypore." Fruiting bodies are annual but persistent, bracket-like, 2.5 – 15 cm wide, upper surface convex to flat with a thin, sharp margin, usually zonate, and may have matted hair on the surface or be smooth. They are gray to brown or reddish brown. The pore

Daedaelopsis confragosa — top

Daedaelopsis confragosa — gills

surface is poroid to maze- or gill-like, white to brownish, pink when buised. This fungus is extremely variable in appearance. It forms a whiterot on dead wood of many hardwood genera, more rarely on conifers. It is infrequent in the West and more common in the Northwest (Gilbertson and Ryvarden, 1986). In Arizona, it has been reported on Arizona alder (*Alnus oblongifolia*), Bigtooth maple (*Acer grandidentatum*), white fir (*Abies concolor*) and Douglas-fir (*Pseudotsuga menziesii*) (Gilbertson et al., 1974).

Ganoderma applanatum

"Artist's Conk." Fruiting body is perennial, 5 – 52 cm wide or even larger, convex, hoof-shaped to fan-shaped, sessile. The upper surface is hard, concentrically zonate and furrowed, gray to brown in color. The spore-bearing surface is poroid (pores clearly visible), white at first, becoming off-white to dingy yellow with age, staining brown upon bruising (the characteristic used by artists for etching). Pores are very small, 4 – 6 per mm. This fungus is very common, and may be solitary or in overlapping clusters on stumps, logs, or wounds of living trees (Binion et al. 2008). It forms a mottled whiterot of roots, root crown and trunks. In the East, the presence of conks can be cause for immediate removal of the affected tree as conks are often associated with advanced decay and potential failure (Luley 2005), and are frequently observed on stumps and fallen logs. In some parts of the West, conks are most frequently observed on big leaf maple (*Acer macrophyllum*) and bay laurel (*Umbellularia californica*) where they are not associated with advanced decay (D. Shaw personal communication). In Arizona, it is found almost exclusively on live aspen as a root and butt rot (M. Fairweather personal communication; Gilbertson and Ryvarden 1986). The fungus often enters a tree through wounds in exposed roots and base of tree. Decay commonly extends 1 – 2 m above and below the fruiting body. Decline and mortality are more pronounced during periods of environmental stress. *Ganoderma brownii*, which is more hoof-shaped and has an orange pore surface, is a closely related, but uncommon, species that occupies a similar niche in California (Swiecki and Bernhardt 2006). In Arizona, *G. applanatum* is primarily associated with trembling aspen as a root and buttrot (Gilbertson et al. 1974).

Ganoderma applanatum

Ganoderma lucidum

"Reishi," "Varnish Conk." Fruiting body annual, 2.5 – 3.5 cm wide, semi-circular to fan-shaped or kidney-shaped, surface with concentric zones and furrows, shiny, dark red, reddish-brown to orange-brown becoming ochre or yellow toward the margin. The stipe is lateral, 2.5 – 10 cm long and 0.5 – 4 cm thick. The spore-bearing surface is poroid, off-white to yellow initially, becoming brown with age or upon bruising. Pores are small, 4 – 7 per mm (Binion et al. 2008). This fungus causes a white root and butt rot of living native hardwoods and exotic ornamental hardwood trees and shrubs. Fruiting bodies develop at or near the ground line (Gilbertson and Ryvarden 1986). The fungus is found in California and the Southwest but not the Rocky Mountains or Pacific Northwest (Swiecki and Bernhardt 2006). In the Southwest, Ganoderma root rot causes the gradual decline and death of mature Fremont cottonwood. Fruiting bodies develop at the base of the tree during the rainy season (Olsen 1998). In Arizona, it has also been reported on river she-oak (*Casuarina cunninghamiana*), netleaf hackberry (*Celtis reticulata),* loquat (*Eriobotrya japonica*), Modesto ash, European olive (*Olea europea*), Arizona sycamore, Emory oak (*Quercus emoryi*), silverleaf oak (*Quercus hypoleucoides*), African sumac (*Rhus lancea*), and Peruvian peppertree (*Schinus molle*)(Gilbertson et al. 1974). In California, fruiting bodies generally do not form until there is extensive decay with an elevated risk of failure (Swiecki and Bernhardt 2006). This is in contrast to the eastern and Midwestern United States where the presence of fruiting bodies alone is usually not reason for tree removal (Luley 2005). The closely related varnish conks, *Ganoderma tsugae* and *G. oregonense,* are found on conifers.

Bjerkandera adusta

Gloeophyllum sepiarium — top

Gloeophyllum sepiarium — bottom

Hericium americanum

Gloeophyllum sepiarium

The fruiting bodies are annual to perennial, broadly sessile, up to 7 cm wide, 12 cm long and 6 – 8 cm thick at the base of the pileus, semicircular or rosette-shaped, often in clusters from a common base or fused laterally. The top of the fruiting body is initially a bright orange-brown but darkens with age to reddish brown and finally gray to black. The pore surface is pale brown, darkening with age. The pores resemble parallel gills (lamellae) mixed in with pored areas of variable size. This fungus causes a brown rot of dead hardwoods and conifers; ubiquitous throughout North America. It is quite resistant to high temperatures and dry conditions and can be found frequently on case-hardened logs throughout the West. It is more commonly associated with conifers, but is also present on alder, birch (*Betula*), hawthorn (*Crataegus*), poplar, cherry (*Prunus*), willow, and especially aspen. It is one of the most important brown-rot fungi in the creation of coarse woody debris (Gilbertson and Ryvarden 1986).

Gloeoporus dichrous

Fruiting bodies are annual, resupinate (flat) to pileate (with a cap), often effuse-reflexed, usually clustered in shelves. Soft when fresh but resinous and hard when dry. Caps are narrow with a white to cream upper surface and rarely above 4 cm wide, 10 cm long, and 5 mm thick at the base. The pore surface is initially light reddish, darkening to purple and brown with age. Pores are round to angular, 4 – 6 per mm, often quite shallow and appear more like a reticulated network than a traditional pore structure. This fungus is easy to recognize because of its deep reddish pore surface and the white, cottony pileus and context. The pore surface is gelatinous to rubbery and can be peeled away from the rest of the fruiting body with a finger nail when fresh. It causes a white rot on dead wood of many different hardwoods and may also be found on dead conifers. It can even fruit on top of other polypores. This fungus is widely distributed throughout North America (Gilbertson and Ryvarden 1986). In Arizona, *G. dichrous* occurs on Arizona sycamore and a variety of oak species (Gilbertson et al. 1974).

Hericium americanum

Fruiting bodies are large, up to 25 cm in diameter, and are composed of many branches with long white spines hanging down from the branch tips. Young specimens are white but age to yellow. The fruiting body is attached to the wood with a stout, thick stalk. It forms a white rot on the logs and standing trunks of hardwoods and conifers (Binion et al. 2008). In Arizona, it is associated with aspen (M. Fairweather personal communication).

Inonotus arizonicus

Basidiocarps form on the main trunk of trees or in large basal cavities. The fruiting bodies are annual, effused or effused-reflexed, up to 10 cm wide, 16 cm long, and 8 cm thick at the base, ungulate (hooflike) to applanate (flattened and spreading) with either a single pileus or several pilei stacked on top of each other. The upper and lower surfaces of the fruiting body are brown, with the pore surface bruising darker with handling. The pores are

Gloeoporus dichrous — top

Gloeoporus dichrous — bottom

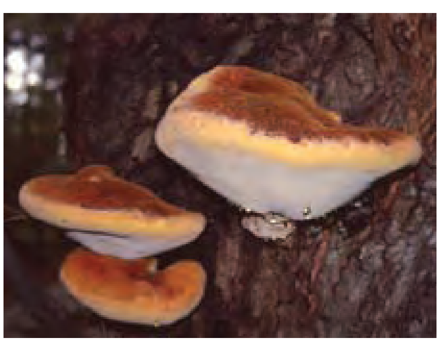
Inonotus arizonicus

angular, 3 – 5 per mm (Gilbertson and Ryvarden 1986). This fungus is the primary cause of heartrot of living Arizona sycamore in Arizona, New Mexico and California (Goldstein and Gilbertson 1981). The decay is a uniform white rot; brown thread-like masses may be present in advanced stages of decay. The fungus can continue to decay wood saprotrophically after tree death and may form fruiting bodies on dead standing and fallen trees. The fungus is common but only within the Southwest (Gilbertson and Ryvarden 1986).

Inonotus hispidus

"Shaggy Polypore." Fruiting body shelflike, dimidiate (semi-circular) broadly attached, usually solitary, up to 10 cm wide by 15 cm long by 8 cm thick at the base. Top, including the edge, is reddish orange, becoming reddish brown to nearly black with age, no zonations, but with many coarse hairs when young ("hispid"). Pore surface is yellow-brown becoming dark brown with age. Pores are angular, 1 – 3 per mm, becoming eroded and uneven. The fungus causes a white heartrot and saprot of living hardwoods and is commonly associated with trunk cankers on oaks. In Arizona, it is a major decay fungus of Arizona walnut and may often be found in association with *Phellinus weirianus.* It is quite common to see both fungi fruiting on the same tree (Gilbertson and Ryvarden 1986). *Inonotus hispidus* also occurs on boxelder (*Acer negundo*), California buckthorn (*Rhamnus californica*), and several species of oak (Gilbertson et al. 1974).

Inonotus hispidus



***Inonotus munzii* — close-up**

***Inonotus munzii* — distance**

Inonotus munzii

Fruiting bodies are sessile, often in large clusters on the trunk, applanate to hoof-shaped, 20 cm wide by 30 cm long by 6 cm thick at the base. The upper surface is initially a bright yellow brown becoming reddish brown with age. Pore surface is a yellow brown with angular pores, 2 – 4 mm/diameter. *Inonotus munzii* causes a major white heartrot of living hardwoods and continues to decay dead standing trees and stumps. It is one of the main decay fungi of willow and cottonwood in the Southwest. It is also common on California pepper tree (*Schinus molle*), white mulberry (*Morus alba*) and many ornamentals in southern AZ (Gilbertson and Ryvarden 1986). Inonotus heartrot is often associated with water-stressed trees or wounds. The fungus is not considered a primary pathogen, but stressed trees will decline over many years. Branch dieback is common and large dead branches should be removed in populated areas (Olsen 1998).

Laetiporus gilbertsonii

Fruiting bodies forming clusters of overlapping shelves, up to 20 cm wide, with a lateral narrow or wide stipe or sessile. Upper surface can be pale salmon-orange or pale pinkish-orange to tan or light brown in age, sometimes nearly white. Pore surface is lemon-yellow to pale lemon-yellow. Pores are initially circular, becoming more angular with age, 2 – 4 per mm, present along the stipe to the attachment point. This fungus causes a brown rot of hardwoods in the Southwest and is often associated with oak and eucalypts such as blue gum (*Eucalyptus globulus)* in living trees, dead trunks, and logs (Burdsall and Banik 2001). In Arizona, *Laetiporous gilbertsonii* has been observed on Modesto ash (M. Fairweather personal communication). The decay is a cubical brown heartrot that may lead to failure in the main stem or butt. Decay may progress into major roots (Luley 2005). The presence of *Laetiporus* fruiting bodies is often an indicator of extensive decay and should be taken seriously. *Laetiporus gilbertsonii*

Inonotus gilbertsonii

var. *pallidus* is similar but has a pale orange to pale brown pileus surface and a white pore surface. *Laetiporus conifericola* grows only on conifers (Burdsall and Banik 2001).

Perenniporia fraxinophila

Fruiting bodies are sessile, resupinate or effused-reflexed, either single or in clusters, hoof-shaped, up to 7 cm wide, 9 cm long, and 7 cm thick at the base. The upper surface is usually grayish-black. The pore surface is ivory to buff with circular to angular pores, 3-5 per mm. *Perenniporia fraxinophila* causes a white trunk rot of living ash trees and is also on other hardwoods as well as juniper. It is found throughout North America in the range of ash with the exception of the Pacific Northwest and Gulf Coast. It is very common on Modesto ash in Arizona and New Mexico (Gilbertson and Ryvarden 1987)

Phellinus everhartii

Fruiting body is perennial, sessile, and hoof-shaped, up to 6 cm wide, 13 cm long, and 8 cm thick at the base. The upper surface of conk is dark brown to black, velvety when young but becoming smooth and eroded with age. The spore bearing surface is poroid with a velvety appearance, dark chocolate brown, pores circular

Perenniporia fraxinophila

Phellinus everhartii

to angular, 5-6 per mm. It causes a white heartrot of living hardwoods, primarily on oak and also on walnut (USDA Forest Service 2013; Gilbertson and Ryvarden 1987). There are several other similar species that are difficult to distinguish without a microscope. It is common in the Southwest (Gilbertson and Ryvarden 1987).

Phellinus gilvus

"Mustard Yellow Polypore." Fruiting body annual to perennial, sessile or slightly effused-reflexed, solitary or shelving in large numbers, up to 7 cm wide, 12 cm long, and 3 cm thick at the base. This fungus is quite variable in appearance. The upper surface is dark yellow-brown to rusty brown, velvet when young, becoming smooth with age, tapering to a sharp margin. The spore-bearing surface is poroid, reddish brown to dark purple brown, with circular to angular pores, 1 – 5 per mm (Binion et al. 2006). *Phellinus gilvus* causes a white rot of heartwood of living oaks and a uniform white rot of dead wood of many hardwood species (Gilbertson and Ryvarden 1987). It is the most common conk on

Phellinus gilvus

Phellinus weirianus

oak and tanoak in California (Wood 2010). In Arizona, it occurs on alder, ash, walnut, sycamore, cherry, oak, mesquite (*Prosopis juliflora*), and Gooding's willow (*Salix gooddingii*) (Gilbertson et al. 1974).

Phellinus weirianus

Fruiting body is sessile and usually hoof-shaped, up to 30 cm wide by 20 cm long by 15 cm thick at the base. The upper surface darkens to black with age but has a golden brown margin. The pore surface is bright golden brown with small, circular pores 5 – 7 per mm. This fungus is found exclusively on *Juglans*, especially Arizona walnut (*J. major*), in the southwestern U.S. and Mexico. It forms a white heartrot of living walnut (Gilbertson and Ryvarden, 1987) and is frequently found in association with *Inonotus hispidus*.

Pleurotus ostreatus complex

"Oyster mushroom." The *Pleurotus ostreatus* complex is highly variable and contains many cryptic species that share morphological characteristics and have overlapping ranges. Early work (Vilgalys et al. 1993) differentiated 3 intersterility groups which corresponded to *Pleurotus ostreatus* (Group I), *Pleurotus pulmonarius* (Group II) and *Pleurotus populinus* (Group III). *Pleurotus populinus* is associated only with poplar and cottonwood. In this same paper, however, the vouchered specimen collected in a study on aspen-decaying fungi from Arizona (Lindsey and Gilbertson 1978) was *Pleurotus ostreatus*. It was noted that *P. pulmonarius* can also be

Pleurotus ostreatus

found on aspen and other *Populus* species, although it tends to favor higher, drier sites while *P. ostreatus* is more frequently associated with lowland areas along rivers and streams. These fungi are easily recognized as large, fleshy, white-to brown- to lilac-colored fruiting bodies that are select edibles. They tend to be gray to white and relatively thin-fleshed on oaks to thick fleshed, grey-brown shelves on cottonwood and willow. The cap can be 5 – 25 cm in diameter, convex to nearly flat at maturity with a margin that is lobed to wavy, especially when young. Surface of the cap is smooth. The gills are white, sometimes becoming yellowish with age. The gills continue onto the upper portion of the stalk, when present. The stalk is often absent but when present is short and thick, 0.5-3.0 cm long, 0.5-2.0 cm thick, eccentric or lateral with dense white hairs at the base. The fruiting body may have the odor of anise when fresh. It is usually found in a cluster of overlapping shelves on logs and boles of hardwoods. Fruiting begins in early fall and may continue through winter in the mild climates of California (Wood 2010). These fungi are all white-rotters and can be opportunistic pathogens (Dr. D. Rizzo personal communication).On cottonwood, *Pleurotus* sp. can cause a root and stem rot, resulting in tree decline, suppression, crown thinning, and eventual death (USFS 1975).

Polyporus species

The genus *Polyporus* is a large group of poroid fungi with a central to lateral stipe. Most species have a light to deep brown upper surface, are tough when fresh but woody when dried. Some of the common species are: *P. arcularius*, a smallish polypore (up to 4 cm wide) with a central stipe and radially arranged hexagonal pores; *P. badius* (= *Royoporus badius*), a fairly large (up to 15 cm broad) but thin polypore with a central or lateral stipe that is black and minutely hairy at its base; and *P. brumalis*, which is of medium size (up to 8 cm wide) with a central or lateral stipe and angular pores. All cause white rots of woody debris and dead trees (Binion 2008; Gilbertson and Ryvarden 1987).

Pycnoporus cinnabarinus

Fruiting bodies are annual, sessile to effused-reflexed, nearly round to elongated, rather leathery when fresh, and up to 7 cm wide, 13 cm long, and 4 cm thick at the base. The upper surface is reddish to apricot orange, lighter or darker with age. The pore surface is red and stays reddish longer than the upper surface. The pores are circular to angular, 3-4 per mm. This fungus forms a white rot of dead hardwood logs and stumps occurring only rarely

Rigidoporous ulmarius

on conifers. It is found throughout North America, including Alaska, and Canada (Gilbertson and Ryvarden 1987). In Arizona, it is associated with Freemont cottonwood, spiny cholla (*Opuntia spinosior*), Emory oak, and several species of pines (Gilbertson et al., 1974).*Pycnoporous sanguineus* is similar but the fruiting bodies are thinner, more brightly colored, and shiny (Kuo2010). It is also associated with a white rot of dead hardwoods. In Arizona, *Pycnoporus sanguineus*is primarily in the southern portion of the state and has been reported on Arizona walnut (*Juglans major*), Goodding's willow (*Salix gooddingii*), and Emory oak (*Quercus emoryi*) (Gilbertson et al., 1974).

Rigidoporous ulmarius

The fruiting bodies of this fungus are often very inconspicuous under exposed roots or in hollow, decayed areas at the base of trees. They can often be located by the heavy accumulation of white spores deposited nearby (Gilbertson et al. 1974). The fruiting bodies are perennial, sessile, effused-reflexed, and up to 9 cm wide,

Polyporus arcularius

***Polyporus arcularius* - pores**

Pycnoporus cinnabarinus

***Schizophyllum commune* — top**

***Schizophyllum commune* — gills**

30 cm long, and 6 cm thick at the base. The upper surface is buff to cream colored and often contains plant litter when it develops under roots or below the soil surface. The pore surface is pinkish buff when fresh, drying to a pale, brownish pink or darker brown. The pores are angular, 5 – 6 per mm and may require a hand lens to see. This fungus forms a yellow, stringy root and butt rot in living hardwoods and can continue to decay the wood after the tree is dead. It is very common on Fremont cottonwood (*Populus fremontii*) in Arizona and is found throughout the southern U.S. and Central America (Gilbertson and Ryvarden 1987).

Schizophyllum commune

"Split-gill Fungus." Fruiting bodies are leathery, fan-shaped brackets, 1 – 3.5 cm in diameter, frequently lobed or fused at the base with other brackets. The upper surface is densely hairy, light grayish-brown when moist but ashy grey to white when dry. The lower surface is light gray and consists of well-spaced, longitudinally split gills. The stipe is usually absent. The flesh is thin, light grey to brown, and tough. This fungus can be found year-round, usually in clusters, on dead boles and branches. (Wood 2010). It causes a white rot of dead hardwoods. In Arizona, it has been reported on Modesto ash (*Fraxinus velutina* 'Modesto') and Goodding's willow (*Salix gooddingii*) (Gilbertson et al. 1974).

Steccherinum ochraceum

Fruiting bodies are annual, broadly effuse, often resupinate or effuse-reflexed with a narrow pileus. They are tightly attached to the substrate. Individual patches sometimes coalesce to form very large fruiting bodies over the entire undersurface of major branches. The upper surface, when present, is wooly and white to gray to tan. The spore-bearing surface is orange to tan to slightly pinkish cinnamon and borne on spines up to 2 mm long. The margin of fruiting body is white and without spines. *Steccherinum ochraceum* is common on dead wood of many different hardwood trees (Binion et al. 2008). In Arizona, it has been reported on Arizona alder (*Alnus oblongifolia*), Arizona walnut (*Juglans major*), and blue spruce (*Picea pungens*) (Gilbertson et al. 1974).

Steccherinum ochraceum

Trametes species

The genus *Trametes* contains many common saprot fungi with broad host and geographical ranges. The group is characterized primarily by microscopic characteristics – the poroid fruiting bodies are formed from three different types of fungal hyphae which give them a characteristically hard, leathery texture. *Trametes versicolor*, the "Turkey Tail Fungus" has a zonate, multicolored upper surface varying from hairy to smooth or velvety in narrow concentric zones. It often forms large clusters of shelves. *Trametes cervina* is only faintly zonate and with much more subdued colors on the upper surface - predominantly shades of pinkish buff to cinnamon-buff or clay color – with coarse, stiff hairs. The pore surface is cinnamon-buff, becoming a darker brown with age. Pores are irregular, up to 1 mm in diameter and eventually split, forming tooth-like structures. All of these fungi are strong white-rotters (Gilbertson and Ryvarden 1987). *Trametes versicolor* can attack and colonize cambium adjacent to dead wood and form cankers. The presence of *Trametes* and other saprot fungi is an indication that the branch or section of trunk is dead and decayed. Sanitation pruning to remove infected branches is recommended since some of them can infect and colonize healthy tissue (Luley 2005).

Trichaptum biforme

"Violet-toothed Polypore." Fruiting bodies are annual, sessile or effused-reflexed, solitary or shelving, often coalescing to form large sheets. They

Trametes cervina

Trametes versicolor

Trichaptum biforme - top

Trichaptum biforme — bottom

can be up to 6 cm wide and 3 mm thick at the base. The upper surface is gray to tan, hairy to smooth, with concentric zones of thick and thin woolliness. Pore surface is purple to pink, especially at the margins, but becoming brown with age. Pores are initially angular, 3 – 5 per mm, but eventually erode and split to form tooth-like structures. This fungus is very common on fallen woody debris, logs and stumps of hardwoods (Binion et al. 2008) where it forms a white pocket rot of sapwood. The wood becomes lacy and fragile with small empty pockets (Gilbertson and Ryvarden 1987). *Trichaptum abietinum* is similar, but grows on conifers.

Photo credits: Photos used with permission and thanks from Ettore Balocchi, Harold H. Burdsall, Jr., Whitney Cranshaw, Mary Lou Fairweather, Jessie A. Glaeser, Larry Grand, Steven Katovich, Andrew Khitsun (http://www.wisconsonmushrooms.com), Steve Trudell, Michael Wood (http://www.mykoweb.com), and Thomas J.Volk (http://TomVolkFungi.net). Please contact senior author for permission to use photographs from this paper.

Jessie A. Glaeser, USFS, Northern Research Station, Madison, WI 53726 (jglaeser@fs.fed.us) and Kevin T. Smith, USFS, Northern Research Station, Durham, NH 03824 (ktsmith@fs.fed.us)

References

Baumgartner, K. and Rizzo, D.M. 2001a. Distribution of *Armillaria* species in California.Mycologia 93: 821-830.

Baumgartner, K. and Rizzo, D.M. 2001b. Ecology of *Armillaria* spp. in mixed-hardwood forests of California. Plant Dis. 85: 947-951.

Binion, D.E., Stephenson, S.L., Roody, W.C., Burdsall, H.H., Jr., Vasilyeva, L.N., and Miller, O.K., Jr. 2008.Macrofungi of Oak. Morgantown, WV: West Virginia University Press. 467 pp.

Burdsall, H.H. Jr. and Banik, M.T. 2001. The genus *Laetiporus* in North America. Harvard Papers in Botany 6: 43-55.

Burdsall, H.H. Jr. and Volk, T.J. 1993. The state of taxonomy of the genus *Armillaria*. McIlvainea 11:4-12.Modified version available at http://tomvolkfungi.net (accessed 05-26-2010**).**

Cowling, E.B., 1961: Comparative biochemistry of the decay of sweetgum sapwood by white-rot and brown-rot fungi. U.S. Dep. Agric. Tech. Bull. No. 1258, pp. 1–75.

Gilbertson, R.L., Martin, K.J., and Lindsey, J.P. 1974. Annotated check list and host index for Arizona wood-rotting fungi. Technical Bulletin 209. Tucson, AZ: Agricultural Experiment Station, University of Arizona, Tucson. 48 pp.

Gilbertson, R.L. and Ryvarden, L. 1986: North American Polypores. Vol. 1. Oslo: Fungiflora. 1-433.

Gilbertson, R.L. and Ryvarden, L. 1987: North American Polypores. Vol. 2. Oslo: Fungiflora. 437-885.

Goldstein, D. and Gilbertson, R.L. 1981. Cultural Morphology and Sexuality of *Inonotus arizonicus*. Mycologia 73:167-180.

Highley, T.L. and Kirk, T.K. 1979: Mechanisms of wood decay and the unique features of heartrots. Phytopathology 69(10): 1151- 1157.

Kauserud, H., Shalchian-Tabrizi, K., Decock, C. 2007. Multilocus sequencing reveals multiple geographically structured lineages of *Coniophora arida* and *C. olivacea* (Boletales) in North America. Mycologia 99: 705-713.

Klopfenstein, N.B., Hanna, J.W., Fairweather, M.L., Shaw, J.D., Mathiasen, R., Hoffman, C., Nelson, E., Kim, M.S., Ross-Davis, A.L. 2011.Developing a prediction model for *Armillaria solidpes* in Arizona. In: Zeglen, S. and Palacios, P. [eds]. Proceedings of the 59th Annual Western International Forest Disease Work Conference; 2011 October 10-14; Leavenworth, WA.

Kuo, M. 2010.*Pycnoporus cinnabarinus*. Retrieved from the MushroomExpert.Com Web site: http://www.mushroomexpert.com/pycnoporus_cinnabarinus.html (accessed 04-23-2013)

Lindsey, J.P. and Gilbertson, R.L. 1978. Basidiomycetes that decay aspen in North America. Germany: J. Cramer. 406 pp.

Luley, C. J., 2005: Wood Decay Fungi Common to Urban Living Trees in the Northeast and Central United States. Naples, NY: Urban Forestry LLC. 60 pp.

Manion, P.D. (2003) Evolution of concepts in forest pathology. Phytopathology 93: 1052–1055.

Olsen, M. 1998. Extension Plant Pathology – Plant Disease Identification. University of Arizona, Tucson.[Available at http://ag.arizona.edu/PLP/plpext/index.html (accessed 04-10 -013)].

Shigo, A.L. 1984. Compartmentalization: a conceptual framework for understanding how trees grow and defend themselves. Annual Review of Phytopathology 22: 189–214.

Shortle, W.C., Smith, K.T., and Dudzik, K.R. 1996: Decay diseases of stemwood: Detection, diagnosis, and management. In: Forest Trees and Palms. Ed. by Raychaudhuri, S.P.; Maramorosch, Karl, New Delhi, India: Oxford & IBH Publishing: 95-109. [Available at http://www.nrs.fs.fed.us/pubs/5514 (accessed 04-24-2013)].

Smith, K.T. 2006.Compartmentalization today. Arboricultural Journal 29, 173-184.

Swiecki, T.J. and Bernhardt, E.A. A Field Guide to Insects and Diseases of California Oaks. PSW-GTR-197. Washington D.C.: U.S. Forest Service, Pacific Southwest Research Station. 152 pp.

Tainter, F.H. and Baker, F.A. 1996: Principles of Forest Pathology. New York: John Wiley and Sons. 805 pp.

Toupin, R., Filip, G., Erkert, T., Barger, M. 2008. Field Guide for Danger Tree Identification and Response. R6-NR-FP-PR-01-08. Washington, DC: U.S. Forest Service. 64 pp.

U.S. Department of Agriculture, Forest Service, Northern Research Station. 2013. Center for Forest Mycology Research Herbarium Database. http://www.fpl.fs.fed.us/research/centers/mycology/culture-collection.shtml (accessed 04-24-2013).

U.S. Department of Agriculture, Forest Service, Forest Health Protection, Rocky Mountain Region. 2011. Coniphora root and butt rot. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5353724.pdf (accessed 04- 15-2013).

U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station and Southeastern Area, State and Private Forestry. 1975. Insects and diseases of Cottonwood. GTR-SO-8. 27-30.http://www.srs.fs.usda.gov/pubs/gtr/gtr_so008.pdf (accessed 04-18-2013).

Vilgalys, R., Smith, A., Sun, B.L., and Miller, O.K. 1993. Intersterility groups in the *Pleurotus ostreatus* complex from the continental United States and adjacent Canada. Can. J. Bot. 71: 113-128.

Volk, T.J., Burdsall, H.H. Jr., and Banik, M.T. 1996. *Armillaria nabsnona*, a new species from western North America.Mycologia 88:484-491.

Wood, M. 2010. Mykoweb-California Fungi, version 2010.07.21. Available at: http://www.mykoweb.com/CAF/index.html. (accessed 04-24-2013).

Home study for CEUs

You may receive one hour of Certified Arborist and/or WCISA Certified Tree Worker continuing education units (CEUs) for reading the following article and completing the test questions. Copy the question pages and use it to record your answers. Darken the correct letter choices and circle your choice for true and false or correct choice questions. Each question has only one correct answer. Passing score for this test is 15 correct answers (80%).

Next, complete the registration information on this form and send it to:

WCISA Administrative Office
31883 Success Valley Dr.
Porterville, CA 93257
559-784-8711 fax

Note: If 80 percent or greater of the questions have been answered correctly, the ISA will be notified of the CEU assignment for Certified Arborists and it will be posted by the ISA. The Western Chapter will post the CEU for Certified Tree Workers. If a passing score is not achieved, the test will be returned for corrections. No CEU confirmations will be sent to you.

Registration Information

Name: ________________

Cert. # ________________

Address: ______________
City: ________________

State: ______ Zip: _______

Home study for CEUs: Decay fungi of riparian trees in the Southwestern U.S.

Fall, September 30, 2013 — Expiration date for submitting answer sheet is October 1, 2014. The CEUs from this article can only be applied to the 3-year current certification period.

1. Riparian forests are prone to injury and infection by wood decay fungi due to frequent disturbance events. **T** or **F**?
2. Scientists are now relying more on DNA sequence analysis rather than traditional groupings of organisms on the basis of shared morphological similarities to establish genetic relationships among fungi and other organisms. **T** or **F**?
3. Observations based on fungal habitat, spatial position (location in tree), and the appearance of the decayed wood is of little value to risk assessment specialists. **T** or **F**?
4. **White** / **brown** rot fungi degrade the cellulose and hemicellulose in the wood cell wall, but do not significantly degrade the lignin. (**circle correct choice**)
5. Brown-rotted wood in advanced decay is often seen as cubical fragments. **T** or **F**?
6. White-rot fungi are more frequently associated with **hardwoods** / **conifers** and brown rot fungi are more frequently associated with **hardwoods** / **conifers** (**circle correct choices**)
7. Many small pockets of decay throughout the infected volume of wood, describes a type of rot known as? ________________
8. Significant strength loss occurs early in the decay process when white rot fungi are involved. **T** or **F**?
9. Loss of wood strength occurs gradually when brown rots are involved. **T** or **F**?
10. Wood decay fungi that attack wood in service or as felled logs, slash, or dead trees are referred to as ________________
11. Wood decay fungi that can attack woody tissue of living trees are called? ________________
12. Pathogenic wood decay fungi can be further subdivided into **two** categories based on the position of the fungus within the living tree and type of wood they degrade. Name them: __________, ________________
13. Fruiting bodies of saprot fungi around the outer circumference of the stem usually do not indicate structural weakness because the decay is superficial. **T** or **F**?
14. Early-seral tree species generally strongly resist the spread of infection after the wounding of live sapwood.**T** or **F**?
15. Dead wood of early-seral tree species, including the dead wood attached to living trees, is generally of low durability and therefore decays readily. **T** or **F**?
16. Early-seral tree species in highly trafficked areas are of special concern because they are typically weak compartmentalizers. **T** or **F**?
17. White mycelial fans under the bark of diseased roots and the root crown often associated with clusters of gilled mushrooms indicate what genus of root rotting fungi? ________________
18. Fruiting bodies are variable, but upper the surface is dark yellow-brown to rusty brown and velvet when young; it is the most common conk on oak and tanoak in California, causing a white rot of heartwood of living oaks and a uniform white rot of dead wood of many hardwood. This best describes what fungus? ________
19. A common saprot fungus that can invade living sapwood. Fruiting bodies are hard, and leathery and often found in clusters on branches or dead tissue. The upper surface is zonate multicolored, somewhat resembling a turkey's tail. This best describes what fungus? ________________