5 Biological Properties of Wood

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There are numerous biological degradations that wood is exposed to in various environments. Biological damage occurs when a log, sawn product, or final product is not stored, handled, or designed properly. Biological organisms such as bacteria, mold, stain, decay fungi, insects, and marine borers depend heavily on temperature and moisture conditions to grow. Figure 5.1 gives the climate index for decay hazard for the United States of America. The higher the number means a greater decay hazard. The southeastern and northwest coasts have the greatest potential, and the southwest has the lowest potential for decay. This chapter will first focus on the biological organisms and their mechanism of degradation, and then prevention measures. If degradation cannot be controlled by design or exposure conditions, then protection with preservatives is warranted.

5.1 BIOLOGICAL DEGRADATIONS

5.1.1 BACTERIA

Bacteria, the early colonizers of wood, are single-celled organisms that can slowly degrade wood that is saturated with water over a long period of time. They are found in wood submerged in seawater and

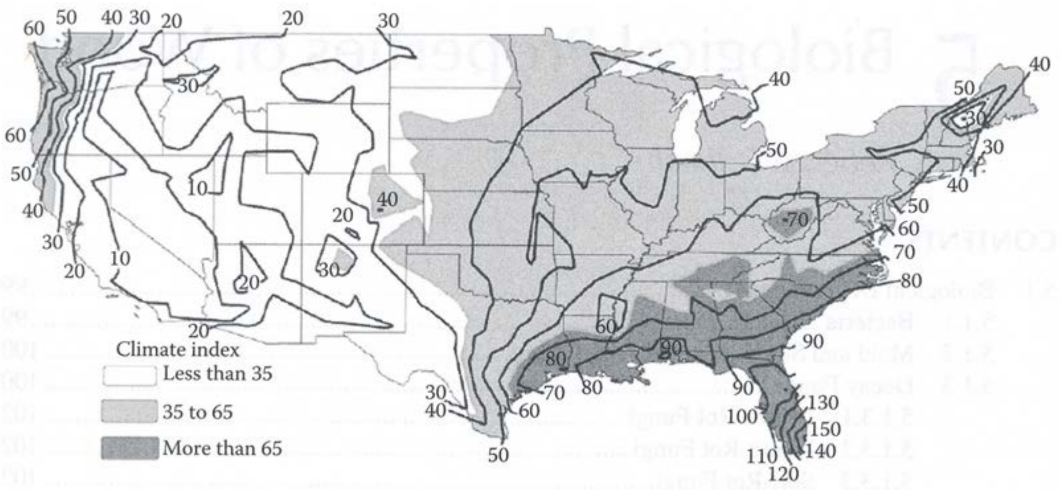

FIGURE 5.1 Climate index for decay potential for wood in service. Higher numbers (darker areas) have greater decay hazard.

freshwater, aboveground exposure, and in-ground soil contact. Logs held under water for months may have a sour smell attributed to bacteria. Bacteria usually have little effect on the properties of wood except over a long time period. Some bacteria can make the wood more absorptive which can make it more susceptible to decay. When dried, the degraded area develops a cross checking on the tangential face. The sapwood is more susceptible than the heartwood and the earlywood more than the latewood.

5.1.2 MOLD AND STAIN

Mold and stain fungi cause damage to the surface of wood, and only differ on their depth of penetration and discoloration. Both grow mainly on sapwood and are of various colors. Molds are usually fuzzy or powdery growth on the surface of wood and range in color from different shades of green, to black or light colors. On softwoods, the fungal hyphae penetrate into the wood, but it can usually be brushed or planed off. On the other hand, on large pored hardwoods, staining can penetrate too deeply to be removed.

The main types of fungus stains are called sapstain or blue stain. They penetrate deeply into the wood and cannot be removed by planing. They usually cause blue, black, or brown darkening of the wood, but some can also produce red, purple, or yellow colors. Figure 5.2 shows the discoloration on a cross section of wood that appears as pie-shaped wedges that are oriented radially.

The strength of the wood is usually not altered by molds and stains (except for toughness or shock resistance), but the absorptivity can be increased making it more susceptible to moisture and then decay fungi. Given moist and warm conditions, mold and stain fungi can establish on sapwood logs shortly after they are cut. To control mold and stain, the wood should be dried to less than 20% moisture content or treated with a fungicide. Wood logs can also be sprayed with water to increase the moisture content to protect wood against fungal stain, as well as decay.

5.1.3 DECAY FUNGI

Decay fungi are single-celled or multicellular filamentous organisms that use wood as food. Figure 5.3 shows the decay cycle of wood. The fungal spores spread by wind, insects, or animals. They germinate on moist, susceptible wood, and the hyphae spread throughout the wood. These hyphae secrete enzymes that attack the cells and cause wood to deteriorate. After serious decay, a new

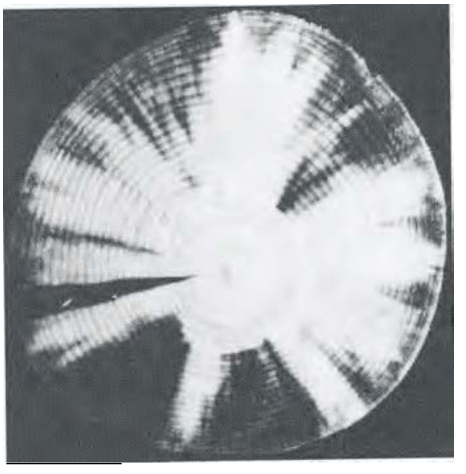

FIGURE 5.2 Radial penetration of sapstain fungi in a cross section of pine.

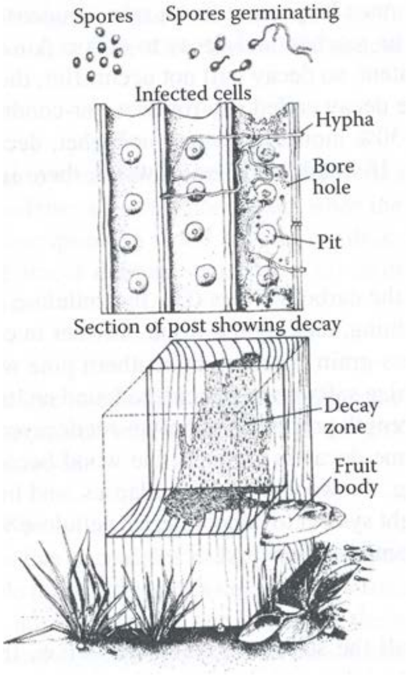

FIGURE 5.3 The wood decay cycle.

fruiting body may form. Brown-, white-, and soft-rot fungi all appear to have enzymatic systems that demethoxylate lignin, produce endocellulases, and use single-electron oxidation system to modify lignin, with some fungi (Eaton and Hale 1993).

In the early or incipient stage of wood decay, serious strength losses can occur before it is even detected (see Chapter 10). Toughness or impact bending is most sensitive to decay. With incipient decay the wood may become discolored on unseasoned wood, but it is harder to detect on dry wood. The advanced stages of wood decay are easier to detect. Decayed wet wood will break across the grain, while sound wood will splinter.

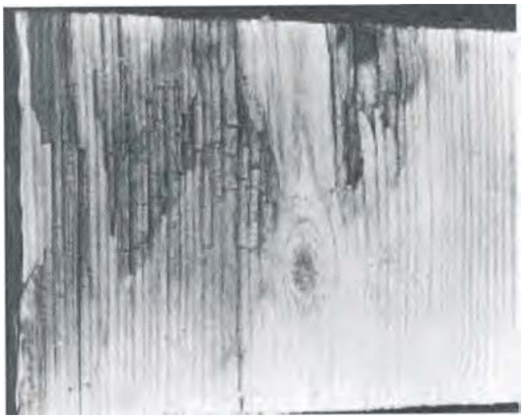

FIGURE 5.4 Brown-rot decay of southern pine wood.

Decay fungi need food (hemicellulose, cellulose, and lignin), oxygen (air), the right temperature (10-35°C; optimum 24-32°C), and moisture (above the fiber saturation point; about 30% moisture content) to grow. Free water must be present (from rain, condensation, or wet ground contact) for the fiber saturation point to be reached and decay to occur. Air-dried wood will usually have no more than 20% moisture content, so decay will not occur. But, there are a few fungi that transport water to dry wood and cause decay called dry-rot or water-conducting fungi. When free water is added to wood to attain 25-30% moisture content or higher, decay will occur. Yet, wood can be too wet or too dry for decay. If wood is soaked in water, there is not enough air for the fungi to develop.

5.1.3.1 Brown-Rot Fungi

Brown-rot fungi decompose the carbohydrates (i.e., the cellulose and hemicelluloses) from wood, which leaves the lignin remaining, making the wood browner in color, hence the name. Figure 5.4 shows the dark color and cross-grain checking of southern pine wood caused by brown-rot decay. Brown-rot fungi mainly colonize softwoods, but can be found on hardwoods as well. Because of the attack on the cellulose, the strength properties of brown-rot decayed wood decrease quickly, even in the early stages. When extreme decay is attained, the wood becomes a very dark, charred color. After the cross-grain cracking, the wood shrinks, collapses, and finally crumbles. Brown-rot fungi first use a low molecular weight system to depolymerize cellulose within the cell wall, and then use endocellulases to further decompose the wood.

5.1.3.2 White-Rot Fungi

White-rot fungi decompose all the structural components (i.e., the cellulose, hemicellulose, and lignin) from wood. As the wood decays it becomes bleached (in part from the lignin removal) or "white" with black zone lines. White-rot fungi occur mainly on hardwoods, but can be found on softwoods as well. The degraded wood does not crack across the grain until it is severely degraded. It keeps its outward dimensions, but feels spongy. The strength properties decrease gradually as decay progresses, except toughness. White-rot fungi have a complete cellulase complex and also the ability to degrade lignin.

5.1.3.3 Soft-Rot Fungi

Soft-rot fungi are related to molds, and occur usually in wood that is constantly wet, but can also appear on surfaces that encounter wet-dry cycling. The decayed wood typically is shallow in growth and "soft" when wet, but the undecayed wood underneath is still firm. Upon drying, the decayed surface is fissured. Figure 5.5 shows surface checking of soft-rotted wood when dry. The wood

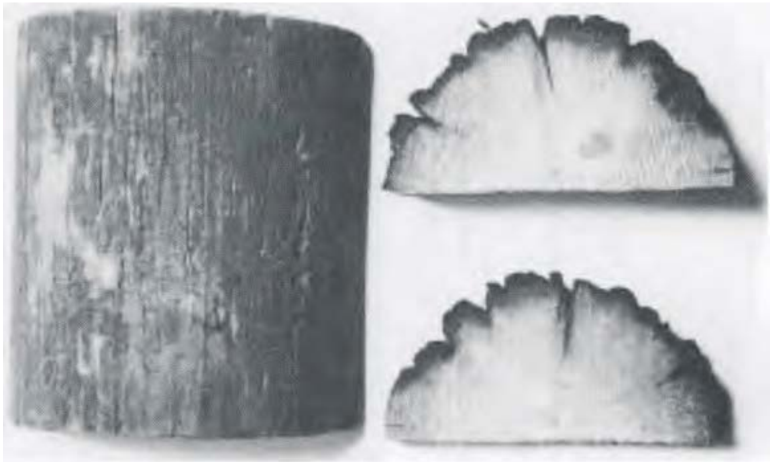

FIGURE 5.5 Soft-rot decay of a treated pine pole.

becomes darker (dull-brown to blue-gray) when decayed by soft-rot fungi. Soft-rot fungi first have a system to free the lignin in the wood to then allow the cellulases access to the substrate.

5.1.4 INSECTS

Insects are another biological cause of wood deterioration. Both the immature insect and the adult form may cause wood damage, and they are often not present when the wood is inspected. Therefore, identification is based on the description of wood damage as described in Table 5.1. Figure 5.6 shows pictures of four types of insect damage caused by: (a) termites, (b) powder-post beetles, (c) carpenter ants, and (d) beetles.

5.1.4.1 Termites

Termites are the size of ants and live in colonies. Figure 5.7 is a map of the United States showing the northern limit, (a) of the subterranean termites that live in the ground, and (b) drywood termites or nonsubterranean which live in wood.

5.1.4.1.1 Subterranean Termites

The native subterranean termites live in colonies in the ground; have three stages of metamorphosis (egg, nymph, and adult); and have three different castes (reproductives, workers, and soldiers). They can have winged and wingless adults living in one colony at the same time. Two reproductives (swarmers) are needed to start a colony. Figure 5.8 shows the difference between a winged termite (a) and a winged ant (b). The termite has longer wings and no waist indentation. They are light tan to black, with four wings, three pairs of legs, one pair of antennae, a pair of large eyes, and about 8-13 mm long. Thousands of the swarmers are released from a colony during the daylight hours in the spring or early summer. They fly a short way and then lose their wings. Females attract the males, they find a nesting site, and eggs are laid within several weeks. The worker members are the ones that cause the destruction of the wood.

Moisture is critical for the termites, either from their nest in the soil, or the wood they are feeding on. They will form shelter tubes made of particles of soil, wood, and fecal material. These shelter tubes protect the termites and allow them to go from their nest in the soil to the wood above ground. Termites prefer eating the softer earlywood than the harder latewood.

To protect a house from termites, the soil should be treated with an insecticide, as well as the use of good design and construction practices, such as building the foundation with concrete or

TABLE 5.1
Description of Wood Damage Caused by Insects

Type of Damage	Description	Causal Agent	Damage: Begins	Damage: Ends
Pin holes	0.25-6.4 mm (1/100-1/4 in.) in diameter, usually circular			
	Tunnels open:			
	Holes 0.5-3 mm (1/50-1/8 in.) in diameter; usually centered in dark streak or ring in surrounding wood	Ambrosia beetles	In living trees and unseasoned logs and lumber	During seasoning
	Holes variable sizes; surrounding wood rarely dark stained; tunnels lined with wood-colored substance	Timber worms	In living trees and unseasoned logs and lumber	Before seasoning
	Tunnels packed with usually fine sawdust:			
	Exit holes 0.8-1.6 nun (1/32-1/16 in.) in diameter; in sapwood of large-pored hardwoods; loose floury sawdust in tunnels	Lyctid powder-post beetles	During or after seasoning	Reinfestation continues until sapwood destroyed
	Exit holes 1.6-3 mm (1/16-1/8 in.) in diameter; primarily in sapwood, rarely in heartwood; tunnels loosely packed with fine sawdust and elongate pellets	Anobiid powder-post beetles	Usually after wood in use (in buildings)	Reinfestation continues; progress of damage very slow
	Exit holes 2.5-7 mm (3/32-9/32 in.) in diameter; primarily sapwood of hardwoods, minor in softwoods; sawdust in tunnels fine to coarse and tightly packed	Bostrichid powder-post beetles	Before seasoning or if wood is rewetted	During seasoning or redrying
	Exit holes 1.6-2 mm (1/16-1/12 in.) in diameter; in slightly damp or decayed wood; very fine sawdust or pellets tightly packed in tunnels	Wood-boring weevils	In slightly damp wood in use	Reinfestation continues while wood is damp
Grub holes	3-13 mm (1/8-1/2 in.) in diameter; circular or oval			
	Exit holes 3-13 mm (1/8-1/2 in.) in diameter; circular; mostly in sapwood; tunnels with coarse to fibrous sawdust or it may be absent	Roundheaded borers (beetles)	In living trees and unseasoned logs and lumber	When adults emerge from seasoned wood or when wood is dried
	Exit holes 3-13 mm (1/8-1/2 in.) in diameter; mostly oval; in sapwood and heartwood; sawdust tightly packed in tunnels	Flatheaded borers (beetles)	In living trees and unseasoned logs and lumber	When adults emerge from seasoned wood or when wood is dried
	Exit holes -6 mm (-1/4 in.) in diameter; circular; in sapwood of softwoods, primarily pine; tunnels packed with very fine sawdust	Old house borers (a roundheaded borer)	During or after seasoning	Reinfestation continues in seasoned wood in use

	Exit holes perfectly circular, 4-6 mm (1/6-1/4 in.) in diameter; primarily in softwoods; tunnels tightly packed with coarse sawdust, often in decay softened wood	Woodwasps	In dying trees or fresh logs	When adults emerge from seasoned wood, usually in use, or when kiln dried
	Nest entry hole and tunnel perfectly circular -13 mm (-1/2 in.) in diameter; in soft softwoods in structures	Carpenter bees	In structural timbers, siding	Nesting reoccurs annually in spring at same and nearby locations
Network of galleries	Systems of interconnected tunnels and chambers	Social insects with colonies		
	Walls look polished; spaces completely clean of debris	Carpenter ants	Usually in damp partly decayed, or soft-textured wood in use	Colony persists unless prolonged drying of wood occurs
	Walls usually speckled with mud spots; some chambers may be filled with "clay"	Subterranean termites	In wood structures	Colony persists
	Chambers contain pellets; areas may be walled-off by dark membrane	Dry-wood termites (occasionally damp wood termites)	In wood structures	Colony persists
Pitch pocket	Openings between growth rings containing pitch	Various insects	In living trees	In tree
Black check	Small packets in outer layer of wood	Grubs of various insects	In living trees	In tree
Pith fleck	Narrow, brownish streaks	Fly maggots or adult weevils	In living trees	In tree
Gum spot	Small patches or streaks of gum-like substances	Grubs of various insects	In living trees	In tree
Ring distortion	Double growth rings or incomplete annual layers of growth	Larvae of defoliating insect or flatheaded cambium borers	In living trees	In tree
	Stained area more than 25.4 mm (1 in.) long introduced by insects in trees or recently felled logs	Staining fungi	With insect wounds	With seasoning

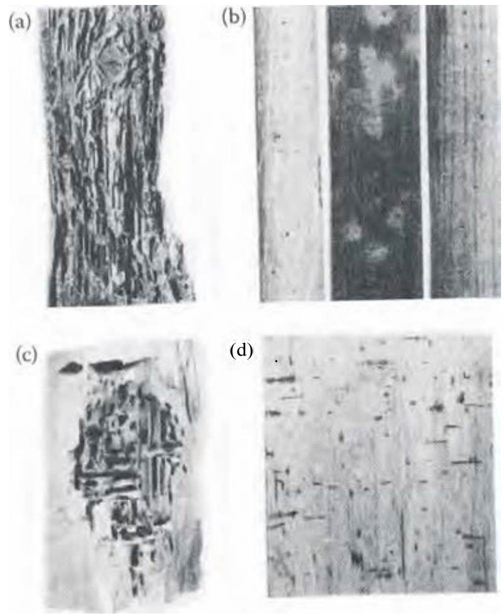

FIGURE 5.6 Types of insect damage caused by: (a) termites, (b) powderpost beetles, (c) carpenter ants, and (d) beetles.

FIGURE 5.7 Map of termite location in the United States. (a) Subterranean northern limit and (b) drywood termites northern limit.

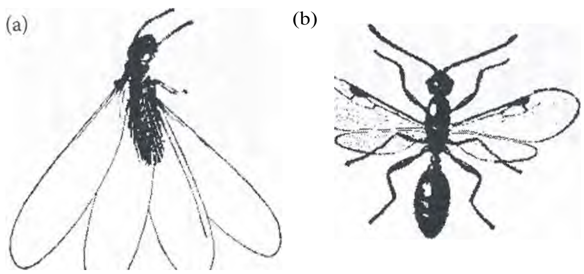

FIGURE 5.8 A winged termite with long wings (a) and a winged ant with a waist indentation (b).

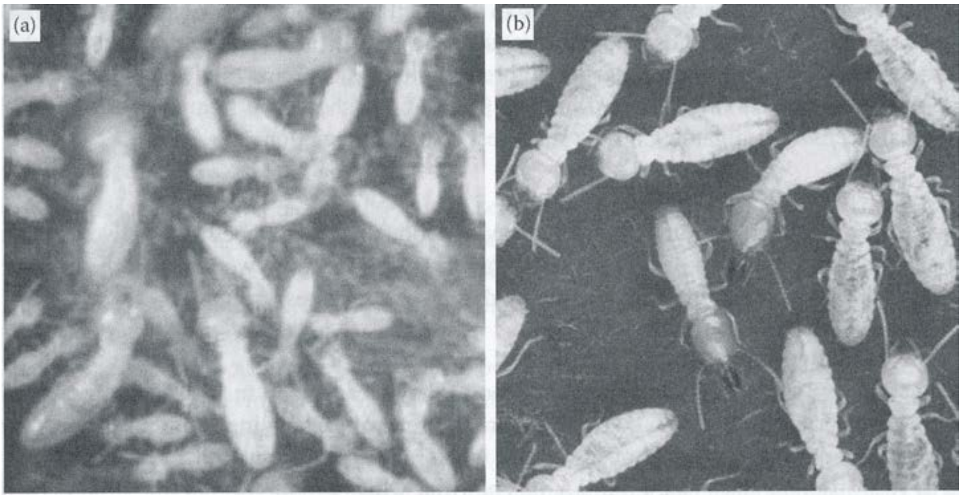

FIGURE 5.9 Subterranean termites (a) and Formosan termites (b).

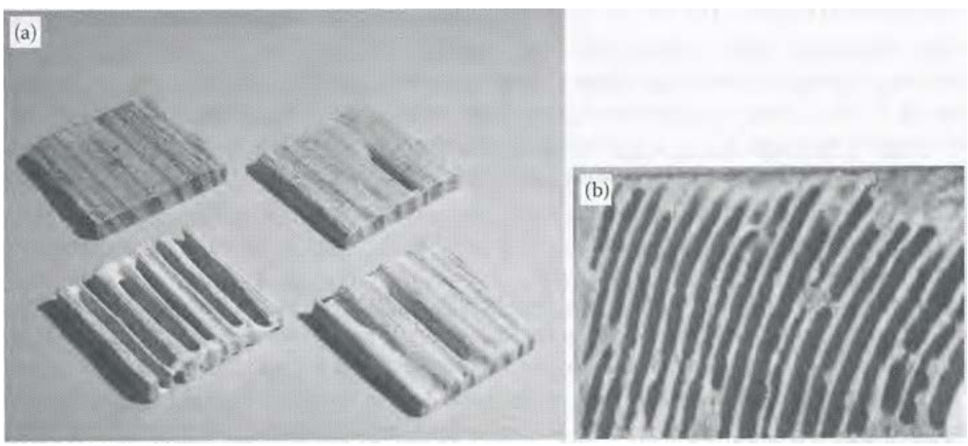

FIGURE 5.10 Subterranean termite attack of wood: (a) "grazing" to final degradation and (b) removal of predominantly spring wood.

pressure-treated wood. If termites get into a building, then a termite control specialist from a national pest control operator association should be contacted.

Figure 5.9 shows subterranean and Formosan termites and Figure 5.10 shows subterranean termite attack from "grazing" to final degradation. Note that this termite attacks the softer spring wood rather than the harder latewood.

5.1.4.1.2 Formosan Subterranean Termites

The Formosan subterranean termite is originally from the Far East. It moved to Hawaii, other Pacific islands, California, Texas, and the southeastern United States. The Formosan termite multiplies and causes damage quicker than the native subterranean species. It nests in wood that is wet from prolonged periods and is good at starting aboveground colonies. Infestation control measures are the same as for the native species, but treatment should be performed within a few months.

5.1.4.1.3 Nonsubterranean (Drywood) Termites

Nonsubterranean termites are found in the southern edge of the continental United States from California to Virginia, the West Indies, and Hawaii. Drywood termites do not multiply as quickly as the subterranean termites, but they can live in drywood without outside moisture or ground contact. Infestations can enter a house in wood products such as furniture. Prevention includes examining all wood and cellulose-based materials before bringing inside, removing woody debris from the outside, and using preservative-treated lumber. Infestations should be treated or fumigated by a professional licensed fumigator. Call the state pest control association.

5.1.4.1.4 Dampwood Termites

Dampwood termites colonize in damp and decaying wood and do not need soil to live, if the wood is wet enough. They are most prevalent on the Pacific Coast. Keeping wood dry is the best protection for preventing colonization and damage by dampwood termites.

5.1.4.2 Carpenter Ants

Carpenter ants use wood for shelter instead of food. They prefer wood that is soft or decayed. They can be black or brown and live in colonies. There are several casts: winged and unwinged queens, winged males, and different sizes of unwinged workers. Carpenter ants have a narrow waist and wings of two different sizes (see Figure 5.8). The front wings are larger than the hind ones. They create galleries along the grain of the wood and around annual rings. They attack the earlywood first, and only the latewood to access between the galleries. Once a nest is established, it can extend into sound wood (Figure 5.11). The inside of the gallery is smooth and clean because the ants keep removing any debris, unlike the termites.

One way to keep carpenter ants from colonizing wood is to keep moisture out and decay from happening. If they do get into the house, then the damaged wood should be removed and the new wood should be kept dry. If it is not possible to keep the wood dry, then a preservative-treated lumber should be used. To treat indoors with insecticides, the state pest control association should be called.

5.1.4.3 Carpenter Bees

Carpenter bees are like large bumblebees, but they differ in that their abdomens shine because the top is hairless. The females make 13 mm tunnels into unfinished softwood to nest. The holes are partitioned into cells, and each cell holds one egg, pollen, and nectar. Carpenter bees reuse nests year after year, therefore some tunnels can be quite long with many branches. They can nest in stained, thinly painted, light preservative salt treatments, and bare wood. To control carpenter bees, an insecticide can be injected in the tunnel, plugged with caulk, and then the entry hole surface treated so that the bees do not use it again the next year. A thicker paint film, pressure preservative treatments, screens, and tight-fitting doors can help prevent nesting damage.

5.1.4.4 Beetles

Table 5.1 describes the types of wood damage that results from various beetles.

5.1.4.4.1 Lyctid Powderpost Beetles

Lyctid beetles cause significant damage to dry hardwood lumber, especially with large pores such as oak, hickory, and ash. They are commonly called powderpost beetles because they make a fine,

FIGURE 5.11 Carpenter ant damage extending into sound wood.

powdery sawdust during infestation. Activity and damage is greatest when the moisture content of wood is between 10% and 20%, but activity can occur between 8% and 32% moisture content. Infestation can be detected after the first generation of winged adult beetles emerges from the wood producing small holes (0.8-1.6 mm diameter), and a fine wood powder falls out.

5.1.4.4.2 Anobiid Powderpost Beetles

Anobiid beetles are found on older and recently seasoned hardwoods or softwoods throughout the United States of America. They prefer the sapwood that is closest to the bark and their exit holes are 1.6-3 mm in diameter. Their life cycle is 2-3 years and they need about 15% moisture content. If the infestation is old, then there may be very small round (0.8 mm) emergence holes from parasitic wasps larvae that feed on the beetle larvae.

There are several approaches to try to control powderpost beetles. One is to control the environmental conditions by lowering the moisture content of the wood through ventilation, insulation and vapor barriers, as well as good building design. Another is to use chemical treatment by brushing or spraying the wood with insecticides, using boron diffusion treatments, or fumigating if infestation is extensive. Using pressure-treated wood can prevent beetle attack. Another approach is to just eliminate or reduce the beetle population.

5.1.4.4.3 Flatheaded Borers

Flatheaded borers are metallic-colored beetles that vary in size, but a hammer-headed shape produced by an enlarged, flattened body region behind the head characterizes the larvae. The adult flatheaded borer emerges causing 3-13 mm oval or elliptical exit holes in sapwood and heartwood of living trees and unseasoned logs and lumber. Powdery, pale-colored sawdust is found tightly packed in oval to flattened tunnels or galleries in softwoods and hardwood. The adult females lay eggs singly or in groups on the bark or in crevices in the bark or wood. The larvae or young borers mine the inner bark or wood. Since most infestations occur in trunks of weakened trees or logs, the best method of control is to spot treat the local infestations which can be done by applying insecticides to the surface of the wood. This may prevent reinfestation, or kill the larvae that feed close to the surface.

5.1.4.4.4 Cerambycids

The long-horned beetles and old house borers are collectively called the Cerambycids, or the roundheaded beetles.

5.1.4.4.4.1 Long-Horned Beetles The long-horned beetle or roundheaded beetle is the common name of the Asian Cerambycid Beetle, *Anoplophora glabripennis* that is indigenous to southern China, Korea, Japan, and the Isle of Hainan. It is extremely destructive to hardwood tree species and there is no known natural predator in the United States. It attacks not just stressed or aging trees, but healthy trees of any age, and it produces new adults each year, instead of every 2-4 years like other longhorn beetles. The beetle bores into the heartwood of a host tree, eventually killing the tree.

The beetle is believed to have hitchhiked into the United States in wooden crating of a cargo ship in the early 1990s. It was discovered in the United States in August 1996 in Brooklyn, New York. Within weeks another infestation was found on Long Island, in Amityville, New York. Two years later in July of 1998 the beetle was found in Chicago, Illinois. It attacks many healthy hardwood trees, including maple, horsechestnut, birch, poplar, willow, and elm.

The adult beetles have large-bodies; are black with white spots; and have very long black and white antenna. They make large circular holes (3-13 mm diameter) upon emergence and can occur anywhere on the tree, including branches, trunks, and exposed roots. Oval to round, darkened wounds in the bark may also be observed, and these are oviposition sites where adult females chew out a place to lay their eggs. The larvae chew banana-shaped tunnels or galleries into the wood, causing heavy sap flow from wounds and sawdust accumulation at tree bases. These galleries interrupt the flow of water from the roots to the leaves. They feed on, and over-winter in, the interiors of trees. Quarantine is usually imposed on firewood and nursery stock in a known infected area and all infested trees are immediately destroyed.

5.1.4.4.4.2 Old-House Borers Another roundheaded borer is called the old-house borer. The adult is a large (18-25 mm), black to dark brown, elongated beetle which burrows in structural wood, old and new, seasoned and unseasoned, softwood lumber, but not hardwoods. It is capable of reinfesting wood in use and is found along the Atlantic seaboard.

The adults lay their eggs in the cracks and crevices of wood and they hatch in about 2 weeks. The larvae can live in seasoned softwood for several years. They feed little during the winter months of December through February, but when the larvae are full grown, which usually takes about 5 years, they emerge through oval holes (6-9 mm) in the surface of the wood. Moisture content of 15-25% encourages growth. Emergence happens during June and July. During the first few years of feeding, the larvae cannot be heard, but when they are about 4 years old chewing sounds can be heard in wood during the spring and summer months. Damage depends on the number of larvae feeding, the extent of the infestation, how many years, and whether there has been a reinfestation. To control old-house borers insecticides can be applied to the surface of wood. When there is an extensive and active infestation of the old-house borer, then fumigation may be the best control method. To prevent reinfestation, small infestations can be controlled by applying insecticides to the surface of the wood, which kills the larvae that may feed close to the surface, and contacts the chemical just below the surface.

5.1.5 Marine Borers

Marine-boring organisms in salt or brackish waters can cause extensive damage to wood. Attack in the United States is significant along the Pacific, Gulf, and South Atlantic Coasts, and slower along the New England Coast because of cold-water temperatures. The marine borers that cause the most damage in the United States are shipworms, Pholads, crustaceans, and pillbugs (Figure 5.12).

5.1.5.1 Shipworms

Shipworms are worm-like mollusks that cause great damage to wooden boats, piers, and structures. They belong in the family Teredinidae and the genera *Teredo* or *Bankia.* They are found in salt water along the United States Coastal waters, but some can adapt to less saline conditions and live in many of the estuaries. The young larvae swim to wood and bury themselves using a pair of boring shells on their head. They have a tail that has two siphons: one to draw in water containing microscopic organisms for food and oxygen for respiration; and the second siphon to expel waste and for reproduction. The larvae eat the wood and organisms from the ocean, and grow worm-like bodies, but they never leave the wood. The shipworms grow in length and diameter, but their entrance holes are only the size of the young larvae (1.6 mm, see Figure 5.13). The inside of the wood becomes honeycombed and severely degraded. Adults from the genus *Teredo* grow to be 0.3-0.6 m in length and 13 mm in diameter, while those of the genus *Bankia* grown to be 1.5-1.8 m in length and 22 mm in diameter. To protect wood from shipworms, a marine grade preservative treatment is used such as creosote (400 kg/m^3), chromated copper arsenate (CCA, 40 kg/m^3) or ammoniacal copper citrate (CC, 40 kg/m^3).

5.1.5.2 Pholads

Pholads are also wood-boring mollusks, but are different in that they resemble clams, that is, encased in a double shell (Figure 5.14). They belong in the family Pholadidae with two familiar species the *Martesia* and the *Xylophaga.* They enter the wood when they are very young and grow inside the wood, similar to the shipworms. Their entrance holes are about 6 mm in diameter, and most of the damage to the wood is close to the surface. Pholads grow no bigger than 64 mm long

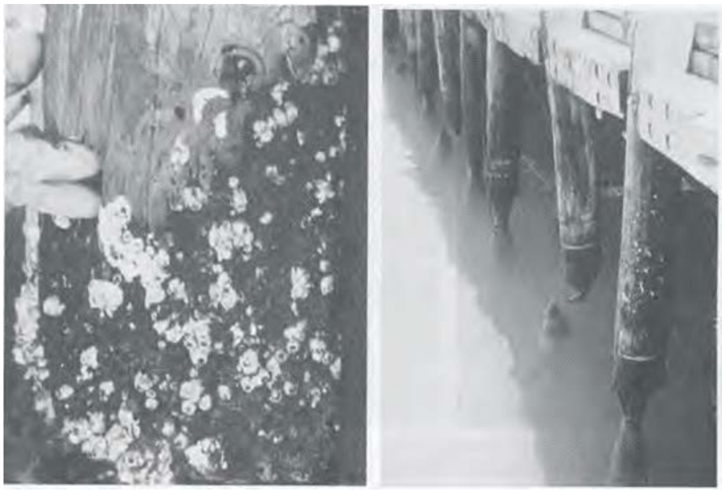

FIGURE 5.12 Damaged to wood due to marine borers.

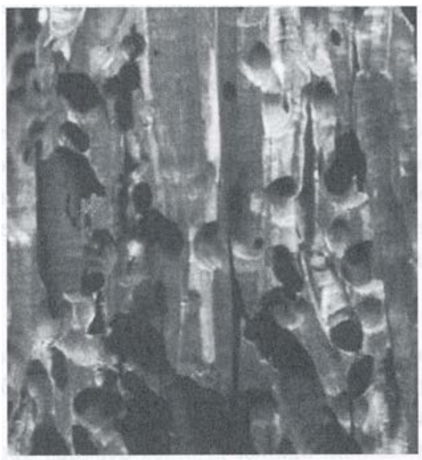

FIGURE 5.13 Internal damage done by shipworms on wood.

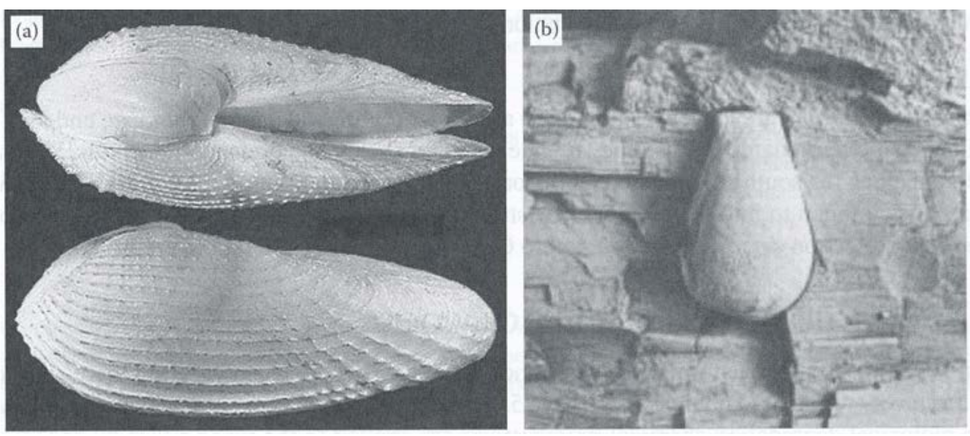

FIGURE 5.14 Pholad wood-borers (a) and one boring in wood (b).

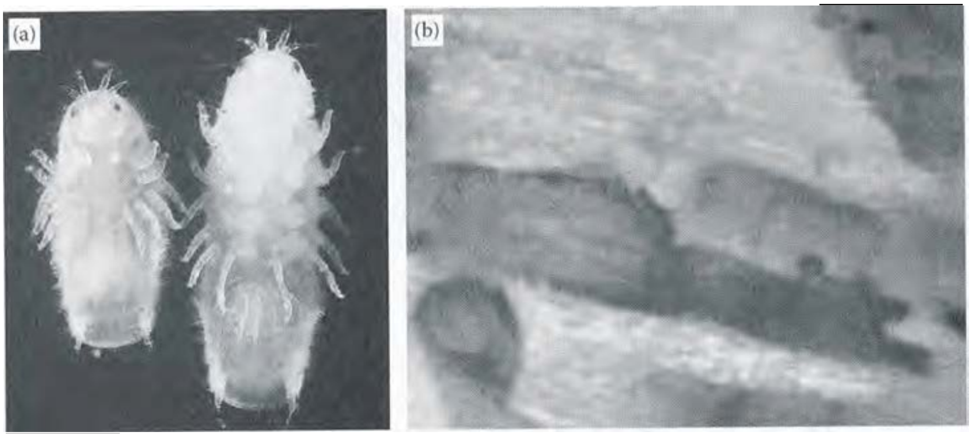

FIGURE 5.15 *Limnoria* wood borer (a) and boring in wood (b).

and 25 mm in diameter, but they can cause extensive damage to wood. They are found in Hawaii, San Diego, California, the Gulf Coast, and from South Carolina down southward. To protect wood from Pholads, either marine-grade creosote (400 kg/m^3), or a dual treatment of CCA, and then creosote are effective.

5.1.5.3 Crustaceans

The crustaceans include gribbles, in the family Limnoriidae, genus *Limnoria,* and the pillbugs, from the family Sphaeromatidae, genus *Spaeroma.* They are related to lobsters and shrimp, and differ from the other marine borers in that they are not imprisoned, so they can move from place to place. The boreholes made are shallow, therefore the borers, combined with water erosion, degrade the surface of the wood (Figure 5.15).

5.1.5.3.1 Gribbles

Gribbles or *Limnoria* are quite small (3-4 mm), and their boreholes are usually only about 13 mm deep, but with water erosion, the borers continually bore in deeper. They prefer earlywood, and the attack is usually located between half tide and low tide levels that result in an hourglass shape. Protection with preservative treatment against gribbles depends upon where and what species is present in the water. Two recommended treatments are either a dual treatment of first CCA (16-24 kg/m$^{3)}$ and then marine grade creosote (320 kg/m^3), or just using a higher concentration of just CCA (40 kg/m$^{3)}$ or just marine-grade creosote (320-400 kg/m^3). To get more information, check with current American Wood Preservers Association (AWPA) Standards (AWPA 2011).

5.1.5.3.2 Pillbugs

Pillbugs or *Spaeroma* are longer (13 mm long) and wider (6 mm wide) than *Limnoria,* and look like a pillbug that lives in damp places. They use the wood for shelter and prefer softer woods. *Spaeroma* are found along the south Atlantic and Gulf Coasts, and from San Francisco southward on the West Coast. It is common to find them in Florida estuaries. Dual treatment with CCA and then creosote is the best protection since they are tolerant to CCA, and with time tolerant to creosote.

5.2 PREVENTION OR PROTECTION OF WOOD

Some wood species have natural decay resistance of the heartwood. It can vary, but there are groupings from very resistant to nonresistant (Table 5.2). When extra protection is needed to protect wood from biological degradation chemical preservatives are applied to the wood either by nonpressure or pressure treatment (Eaton and Hale 1993, Schultz et al. 2008). Penetration and retention of a

TABLE 5.2
Heartwood Decay Resistance of Some Domestic and Imported Woodsa

Very Resistant	Resistant	Moderately Resistant	Slightly or Nonresistant
		Domestic	
Black locust	Baldcypress, old growth	Baldcypress, young growth	Alder, red
Mulberry, red	Catalpa	Cherry, black	Ashes
Osage-orange	Cedar	Douglas-fir	Aspens
Yew, Pacific	Atlantic white	Honey locust	Beech
	Eastern redcedar	Larch, western	Birches
	Incense	Pine, eastern white, old growth	Buckeye
	Northern white	Pine, longleaf, old growth	Butternut
	Port-orford	Pine, slash, old growth	Cottonwood
	Western redcedar	Redwood, young growth	Elms
	Yellow	Tamarack	Basswood
	Chestnut		Firs, true
	Cypress, Arizona		Hackberry
	Junipers		Hemlocks
	Mesquite		Hickories
	Oaks, white		Magnolia
	Redwood, old growth		Maples
	Sassafras		Pines (other than those listed)"
	Walnut, black		Spruces
			Sweetgum
			Sycamore
			Tanoak
			Willows
			Yellow-poplar
		Imported	
Angelique	Aftotmosia (Kokrodua)	Andiroba	Balsa
Azobe	Apamate (Roble)	Avodire	Banak
Balata	Balau"	Benge	Cativo
Goncalo alves	Courbaril	Bubinga	Ceiba
Greenheart	Determa	Ehie	Hura
Ipe (lapacho)	lroko	Ekop	Jelutong
Jarrah	Kapur	Keruingb	Limba
Lignumvitae	Karri	Mahogany, African	Meranti, light redb
Purpleheart	Kempas	Meranti. dark redb	Meranti, yellow"
Teak, old growth	Mahogany, American	Mersawab	Meranti, white"
	Manni	Sapele	Obeche
	Spanish-cedar	Teak, young growth	Okoume
	Sucupira	Tornillo	Parana pine
	Wallaba		Ramin
			Sande
			Sepitir
			Seraya, white

Decay resistance may be less for members placed in contact with the ground and/or used in warm, humid climates. Substantial variability in decay resistance is encountered with most species, and limited durability data were available for some species listed. Use caution when using naturally durable woods in structurally critical or ground-contact applications.

[b] More than one species included, some of which may vary in resistance from that indicated.

chemical will depend upon wood species and the amount of heartwood (more difficult to treat) or sapwood (easier to treat.) The objective of adding wood preservatives is to obtain long-term effectiveness for the wood product, thus sequestering carbon.

Starting January 2004, the U.S. Environmental Protection Agency (EPA) no longer allows the most widely used wood preservative, CCA, for products for any residential use (i.e., play-structures, decks, picnic tables, landscaping timbers, residential fencing, patios, walkways, and boardwalks). However, it has not concluded that arsenic containing CCA-treated wood poses unreasonable risks to the public from the wood being used around or near their homes (EPA 2002). Alternative preservatives such as ammoniacal copper quat (ACQ) and copper azole (CBA) have replaced CCA for residential use (EPA 2002; PMRA 2002). Looking beyond these replacements for CCA may be wood protection systems not based on toxicity, but rather nontoxic chemical modifications to prevent biological degradation. Chemical modification alters the chemical structure of the wood components thereby reducing the biodegradability of wood, as well as increasing its dimensional stability when in contact with moisture (Rowell 1991) (see Chapter 14).

5.2.1 WOOD PRESERVATION

Wood preservatives work by being toxic to the biological organisms that attack wood. The active ingredients in wood preservative formulations are many and varied and each has its own mode of action, some of which are still unknown or unreported. In general mechanisms of toxicity involve denaturation of proteins, inactivation of enzymes, cell membrane disruption causing an increase in cell permeability, and inhibition of protein synthesis.

The degree of protection of a particular preservative and treatment process depends on four basic requirements: (1) toxicity, (2) permanence, (3) retention, and (4) depth of penetration into the wood. Toxicity refers to how effective the chemical is against biological organisms such as decay fungi, insects, and marine borers. Permanence refers to the resistance of the preservative to leaching, volatilization, and breakdown. Retention specifies the amount of preservative that must be impregnated into a specific volume of wood to meet standards, and ensure that the product will be effective against numerous biological agents.

Wood preservatives can be divided into two general classes: (1) oil-type, such as creosote and petroleum solutions of pentachlorophenol; and (2) waterborne salts that are applied as water solutions, such as CCA, ACQ, and CBA. There are many different chemicals in each class and the effectiveness of each preservative can vary greatly depending upon its chemical composition, retention, depth of penetration, and ultimately the exposure conditions of the final product. The degree of protection needed will depend upon geographic location and potential exposures of the wood, expected service life, structural and nonstructural applications, and replacement costs. Wood preservatives should always be used when exposed to ground (soil) contact and marine (salt-water) exposure.

Oilborne preservatives such as creosote and solutions with heavy, less volatile petroleum oils often help to protect wood from weathering, but may adversely influence its cleanliness, odor, color, paintability, and fire performance. Waterborne preservative are often used when cleanliness and paintability of the treated wood are required. In seawater exposure, a dual treatment (waterborne copper-containing salt preservatives followed by creosote) is most effective against all types of marine borers.

Evaluation for efficacy of preservative-treated wood is first performed on small specimens in the laboratory, and then larger specimens with field exposure (ASTM 2010, AWPA 2011) (Figure 5.16). The USDA Forest Service FPL has had in-ground stake test studies on southern pine sapwood ongoing since 1938 in Saucier, Miss., and Madison, Wis (Figure 5.17, Crawford et al. 2002). Table 5.3 shows results of the Forest Products Laboratory studies on 5- by 10- by 46 cm (2- by 4- by 18 in) southern pine sapwood stakes, pressure-treated with commonly used wood preservatives, installed at Harrison Experimental Forest, Mississippi (Figure 5.18). A comparison of preservative-treated

FIGURE 5.16 ASTM soil block test.

FIGURE 5.17 Field test of wood durability.

small wood panels exposed to a marine environment in Key West, Fl. has been evaluated (Figure 5.19) (Johnson and Gutzmer 1990). Outdoor evaluations such as these compare various preservatives and retention levels under each exposure condition at each individual site. These preservatives and treatments include creosotes, waterborne preservatives, dual treatments, chemical modification of wood, and various chemically modified polymers.

Another laboratory test for wood durability is the use of a fungal cellar (Figure 5.20). Small test specimens are placed half their length in unsterile soil of different moisture contents depending on the fungi of interest (see e.g., Stephan et al. 1998). Samples are removed at various times and inspected for fungal attack. Visual damage and weight loss can be determined to give an indication of damage. It is also possible to determine loss of strength which is known to give a faster indicator of fungal attack as compared to weight loss.

The newest laboratory test for fungal decay is the use of a terrestrial microcosm (Nilsson and Bjordal 2007). Very small test specimens are placed in test and inspected at different times. Decay is very rapid making this test very inexpensive, fast, and easy (Figure 5.21).

Exposure conditions and length of product lifetime need to be considered when choosing a particular preservative treatment, process, and wood species (Cassens et al. 1995). The AWPA

TABLE 5.3
Results of the Forest Products Laboratory Studies on 5- by 10- by 46 cm (2- by 4- by 18 in) Southern Pine Sapwood Stakes, Pressure-Treated with Commonly Used Wood Preservatives, Installed at Harrison Experimental Forest, Mississippi

Preservative	Average Retention Kg/m³ (lb/ft³)	Average Life or Condition at Last Inspection
CCA-type III (Type C)	6.41 (0.40)	No failures after 25 years
Coal-tar creosote	160.2 (10.0)	90% failed after 55 years
Copper naphthenate (0.86% copper in No. 2 fuel oil)	1.31 (0.082)	29.6 years
Oxine copper (copper-8-quinolinolate) (in heavy petroleum)	1.99 (0.124)	No failures after 45 years
No preservative treatment		1.8–3.6 years

Source: Adapted from Crawford, D. M., Woodward, B. M., and Hatfield, C. A. 2002. *Comparison of Wood Preservatives in Stake Tests*. 2000. Progress Report. Res. Note FPL-RN-02. US Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI.

FIGURE 5.18 Inspection of a pulled wood stake from a field test.

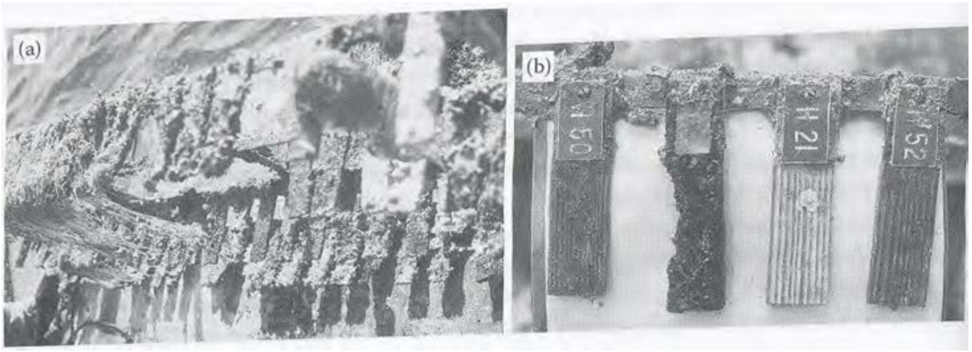

FIGURE 5.19 Small specimen panels in test in the ocean (a) and inspected (b).

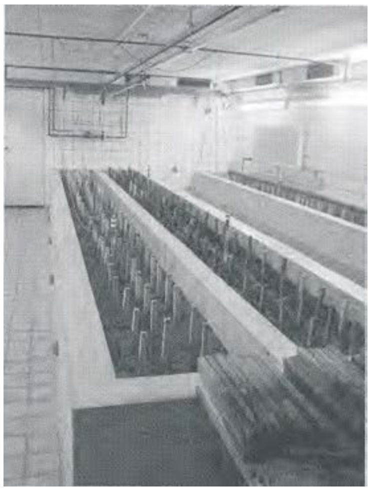

FIGURE 5.20 Federal Institute for Materials Research and Testing Fungus Cellar. Tests of wood preservatives for wood to be used in ground contact. (www.bam.de)

FIGURE **5.21** Terrestrial microcosm.

recently developed the use category system (UCS) standards as a guide to selecting a preservative and loading. The categories are based on the end use and severity of the deterioration hazard (Table 5.4). The categories range from UC1 (interior construction, above ground, dry) to UC5 (seawater and marine borer exposure).

Once the appropriate tests of a durable wood product have been completed, the results are compiled and presented to one of two organizations that reviews and lists durable wood products. Traditionally, durable wood products have been reviewed by AWPA subcommittees, which are composed of representatives from industry, academia and government agencies who have familiarity with conducting and interpreting durability evaluations. More recently the International Code Council—Evaluation Service (ICC—ES) has evolved as an additional route for gaining building code acceptance of new types of pressure-treated wood. The ICC—ES does not standardize preservatives.

TABLE 5.4
Service Conditions for the AWPA Use Category System

Use Category	Service Conditions	Use Environment	Common Agents of Deterioration	Typical Applications
UC1	Interior construction Above ground Dry	Continuously protected from weather or other sources of moisture	Insects only	Interior construction and furnishings
UC 2	Interior construction Above ground Damp	Protected from weather, but may be subject to sources of moisture	Decay fungi and insects	Interior construction
UC3A	Exterior construction Above ground Coated and rapid water runoff	Exposed to all weather cycles, not exposed to prolonged wetting	Decay fungi and insects	Coated millwork, siding, and trim
UC3B	Ground contact or fresh water Non-critical components	Exposed to all weather cycles, normal exposure conditions	Decay fungi and insects	Fence, deck, and guardrail posts, crossties, and utility poles (low decay areas)
UC4A	Ground contact or fresh water Non-critical components	Exposed to all weather cycles, normal exposure conditions	Decay fungi and insects	Fence, deck, and guardrail posts, crossties, and utility poles (low decay areas)
UC4B	Ground contact or fresh water Critical components or difficult replacement	Exposed to all weather cycles, high decay potential includes salt-water splash	Decay fungi and insects with increased potential for biodeterioration	Permanent wood foundations, building poles, horticultural posts, crossties, and utility poles (high decay areas)
UC4C	Ground contact or fresh water Critical structural components	Exposed to all weather cycles, severe environments, extreme decay potential	Decay fungi and insects with extreme potential for biodeterioration	Land and fresh-water piling, foundation piling, crossties and utility poles (severe decay areas)
UC5A	Salt or brackish water and adjacent mud zone Northern waters	Continuous marine exposure (salt water)	Salt-water organisms	Piling, bulkheads, bracing
UC5B	Salt or brackish water and adjacent mud zone NJ to GA, South of San Francisco	Continuous marine exposure (salt water)	Salt-water organisms, including creosote-tolerant *Limnoria tripunctata*	Piling, bulkheads, bracing
UC5C	Salt or brackish water and adjacent mud zone South of GA, Gulf Coast, Hawaii, and Puerto Rico	Continuous marine exposure (salt water)	Salt-water organisms, including Martesia, Sphaeroma	Piling, bulkheads, bracing

Instead, it issues Evaluation Reports that provide evidence that a building product complies with the building codes. The tests required by ICC—ES are typically those developed by AWPA. It is important to note that separate toxicity evaluations by appropriate regulatory agencies (e.g., the U.S. Environmental Protection Agency) are mandatory for any durable wood product that incorporates preservative pesticides. For various wood products, preservatives, and their required retention levels see the current AWPA Book of Standards (AWPA 2011).

5.2.2 TIMBER PREPARATION AND CONDITIONING

Preparing the timber for treatment involves carefully peeling the round or slabbed products to enable the wood to dry quickly enough to avoid decay and insect damage and to allow the preservative to penetrate satisfactorily. Drying the wood before treatment is necessary to prevent decay and stain and to obtain preservative penetration, but when treating with waterborne preservatives by certain diffusion methods, high moisture content levels may be permitted. Drying the wood before treatment opens up the checks before the preservative is applied, thus increasing penetration and reducing the risk of checks opening up after treatment and exposing unpenetrated wood.

Treating plants that use pressure processes can condition green material by means other than air and kiln drying, thus avoiding a long delay and possible deterioration. When green wood is to be treated under pressure, one of several methods for conditioning may be selected. The steaming-and vacuum process is used mainly for southern pines, and the Boulton (or boiling-under-vacuum) process is used for Douglas-fir and sometimes hardwoods.

Heartwood of some softwood and hardwood species can be difficult to treat (see Table 5.5) (Mac Lean 1952). Wood that is resistant to penetration by preservatives, such as Douglas-fir, western hemlock, western larch, and heartwood, may be incised before treatment to permit deeper and more uniform penetration. Incision involves passing the lumber or timbers through rollers that are equipped with teeth that sink into the wood to a predetermined depth, usually 13-19 mm (1/2-3/4 in.). The incisions open cell lumens along the grain that improves penetration, but can result in significant strength reduction. As much cutting and hole boring of the wood product as is possible should be done before the preservative treatment, otherwise untreated interiors will allow ready access of decay fungi or insects.

5.2.3 TREATMENT PROCESSES

There are two general types of wood-preserving methods: (1) pressure processes and (2) nonpressure processes. During pressure processes wood is impregnated in a closed vessel under pressure above atmospheric. In commercial practice wood is put on cars or trams and run into a long steel cylinder, which is then closed and filled with preservative. Pressure forces are then applied until the desired amount of preservative has been absorbed into the wood.

5.2.3.1 Pressure Processes

Three pressure processes are commonly used: full-cell, modified full-cell, and empty-cell. The full-cell process is used when the retention of a maximum quantity of preservative is desired. The steps include: (1) the wood is sealed in a treating cylinder and a vacuum is applied for a half-hour or more to remove air from the cylinder and wood; (2) the preservative (at ambient or elevated temperature) is admitted to the cylinder without breaking the vacuum; (3) pressure is applied until the required retention; (4) the preservative is withdrawn from the cylinder; and (5) a short final vacuum may be applied to free the wood from dripping preservative. The modified full-cell process is basically the same as the full-cell process except for the amount of initial vacuum and the occasional use of an extended final vacuum.

The goal of the empty-cell process is to obtain deep penetration with relatively low net retention of preservative. Two empty-cell processes (the Rueping and the Lowry) use the expansive force of

TABLE 5.5
Penetration of the Heartwood of Various Softwood and Hardwood Speciesa

Ease of Treatment	Softwoods	Hardwoods
Least difficult	Bristlecone pine *(Pinus aristata)* Pinyon *(Pinus edulis)* Pondersosa pine *(Pinus pondersosa)* Redwood *(Sequoia sempervirens)*	American basswood *(Tilia americana)* Beech (white heartwood) *(Fagus grandifolia)* Black tupelo (blackgum) *(Nyssa sylvatica)* Green ash *(Fraxinus pennsylvanica* var. *lanceolata)* Pin cherry *(Prunus pensylvanica)* River birch *(Betula nigra)* Red oaks *(Quercus* spp.) Slippery elm *(Ulmus fulva)* Sweet birch *(Betula lenta)* Water tupelo *(Nyssa aquatica)* White ash *(Fraxinus Americana)*
Moderately difficult	Baldcypress *(Taxodium distichum)* California red fir *(Abies magnifica)* Douglas-fir (coast) *(Pseudotsuga taxifolia)* Eastern white pine *(Pinus strobes)* Jack pine *(Pinus banksiana)* Loblolly pine *(Pinus taeda)* Longleaf pine *(Pinus palustris)* Red pine *(Pinus resinosa)* Shortleaf pine *(Pinus echinata)* Sugar pine *(Pinus lambertiana)* Western hemlock *(Tsuga heterophylla)*	Black willow *(Salix nigra)* Chestnut oak *(Quercus montana)* Cottonwood *(Populus* sp.) Bigtooth aspen *(Populus grandidentata)* Mockernut hickory *(Carya tomentosa)* Silver maple *(Acer saccharinum)* Sugar maple *(Acer saccharum)* Yellow birch *(Betula lutea)*
Difficult	Eastern hemlock *(Tsuga canadensis)* Engelmann spruce *(Picea engelmanni)* Grand fir *(Abies grandis)* Lodgepole pine *(Pinus contorta* var. *latifolia)* Noble fir *(Abies procera)* Sitka spruce *(Picea sitchensis)* Western larch *(Larix occidentalis)* White fir *(Abies concolor)* White spruce *(Picea glauca)*	American sycamore *(Platanus occidentalis)* Hackberry *(Celtis occidentalis)* Rock elm *(Ulmusthom oasi)* Yellow-poplar *(Liriodendron tulipifera)*
Very difficult	Alpine fir *(Abies lasiocarpa)* Corkbark fir *(A. lasiocarpa var. arizonica)* Douglas fir (Rocky Mountain) *(Pseudotsuga taxifolia)* Northern white cedar *(Thuja occidentalis)* Tamarack *(Larix laricina)* Western redcedar *(Thaja plicata)*	American beech (red heartwood) *(Fagus grandifolia)* American chestnut *(Castanea dentate)* Black locust *(Robinia pseudoacacia)* Blackjack oak *(Quercus marilandica)* Sweetgum (redgum) *(Liquidambar styraciflua)* White oaks *(Quercus* spp.)

a As covered in Mac Lean, J. D. 1952. *Preservation of Wood by Pressure Methods.* U.S. Department of Agriculture, Forest Service Washington, DC, 160.

compressed air to drive out part of the preservative absorbed during the pressure period. The Rueping empty-cell process is often called the empty-cell process with initial air. Air pressure is forced into the treating cylinder, which contains the wood, and then the preservative is forced into the cylinder. The air escapes into an equalizing or Rueping tank. The treating pressure is increased and maintained until desired retention is attained. The preservative is drained and a final vacuum is applied to remove surplus preservative. The Lowry process is the same as the Rueping except that there is no initial air pressure or vacuum applied. Hence, it is often called the empty-cell process without initial air pressure.

5.2.3.2 Nonpressure Processes

There are numerous nonpressure processes and they differ widely in their penetration and retention of a preservative. Nonpressure methods consist of (1) surface applications of preservative by brushing or brief dipping, (2) cold soaking in preservative oils or steeping in solutions of waterborne preservative, (3) diffusion processes with waterborne preservatives, (4) vacuum treatment, and (5) various other miscellaneous processes.

5.2.4 PURCHASING AND HANDLING OF TREATED WOOD

The EPA regulates pesticides, and wood preservatives are one type of pesticide. Preservatives that are not restricted by EPA are available to the general consumer for nonpressure treatments, while the sale of others is restricted only to certified pesticide applicators. These preservatives can be used only in certain applications and are referred to as "restricted use." "Restricted-use" refers to the chemical preservative and not to the treated-wood product. The general consumer may buy and use wood products treated with restricted-use pesticides; EPA does not consider treated wood a toxic substance nor is it regulated as a pesticide.

"Consumer Safety Information Sheets" (EPA-approved) are available from retailers of treated-wood products. The sheets provide users with information about the preservative and the use and disposal of treated-wood products. There are consumer information sheets for three major groups of wood preservatives (see Table 5.6): (1) creosote pressure-treated wood, (2) pentachlorophenol pressure-treated wood, and (3) inorganic arsenical pressure-treated wood.

There are two important factors to consider depending upon the intended end use of preservative-treated wood: (1) the grade or appearance of the lumber, and (2) the quality of the preservative treatment in the lumber. The U.S. Department of Commerce American Lumber Standard Committee (ALSC) accredits third-party inspection agencies for treated-wood products. A list of accredited agencies can be found on the ALSC website at www.alsc.org. The treated wood should be marked with a brand, ink stamp, or end tag. These marks indicate that the producer of the treated-wood product subscribes to an independent inspection agency. The stamp or end tag contains the type of preservative or active ingredient, the retention level, and the intended use category or exposure conditions. Retention levels are usually provided in pounds of preservatives per cubic foot of wood and are specific to the type of preservative, wood species, and intended exposure conditions. Be aware that suppliers often sell the same type of treated wood by different trade names. Depending upon your intended use and location, there will be different types of treated wood available for residential use. Also, be aware that some manufacturers add colorants (such as brown) or water repellents (clear) into some of their preservative treatments. When purchasing treated wood, ask the suppliers for more information to determine what preservative and additives were used, as well as any handling precautions.

Note that mention of a chemical in this article does not constitute a recommendation; only those chemicals registered by the EPA may be recommended. Registration of preservatives is under constant review by EPA and the U.S. Department of Agriculture. Use only preservatives that bear an EPA registration number and carry directions for home and farm use. Preservatives, such as creosote and pentachlorophenol, should not be applied to the interior of dwellings that are occupied by

TABLE 5.6
EPA-Approved Consumer Information Sheets for Three Major Groups of Preservative Pressure-Treated Wood

Preservative Treatment	Inorganic Arsenicals	Pentachlorophenol	Creosote
Consumer information	• This wood has been preserved by pressure-treatment with an EPA-registered pesticide containing inorganic arsenic to protect it from insect attack and decay. Wood treated with inorganic arsenic should be used only where such protection is important. • Inorganic arsenic penetrates deeply into and remains in the pressure-treated wood for a long time. However, some chemical may migrate from treated wood into surrounding soil over time and may also be dislodged from the wood surface upon contact with skin. Exposure to inorganic arsenic may present certain hazards. Therefore, the following precautions should be taken both when handling the treated wood and in determining where to use or dispose of the treated wood.	• This wood has been preserved by pressure-treatment with an EPA-registered pesticide containing pentachlorophenol to protect it from insect attack and decay. Wood treated with pentachlorophenol should be used only where such protection is important. • Pentachlorophenol penetrates deeply into and remains in the pressure-treated wood for a long time. Exposure to pentachlorophenol may present certain hazards. Therefore, the following precautions should be taken both when handling the treated wood and in determining where to use and dispose of the treated wood.	• This wood has been preserved by pressure treatment with an EPA-registered pesticide containing creosote to protect it from insect attack and decay. Wood treated with creosote should be used only where such protection is important. • Creosote penetrates deeply into and remains in the pressure-treated wood for a long time. Exposure to creosote may present certain hazards. Therefore, the following precautions should be taken both when handling the treated wood and in determining where to use the treated wood.
Handling precautions	• Dispose of treated wood by ordinary trash collection or burial. Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers in accordance with state and Federal regulations.	• Dispose of treated wood by ordinary trash collection or burial. Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers rated at 20 million BTU/hour or greater heat input or its equivalent in accordance with state and Federal regulations.	• Dispose of treated wood by ordinary trash collection or burial. Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers, because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers in accordance with state and Federal regulations.

	• Avoid frequent or prolonged inhalation of sawdust from treated wood. When sawing and machining treated wood, wear a dust mask. Whenever possible, these operations should be performed outdoors to avoid indoor accumulations of airborne sawdust from treated wood. • When power-sawing and machining, wear goggles to protect eyes from flying particles. • Wear gloves when working with the wood. After working with the wood, and before eating, drinking, toileting, and use of tobacco products, wash exposed areas thoroughly. • Because preservatives or sawdust may accumulate on clothes, they should be laundered before reuse. Wash work clothes separately from other household clothing.	• Avoid frequent or prolonged inhalation of sawdust from treated wood. When sawing and machining treated wood, wear a dust mask. Whenever possible, these operations should be performed outdoors to avoid indoor accumulations of airborne sawdust from treated wood. • Avoid frequent or prolonged skin contact with pentachlorophenol-treated wood. When handling the treated wood, wear long-sleeved shirts and long pants and use gloves impervious to the chemicals (e.g., gloves that are vinyl-coated). • When power-sawing and machining, wear goggles to protect eyes from flying particles. • After working with the wood, and before eating, drinking, and use of tobacco products, wash exposed areas thoroughly. • If oily preservatives or sawdust accumulate on clothes, launder before reuse. Wash work clothes separately from other household clothing.	• Avoid frequent or prolonged inhalations of sawdust from treated wood. When sawing and machining treated wood, wear a dust mask. Whenever possible these operations should be performed outdoors to avoid indoor accumulations of airborne sawdust from treated wood. • Avoid frequent or prolonged skin contact with creosote-treated wood; when handling the treated wood, wear long-sleeved shirts and long pants and use gloves impervious to the chemicals (e.g., gloves that are vinyl-coated). • When power-sawing and machining, wear goggles to protect eyes from flying particles. • After working with the wood and before eating, drinking, and use of tobacco products, wash exposed areas thoroughly. • If oily preservative or sawdust accumulate on clothes, launder before reuse. Wash work clothes separately from other household clothing.
Use site precautions	• All sawdust and construction debris should be cleaned up and disposed of after construction. • Do not use treated wood under circumstances where the preservative may become a component of food or animal feed. Examples of such sites would be use of mulch from recycled arsenic-treated wood, cutting boards, counter tops, animal bedding, and structures or containers for storing animal feed or human food. • Only treated wood that is visibly clean and free of surface residue should be used for patios, decks, and walkways.	• Logs treated with pentachlorophenol should not be used for log homes. Wood treated with pentachlorophenol should not be used where it will be in frequent or prolonged contact with bare skin (e.g., chairs and other outdoor furniture), unless an effective sealer has been applied. • Pentachlorophenol-treated wood should not be used in residential, industrial, or commercial interiors except for laminated beams or building components which are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer are applied. Sealers may be applied at the installation site. Urethane, shellac, latex epoxy enamel, and varnish are acceptable sealers for pentachlorophenol-treated wood.	• Wood treated with creosote should not be used where it will be in frequent or prolonged contact with bare skin (e.g., chairs and other outdoor furniture) unless an effective sealer has been applied. • Creosote-treated wood should not be used in residential interiors. Creosote-treated wood in interiors of industrial buildings should be used only for industrial building components which are in ground contact and are subject to decay or insect infestation and wood-block flooring. For such uses, two coats of an appropriate sealer must be applied. Sealers may be applied at the installation site.

continued

TABLE 5.6 (continued)
EPA-Approved Consumer Information Sheets for Three Major Groups of Preservative Pressure-treated Wood

Preservative Treatment	Inorganic Arsenicals	Pentachlorophenol	Creosote
Use site precautions	• Do not use treated wood for construction of those portions of beehives which may come into contact with honey. • Treated wood should not be used where it may come into direct or indirect contact with drinking water, except for uses involving incidental contact such as docks and bridges.	• Wood treated with pentachlorophenol should not be used in the interiors of farm buildings where there may be direct contact with domestic animals or livestock which may crib (bite) or lick the wood. • In interiors of farm buildings where domestic animals or livestock are unlikely to crib (bite) or lick the wood, pentachlorophenol-treated wood may be used for building components which are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer are applied. Sealers may be applied at the installation site. • Do not use pentachlorophenol-treated wood for farrowing or brooding facilities. • Do not use treated wood under circumstances where the preservative may become a component of food or animal feed. Examples of such sites would be structures or containers for storing silage or food. • Do not use treated wood for cutting-boards or countertops. • Only treated wood that is visibly clean and free of surface residue should be used for patios, decks, and walkways.	• Wood treated with creosote should not be used in the interiors of farm buildings where there may be direct contact with domestic animals or livestock which may crib (bite) or lick the wood. • In interiors of farm buildings where domestic animals or livestock are unlikely to crib (bite) or lick the wood, creosote-treated wood may be used for building components which are in ground contact and are subject to decay or insect infestation if two coats of an effective sealer are applied. Sealers may be applied at the installation site. Coal tar pitch and coal tar pitch emulsion are effective sealers for creosote-treated wood-block flooring. Urethane, epoxy, and shellac are acceptable sealers for all creosote-treated wood. • Do not use creosote-treated wood for farrowing or brooding facilities. • Do not use treated wood under circumstances where the preservative may become a component of food or animal feed. Examples of such use would be structures or containers for storing silage or food. • Do not use treated wood for cutting-boards or countertops.

• Do not use treated wood for construction of those portions of beehives which may come into contact with the honey. • Pentachlorophenol-treated wood should not be used where it may come into direct or indirect contact with public drinking water, except for uses involving incidental contact such as docks and bridges. • Do not use pentachlorophenol-treated wood where it may come into direct or indirect contact with drinking water for domestic animals or livestock, except for uses involving incidental contact such as docks and bridges.	• Only treated wood that is visibly clean and free U.1J1-11141/4:G 1cs1uucJ snoutu 1). LIJGLI 1,1 pauva, decks, and walkways. • Do not use treated wood for construction of those portions of beehives which may come into contact with the honey. • Creosote-treated wood should not be used where it may come into direct or indirect contact with public drinking water, except for uses involving incidental contact such as docks and bridges. • Do not use creosote-treated wood where it may come into direct or indirect contact with drinking water for domestic animals or livestock, except for uses involving incidental contact such as docks and bridges.

humans. Because all preservatives are under constant review by EPA, a responsible State or Federal agency should be consulted as to the current status of any preservative.

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