

CHAP. 16: INSECTS INJURIOUS TO UNFINISHED AND
FINISHED WOOD IN USE^{1/}

by

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^{1/} This chapter discusses control strategies involving pesticides. It does not report recommendations for their use or imply that any uses described have been registered. All uses of pesticides must be registered by appropriate State or Federal agencies, or both, before they can be recommended.

(1979. In Forest insect survey and control, p. 263-352.
J. A. Rudinsky, ed. O.S.U. Book Stores, Inc., Corvallis, Oreg.)

INTRODUCTION

The great architect Frank Lloyd Wright once said, "We may use wood with intelligence only if we understand it" (Hoadley 1976). A part of understanding wood is to understand the role that insects play in its biodeterioration. This chapter is designed to provide an introduction to the recognition, prevention, and control of wood products insects. Emphasis is placed on descriptions of different types of damage, which is often more easily identifiable than the insects responsible. Damage is also more likely to be seen than the insects. Where problems are restricted to limited geographic regions, these regions are clearly defined. Where biology and habits of the insects are discussed, it is for the specific purpose of establishing the relationship of the prevention and control procedures to the biology and habits upon which they are based.

DAMAGE TO WOOD BY INSECTS

Wood-boring insects may be conveniently grouped into those which damage (a) standing trees or newly-felled logs, (b) sawn timber and wood products during seasoning or storage, and (c) wood in use. Certain insect species attack more than one of these groups. The primary concern of this chapter is the group of insects which attack seasoned wood in use. Attention will also be given to insect species which initiate attack in unseasoned wood and survive and complete their development in wood which is in use, and insects which inflict damage to wood before its milling, seasoning, and use.

Insect attack is characterized generally by tunnels or cavities within the wood, often filled with frass composed of powdered, shredded, or fragmented wood and feces, which is sometimes pelletized. Often there are holes of various shapes and sizes on the surface. Frass may be pushed out through the holes, forming small piles beneath or on the surface of infested wood, indicating insects have recently emerged or that they are working inside the wood. Sometimes, when attack is severe, the wood may be reduced to a hollow shell. Often there is little external evidence of insect attack. The interior condition of the wood can be determined only by probing with a sharp instrument, or by tapping the surface to detect hollow areas by differences in sound.

Generally, the most important insects attacking wood in the United States are the subterranean termites. They cause more than 90 percent of the insect damage to wood in use. In tropical and in warmer and more humid temperate climates, drywood termites are a very significant problem. Even where they are common, however, their damage is usually much less severe than that of subterranean termites.

Potential economic losses and the significance of the damage inflicted, as well as appropriate control measures, depend upon the type of pest involved. It is essential, therefore, to accurately identify the cause of the damage and to distinguish insect damage from other factors involved in the deterioration of wood. Failure to appreciate these points often results in needless waste of wood or unnecessary treatments.

TERMITES: BIOLOGY AND IDENTIFICATION

The termites comprise the order Isoptera, one of the oldest and most primitive groups of insects. Termites are social insects and live in colonies. Theoretically, each colony is composed entirely of offspring from one original pair of individuals. In all species there is a definite caste system with each of the adult castes performing an essential function in the life of the colony.

The termites with which we are concerned all feed on wood. Their role in nature is to recycle the tremendous amount of dead and fallen wood that accumulates continuously. Throughout much of the world, they are the most destructive insects to wood. In the continental United States there are only 38 native species of termites. In addition to these, two introduced species, Cryptotermes brevis (Walker) and Coptotermes formosanus Shiraki, are of economic importance. C. brevis may have been introduced into southern Florida from a nearby island, while C. formosanus is believed to have been introduced into the Gulf Coast during World War II. These latter two species are of great economic significance in Hawaii.

Biology and Habits of Termites

Distribution. Termites occur in virtually every state of the United States except Alaska, and in all U.S. territories. They cause varying degrees of damage, depending on the geographic location. The presence or abundance of termites in an area is controlled by their environmental requirements such as temperature, humidity, and soil moisture and type. Termites, in general, have extended their natural range to approximately the 10°C annual mean isotherm north and south of the equator. Because of man-made microclimates in structures, they may well extend their range to areas with colder climates.

For convenience in describing prevention and control procedures, the destructive termites of this country have been grouped into 3 types: dampwood, drywood, and subterranean. The characteristics of these types will be detailed later. Dampwood termites are found as pests in structures only on the Pacific Coast, the desert Southwest and in southern Florida. They are of relatively minor economic importance. The distribution of drywood and subterranean termites in the contiguous states is shown in Fig. 1. Except in southern California and southern Florida, subterranean termites are the most common and destructive type where both types occur. In Hawaii, both drywood and subterranean termites cause severe problems.

Life Cycle and Caste System. The life cycle of termites is unique among insects. Nonsocial insects generally undergo either incomplete or complete metamorphosis. The termite undergoes incomplete metamorphosis but differs substantially from the other insects because it exhibits polymorphism, or has many forms. Termite colonies contain individuals of distinct forms called castes. There are usually 7 types of individuals which are present sometime during the year: larvae, reproductive nymphs, presoldiers, soldiers, workers, or pseudergates, alates or winged reproductives which become primary reproductives, and supplementary (replacement) reproductives. Larvae are immature individuals without any external signs of wing buds or soldier morphology and are the precursors of all the other castes.

Workers (Fig. 2,a) are the individuals responsible for the maintenance of the colony, the gathering of food, and the grooming of other individuals in the colony. Soldiers (Fig. 2,b) are similar to the workers except for their much larger, longer heads, their larger and more formidable mandibles, and their slightly greater length. Soldiers cannot feed themselves but contribute to colony labor by defending the colony. Reproductive nymphs (Fig. 2,c) develop from larvae and eventually molt into winged reproductives (Fig. 2,d). As their names imply, the primary (Fig. 2,e) and supplementary (Fig. 2,f) reproductives have the function of increasing the colony population.

Functional workers make up the largest proportion of the colony. A true worker caste does not exist in any of the termite species of concern in this chapter (Miller 1969). The function of workers is taken over by nymphs or by pseudergates. The pseudergates are size-stable individuals functioning as workers but still capable of molting and becoming nymphs, soldiers or reproductives. In most species larvae past the first 2 stages of growth also function as workers.

All termites in a colony are the same genetically. Any termite at the time of egg-hatching, is capable of becoming a member of any caste in the colony. The mechanisms which regulate the direction of development for each individual are quite complicated and beyond the scope of this chapter. The interested reader is directed to the extensive coverage of caste differentiation (Miller 1969, Noirot 1969).

Reproduction and Dispersal. A well-established, healthy colony of termites will usually produce large numbers of winged reproductives each year. They are then referred to as swarmers or alates. In a given location there may be thousands of alates emerging from numerous colonies at the same time. These swarms or flights are for the purpose of dispersing the species over a larger area, thus ensuring its survival.

The actual flight of most termites is relatively weak. They flutter close to the ground in most cases, and the direction and distance of the flights are strongly influenced by wind. Those that fly at night are attracted to lights. Alates often tumble to the ground after only a very short flight. This period when termites are flying from the nests is extremely dangerous to them. They are heavily attacked by many kinds of predators. They are subject to drying out and to heat and cold. Only a very small percentage survive long enough to start new colonies.

Initiation of New Colonies. After the flight, the wings are shed, breaking off at fracture lines near their bases. In many cases, the female assumes a "calling" position with her abdomen elevated at a right angle to the rest of the body. She releases a pheromone from the underside of her abdomen which attracts nearby males. Once a male encounters a waiting female, the pair moves off in tandem in search of a suitable site for a nest.

Wood-dwelling species (drywood and some dampwood species) enter wood directly, usually taking advantage of natural openings such as bark crevices, knotholes, nail holes, joints, etc. Subterranean and soil-nesting dampwood species usually enter a piece of wood on or near the surface of the soil. The pair excavates a small chamber large enough for the two of them, and seals the entrance. The pair mates usually within a few hours to weeks after they become established.



Figure 1. Subterranean termites are found the the area below A; drywood termites are found in the area below B.

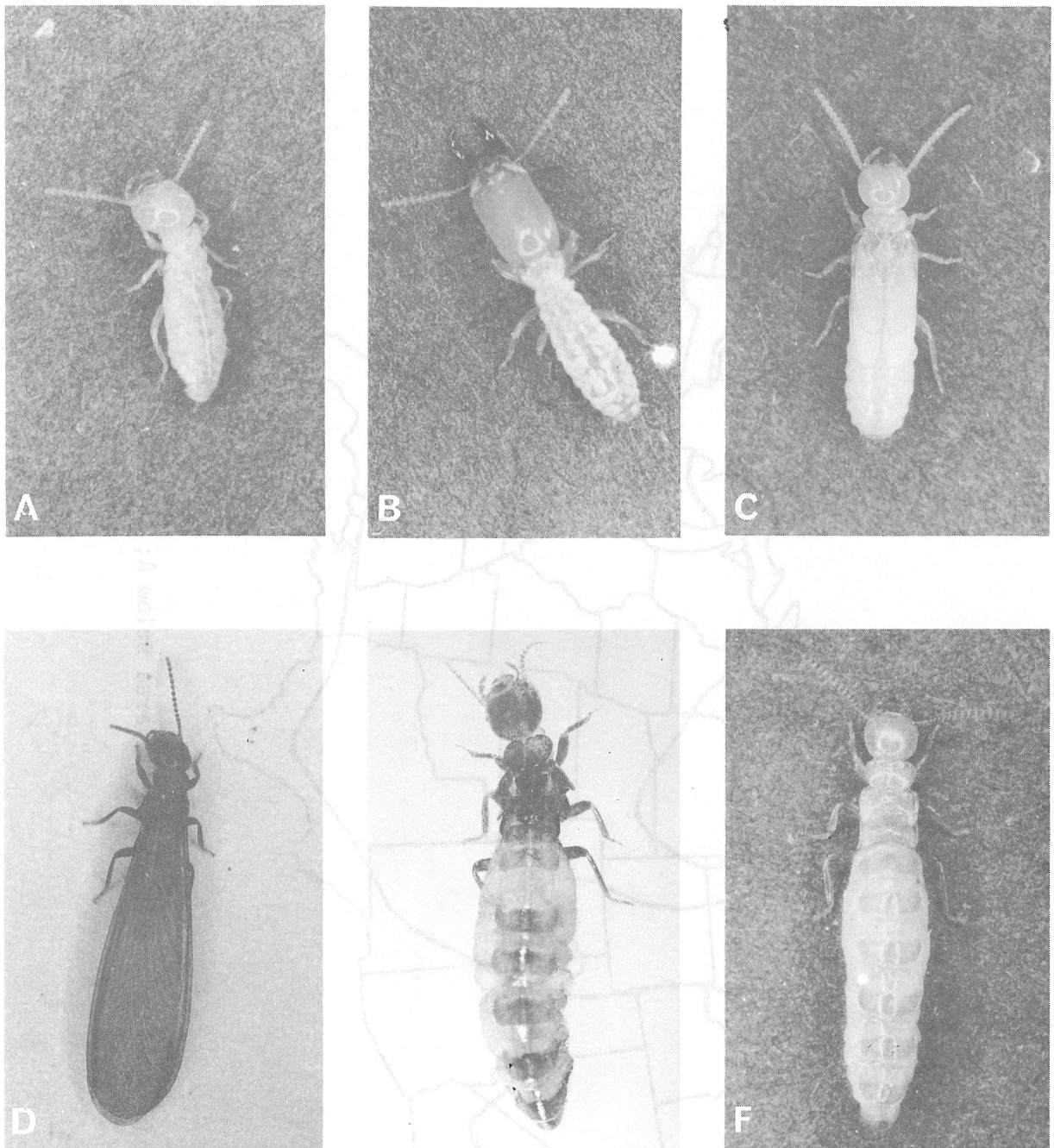


Figure 2. Subterranean termite: (a) worker, (b) soldier, (c) reproductive nymph, (d) adult, winged reproductive, (e) physogastric female winged reproductive, (f) female supplementary reproductive (Courtesy Walter Ebeling, University of California, Los Angeles).

The pair continues to live together for life and to mate periodically. If one of the pair is lost after the colony is well established, it is replaced by the development of a supplementary reproductive. The first eggs are laid within a week, or up to several weeks, after mating. When the first eggs hatch, the larvae are cared for by the reproductive pair. After 2 molts, the larvae assume their role as workers and begin to feed and care for the reproductives. The development of the colony is very slow for several years. Eggs are not deposited continuously. After the first group of eggs has been laid, there is a period of several months before another group is laid. This process continues for several years. As the female matures, she lays a greater number of eggs, and her abdomen becomes enlarged from developing eggs (Fig. 2,e). Eventually, the colony size stabilizes. That is, the queen has reached maximum egg production, and the loss of older individuals by death, and/or by swarming is approximately the same as the number of new individuals produced each year.

The maximum population size reached by a termite colony will depend on several factors. Some species, particularly the drywoods, tend to have relatively small colonies; perhaps several thousand at most. Others may reach populations of several hundred thousand. In most subterranean species, if the primary reproductives are lost, they are replaced by many supplementary reproductives (Fig. 2,f). This may result in extremely large populations.

At times, particularly among the subterranean termites, a group of individuals becomes isolated from the main body of the colony. When this happens, "subcolonies" may develop and exist independently from the main colony. This is possible because of the capacity for many individuals (mainly larvae and workers) to develop into each of the castes of a normal colony.

Food Requirements. In nature, wood serves as the main source of nutrition for most termite species found in the United States. In man-invaded environments, termites attack many products and commodities in addition to wood. Wood products like paper are favorite foods of termites because they are nearly pure cellulose. Also, cotton, burlap, and other vegetable fibers are actively consumed by termites. Termites will also damage many things that they encounter but cannot digest, such as plastics, rubber, asphalt, metal, mortar and many other materials. This occurs primarily when the indigestible items are encountered during the foraging for food.

Strange as it may seem, the termites themselves cannot digest the cellulose which they consume. They are dependent upon large numbers of protozoans that live in their gut. These protozoans engulf the wood particles as they pass through the intestine and break down the cellulose into simpler compounds. This relationship is beneficial to both termites and protozoans (Honigberg 1970).

The workers that consume wood share their nourishment with other members of the colony. The very young larvae, the soldiers and the reproductives, are all provided food from the mouth or the anus of workers. Workers also exchange food, particularly during grooming. Dead or dying members of the colony are also consumed. At times, when soldiers and reproductive nymphs become too numerous, they are killed and consumed by the workers.

Fungi also play a role in termite nutrition (Sands 1969). Certain wood decay fungi are highly attractive to termites. Others are repellent or even toxic. In those instances where an attractive fungus has partially decayed wood, it is more easily digested by termites. The fungus itself may provide a needed source of nitrogen in the termite diet. Subterranean termite damage in wood is often accompanied by fungal decay.

Moisture Requirements. Moisture in specific amounts is vital to the survival of termites. Drywood termites apparently can obtain enough water from the wood upon which they feed and from the very efficient use of water formed internally by the digestive process. Dampwood termites require more water than drywood or subterranean termites and must live in wood that is constantly moist, usually in contact with the soil. Subterranean termites obtain their moisture primarily from the soil. They maintain contact with the soil to survive.

Subterranean termites often must forage far from their initial workings to find food, sometimes above ground. They move underground through a fairly extensive system of galleries. When subterranean termites invade the wood of a structure that is separated from the soil by intervening concrete, masonry or other impervious material, they construct shelter tubes over the surface to the wood (Fig. 3). These tubes are constructed by workers from particles of soil or wood held together with fecal material. Periodically they must return to the moist galleries in the soil to replenish the water lost from their bodies in the relatively dry air of their workings above ground. In those instances where there is an above ground source of moisture from a plumbing or rain leak or from condensation on pipes, termites can remain in the wood without ground contact.

Subterranean Termites

These termites, which usually have their workings associated to some degree with soil, are referred to as subterranean termites. It is important to separate them from other types of termites to make proper decisions concerning their prevention and control. Figure 4 shows the areas where subterranean termites are found and the relative hazard of infestation in the contiguous states. The high hazard designation would apply to Hawaii as well. Most of the subterranean termites of economic significance in the contiguous states belong to the genus *Reticulitermes*. In the southern desert areas of California and Arizona *Heterotermes aureus* Snyder, which is similar to the common *Reticulitermes*, is the most economically important species. In Hawaii, and in limited areas of the contiguous states, there is another, very distinct species that deserves particular attention. This is the Formosan subterranean termite, *Coptotermes formosanus* Shiraki. It has spread from the Far East through shipboard infestations and is the most destructive subterranean species in Hawaii. It is currently found in Houston and Galveston, Texas, in New Orleans, and Lake Charles, Louisiana, and Charleston, South Carolina.

Soldiers of the *Reticulitermes* and *Heterotermes* species are so similar as to appear to be the same unless examined by a specialist. The winged reproductives (alates) vary in body color from coal black to pale yellow-brown. The wings have few hairs, if any. The wing colors vary with species from nearly transparent pale gray to brownish or smoky gray when viewed

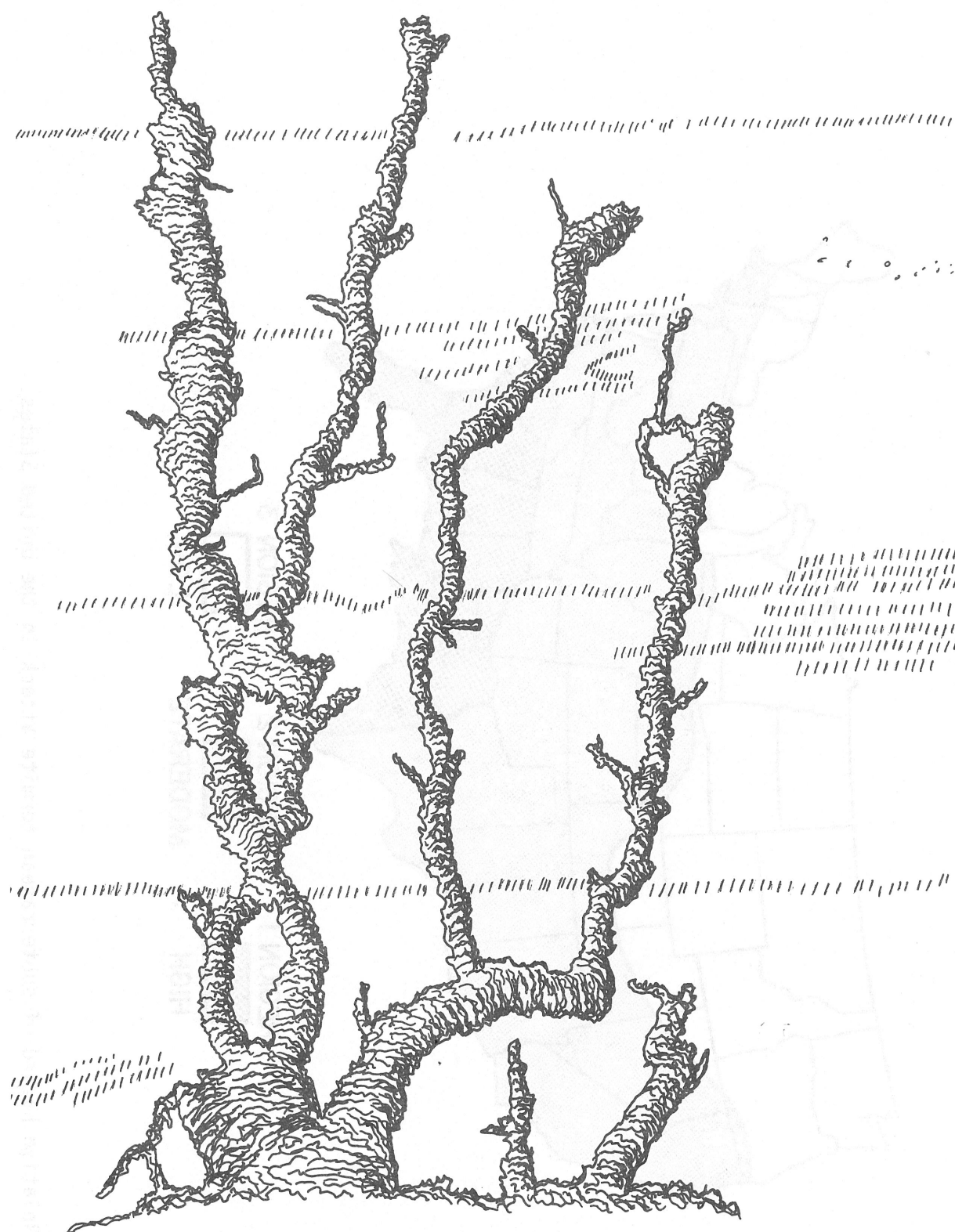


Figure 3. Subterranean termite shelter tube on foundation wall. (From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellog West, Center for Continuing Education, California State Polytechnic University, (1975). Used with permission.)

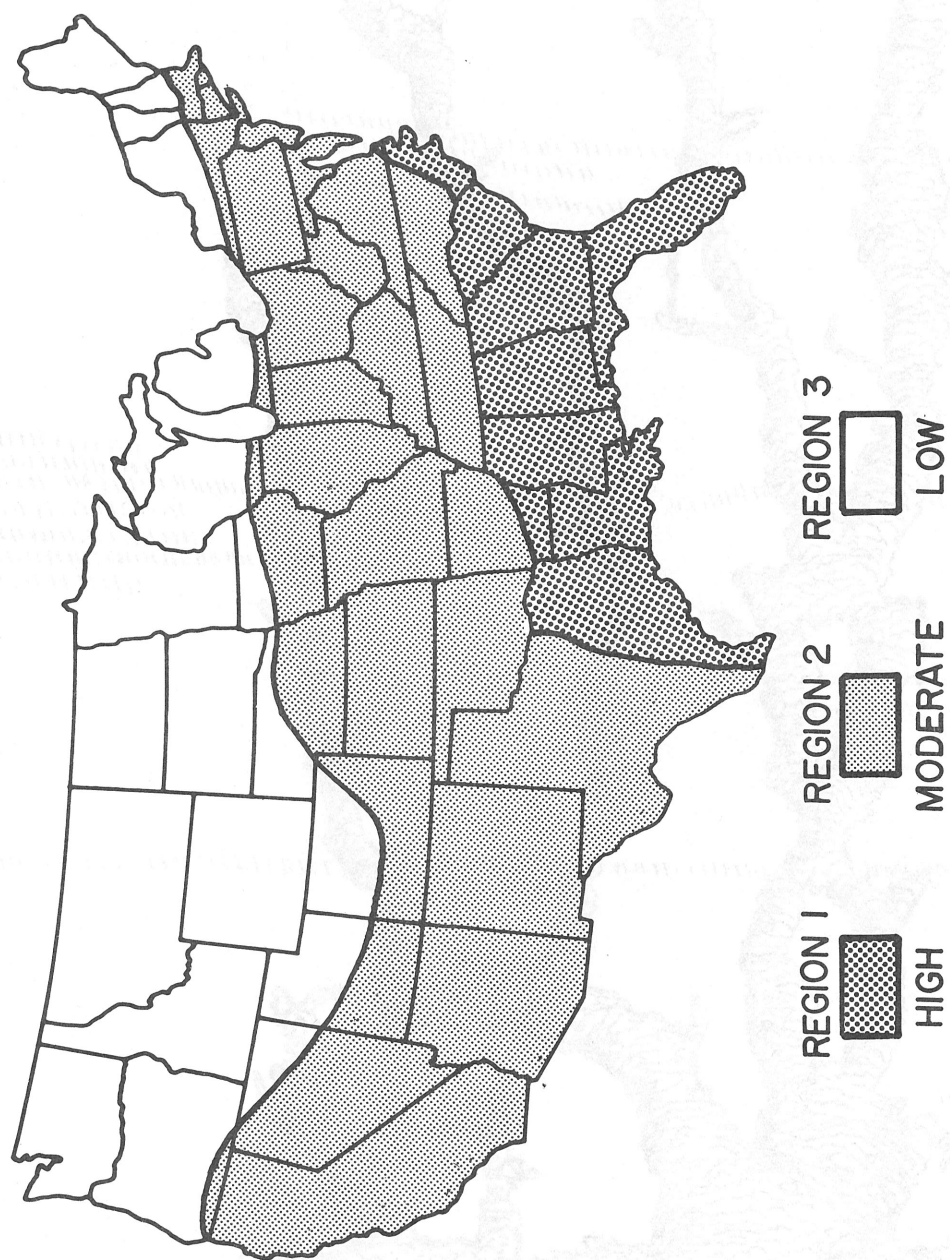


Figure 4. Relative hazard of subterranean termite attack in the United States.

against a white background. The wings have few distinct veins in them except at the leading edge (Fig. 5). There are usually 2 distinct longitudinal veins (costal margin and radial sector). This characteristic will help separate subterranean alates from those of drywoods and dampwoods. The overall length of the alates varies from 8-12 mm. The termite flight season over most of the country is in the spring and early summer. In the deserts of southern Arizona and California, flights are common in the summer shortly after the first rains. Most of our native subterranean termites species swarm during daylight, except in the southwest desert where they fly at dusk or dawn.

When they occur together the most obvious characteristics to distinguish alates of the Formosan subterranean termite from those of native species is by their larger size (up to 15 mm long) and hairy wings (Fig. 5,b). The alates are yellow-brown in color and swarm between dusk and midnight, rather than during mid-day, as do most native subterranean species. The soldiers have oval-shaped heads as compared with the rectangular heads of the native soldiers (Fig. 6). The soldiers of this species exude a whitish, sticky substance from an enlarged opening on the dorsal surface of the head, a habit not shared by the native species. Also, soldiers are much more numerous in C. formosanus.

Sources of Infestation. The termites enter buildings through wood in direct contact with the soil, by building shelter tubes over or through foundation walls, piers, chimneys, etc., and by finding cracks or joints in concrete slab floors and building shelter tubes through them into wood above the crevices (Fig. 7). Anything making contact between the soil and the wood may serve as a support for shelter tubes: trees, vines, weeds, plumbing, etc. It is also possible for termite alates to fly or be blown to a building site and then find a suitable spot to begin a colony. This, of course, would not usually create a damage problem for several years.

It is unlikely that subterranean termites will be incorporated into a structure in infested building materials. When the infested wood is placed in a structure and removed from contact with a moisture source, the termites are not likely to survive long enough to reestablish soil contact.

Signs of Infestation. Naturally, the most obvious sign of an infestation is the presence of live termites in shelter tubes or damaged wood. Most of the time only soldiers, nymphs, and pseudergates are seen. On rare occasions, functional reproductives will be found in infested wood. Primary reproductives are extremely rare in wood; replacement reproductives are more commonly found. The areas where they are active may have slightly larger galleries than other areas, otherwise there is no distinctive "nest." This is true in both soil and wood.

Usually, however, the first sign of subterranean termites, which is recognized by the occupants of a structure, is the appearance of the alates or "swarmers." Termites often swarm when the occupants are away; as a result, the occupants may find only large numbers of discarded termite wings, usually at a window. Formosan subterranean termites swarm in the evening. The alates are attracted to lights, and thus increase the likelihood of discovery.

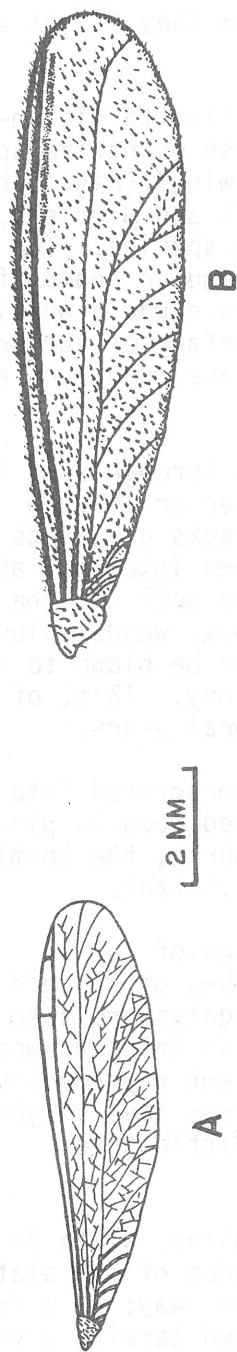


Figure 5. Wings of (a) Reticulitermes spp. and (b) Coptotermes formosanus alates. (Adapted from National Pest Control Association source. Used with permission).

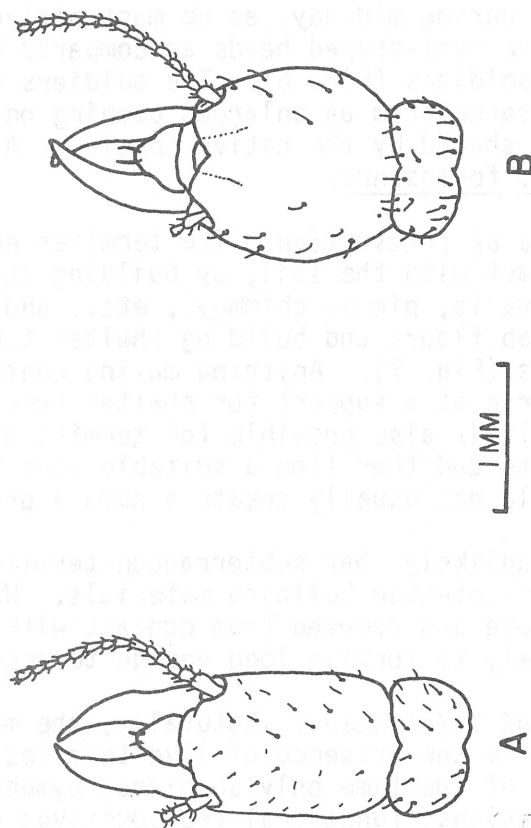


Figure 6. Heads of soldier of (a) native Reticulitermes spp. and (b) Coptotermes formosanus. (Adapted from National Pest Control Association source. Used with permission.)

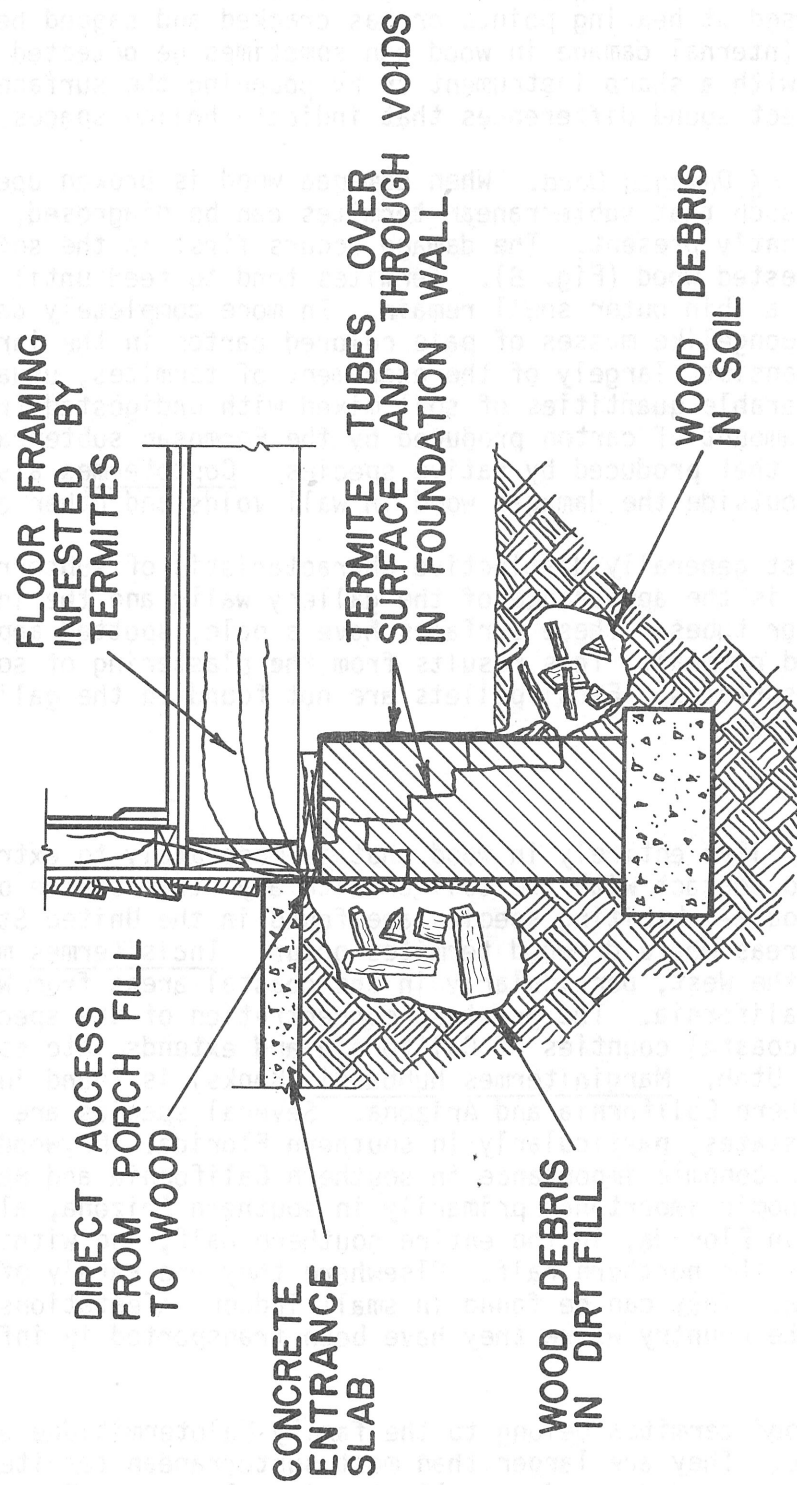


Figure 7. Points of entry in a home for subterranean termites.

Wood that is visibly damaged might also be encountered. Except for the presence of shelter tubes or soil in cracks and crevices, the only external evidence might be dark or blisterlike areas on flooring, trim or framing members. These areas are easily penetrated with a knife or screwdriver. In cases of extreme damage, there might be evidence that a board has partially collapsed at bearing points or has cracked and sagged between points of support. Internal damage in wood can sometimes be detected by probing the surface with a sharp instrument or by pounding the surface with a hard object to detect sound differences that indicate hollow spaces.

Characteristics of Damaged Wood. When damaged wood is broken open, the characteristics are such that subterranean termites can be diagnosed, even if they are not currently present. The damage occurs first in the soft spring growth of infested wood (Fig. 8). Termites tend to feed until only the harder grain and a thin outer shell remain. In more completely damaged areas there may be spongelike masses of pale colored carton in the larger galleries. Carton consists largely of the excrement of termites, usually incorporating considerable quantities of soil mixed with undigested fragments of wood. The amount of carton produced by the Formosan subterranean termite is more than that produced by native species. Coptotermes also commonly places carton outside the damaged wood in wall voids and other areas.

Probably the most generally distinctive characteristic of subterranean termite-damaged wood is the appearance of the gallery walls and the inner surface of the shelter tubes. These surfaces have a pale, spotted appearance similar to dried oatmeal. This results from the plastering of soft fecal material on the surfaces. Fecal pellets are not found in the galleries of subterranean termites.

Drywood Termites

Drywood termites live entirely in wood that is moderately to extremely dry. They require no contact with the soil or with any other source of moisture. Several house-inhabiting species are found in the United States. Figure 1 shows the areas where drywood termites occur. Incisitermes minor (Hagen) is found in the West, particularly in the coastal areas from Washington to southern California. The greatest concentration of the species is in the southwestern coastal counties of California and extends into eastern Arizona and southern Utah. Marginitermes hubbardi (Banks) is found in the desert areas of southern California and Arizona. Several species are found in the southeastern states, particularly in southern Florida. Drywood termites are of extreme economic importance in southern California and Hawaii. They are also of economic importance primarily in southern Arizona, along the Gulf Coast, and in Florida, in the entire southern half, and within 50 miles of the coast in the northern half. Elsewhere they are rarely of any economic significance. They can be found in small indoor infestations in almost any area of the country where they have been transported in infested articles.

All of the drywood termites belong to the family Kalotermitidae and are similar in appearance. They are larger than most subterranean termites and, in most cases, the alates of drywoods are lighter in color. The Formosan subterranean termite resembles the drywoods in size and color. One of the most distinctive features of the alates is the wing veins. In drywoods

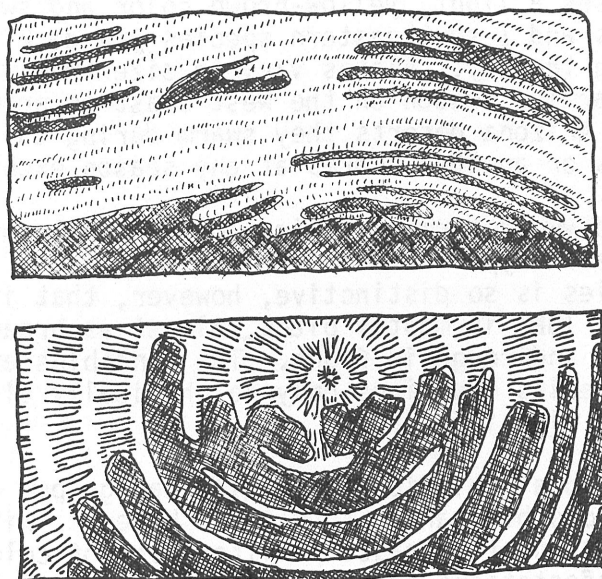


Figure 8. Cross section of wood damaged by subterranean termites. (Used with permission of the Center for Continuing Education, California Polytechnic University. See Figure 3.)

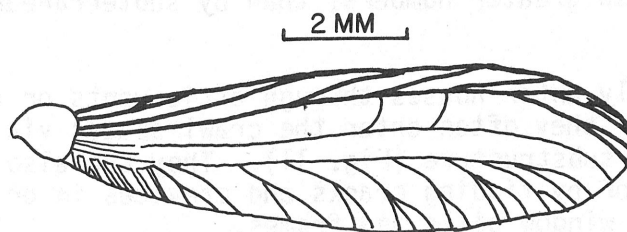


Figure 9. Wing of a drywood termite. (Adapted from National Pest Control Association source. Used with permission.)

there are several distinct longitudinal veins with many cross-veins on the anterior edge of the wing (Fig. 9). The subterranean termite wing has basically only 2 prominent longitudinal veins on the anterior edge (Fig. 5, a and b). The wing colors vary from almost clear to rather smoky black. The alates are in most cases a light, yellow-brown color and swarm at night. The West Coast species and 1 southeastern species are dark brown to black in color and swarm during the day. Alates vary in size from 9 to 15 mm in total length. The swarming season on the West Coast is primarily the fall. In the California and Arizona deserts they swarm during the summer. In the Southeast, one species or another swarms at any season except in the winter.

The soldiers of drywood termites (Fig. 10) generally are typical of the large-headed, large-jawed type found in the subterraneans. The soldier of the *Cryptotermes* species is so distinctive, however, that it should be noted. The head (Fig. 10b) is mostly black, almost as broad as long, high, and distinctly concave and rough in front. The mandibles are not enlarged. The soldier in this species functions only to physically block openings in galleries and workings with its head.

Because the individual colonies are small, damage per colony is less severe when compared to subterranean termites. However, within-building swarming and reinfestation often cause proliferation of colonies, and can result in extensive infestations over a period of time. Colonies established in one place may extend their galleries into boards, books, or furniture. Adjacent colonies sometimes coalesce. Drywood termites have been found to attack all types of wood used in buildings and furnishings. Even so, it takes a long time for drywood termites to cause serious weakness in structural timbers in houses.

Sources of Infestation. There are many ways in which drywood termites can start infestations in houses. The several species native to the Pacific Coast and the Southwest often live in dead limbs of trees, fence posts, or firewood. Alates may fly to nearby structures and also invade new houses from older buildings in nearby areas. In southern California, Arizona, and Florida, it is not uncommon for new houses to be infested by drywood termites within the first 5 years after their construction. In southern California, homes in new residential tracts tend to become infested by drywood termites sooner, and in greater numbers, than by subterranean termites (Ebeling 1975).

Swarmers generally enter houses through attic vents or roof shingles. In hot, dry locations, they often enter the crawl spaces via foundation vents, and damage the substructure (Fig. 11). They can also enter wood exposed on the exterior by finding cracks and crevices in or between boards or trim, particularly window sills and frames.

Mature drywood termite colonies usually consist of a few thousand individuals at most. As a result, they can occupy relatively small wooden articles. They readily establish colonies in furniture, dimension lumber, sash-and-door items, wood pulp or fiber insulation boards, plywood, paper, cloth, and other products containing cellulose. They are easily introduced into buildings with such infested articles.

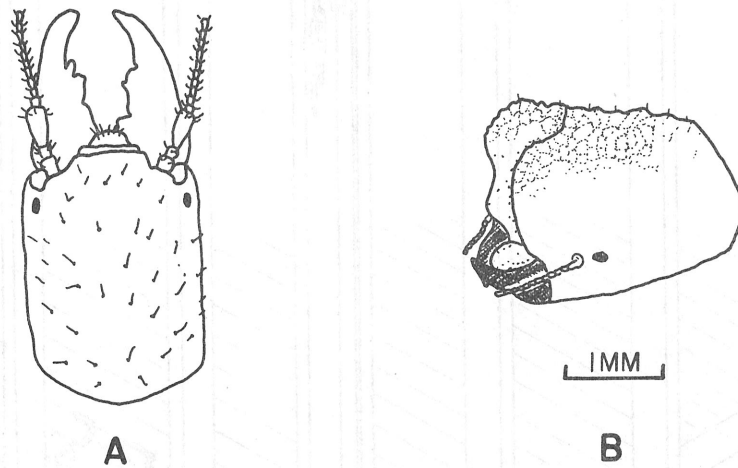


Figure 10. Heads of drywood termite soldiers: (a) Incisitermes and (b) Cryptotermes. (Adapted from National Pest Control Association source. Used with permission.)

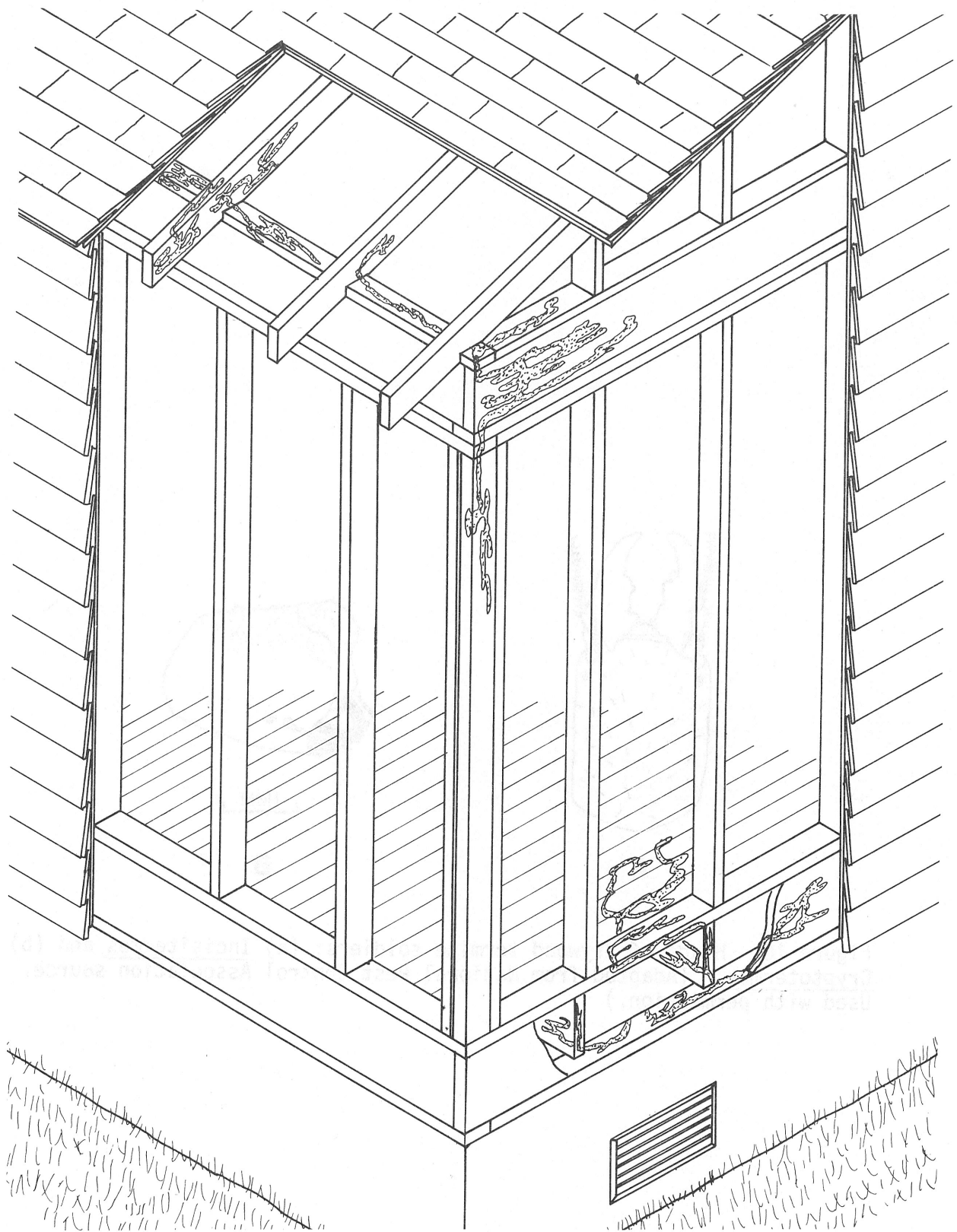


Figure 11. Drywood termite infestation in house attic and substructure.

Signs of Infestation. The first evidence of drywood termite infestations would be piles of fecal pellets. They vary in color from light gray to very dark brown, depending on the wood being consumed. The pellets are hard, elongated (less than 1 mm in length), with rounded ends and 6 flattened or concavely depressed sides (Fig. 12). These pellets are eliminated from the galleries in the wood through round "kick holes." They tend to accumulate on surfaces or in spider webs located below these holes.

There is little external evidence of drywood termite attack other than the pellets. The kick holes are closed with a light brown secretion and fecal pellets. Drywood termites tend to work just under the surface of the wood, leaving a very thin, veneer-like layer. Probing wood with a sharp instrument, or tapping the surface, may reveal hidden damage.

Characteristics of Damaged wood. Wood damaged by drywood termites contains broad chambers connected by tunnels. These tunnels cut across the grain without regard for early wood and late wood (Fig. 13). The galleries are smooth and have no surface deposits, such as those found in subterranean termite workings. Usually some fecal pellets are stored in portions of the galleries. These areas are often closed off by partitions made of fecal pellets cemented together with a light brown secretion.

Dampwood Termites

The dampwood termites form a distinct habitat group. The areas where dampwood termites are found most commonly and are of greatest economic importance are the Pacific Coast states and northern Nevada, Idaho, and Montana, west of the Continental Divide. They thrive in the immediate coastal areas and in the higher elevations that have large amounts of rainfall. They are particularly common in northern California and in western Oregon and Washington. Other species are found in the semiarid and desert regions of the Southwest and in the extreme southern tip of Florida. They are representatives of dampwoods in 3 families of termites. Each will be discussed separately.

Zootermopsis angusticollis (Hagen) and Z. nevadensis (Hagen) (family Hodotermitidae) are found along the Pacific Coast. They are the largest termites found anywhere in the country, and are not likely to be confused with any of the other types. The members of the colony can be recognized by their size, even when no alates or soldiers are present. The larger individuals are 15-20 mm long. The alates may be up to 25 mm in length, including the wings. The wing veins are prominent only in the front edge and are also more numerous than similar veins in the wings of subterranean termites (Fig. 14). The alates vary in color from yellowish-brown to dark brown, depending on the species. They fly at dusk during most months of the year, but tend to be most common in late summer and early fall. The soldiers are quite large, 15-20 mm long, and have very large, dark heads with large mandibles.

The dampwood termite of the dry southwestern areas of the United States, Paraneotermes simplicicornis (Banks), is in the family Kalotermitidae. This species requires much more moisture than other species in this family. They are larger than most subterranean termite species, the alates being 12 mm in length, including wings. Figure 14b shows the wing of a desert dampwood termite. The alates are dark brown with the ventral portion of the abdomen



Figure 12. Drywood termite fecal pellets. (Used with permission of the Center for Continuing Education, California Polytechnic University. See Figure 3.)

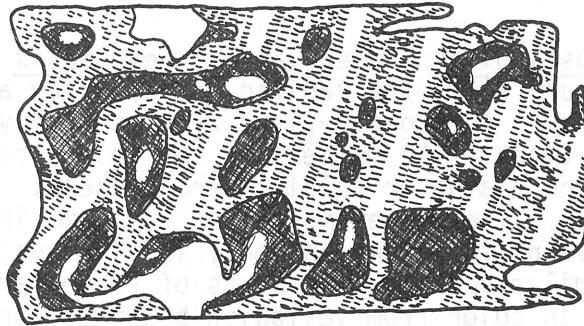


Figure 13. Cross section of wood damaged by drywood termites. (Used with permission of the Center for Continuing Education, California Polytechnic University. See Figure 3.)

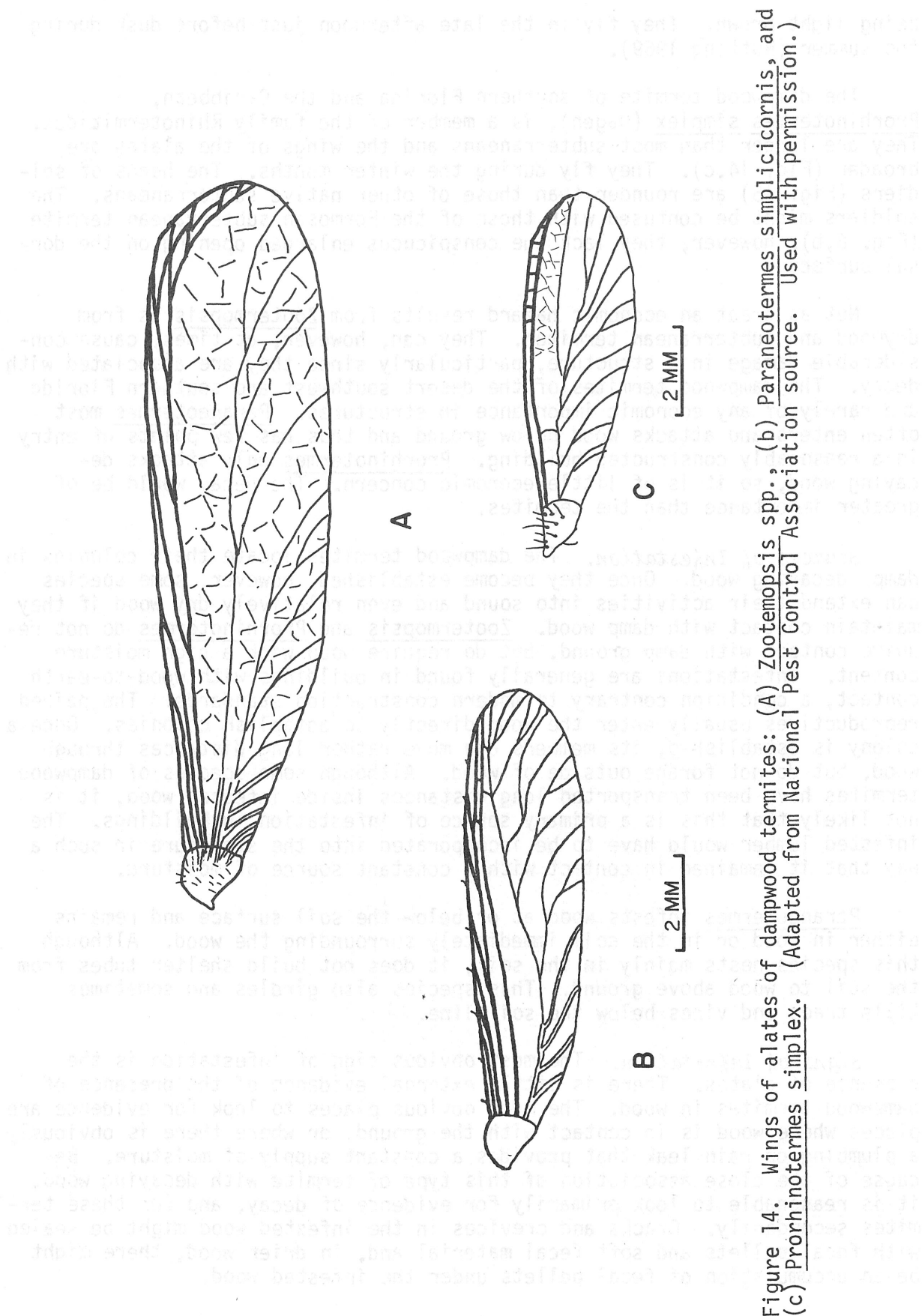


Figure 14. Wings of alates of dampwood termites: (A) *Zootermopsis* spp., (B) *Paraneotermea simplicicornis*, and (C) *Prorhinotermea simplex*. (Adapted from National Pest Control Association source. Used with permission.)

being light brown. They fly in the late afternoon just before dusk during the summer (Nutting 1969).

The dampwood termite of southern Florida and the Caribbean, Prorhinotermes simplex (Hagen), is a member of the family Rhinotermitidae. They are larger than most subterraneans and the wings of the alates are broader (Fig. 14,c). They fly during the winter months. The heads of soldiers (Fig. 15) are rounder than those of other native subterraneans. The soldiers might be confused with those of the Formosan subterranean termite (Fig. 6,b), however, they lack the conspicuous enlarged opening on the dorsal surface.

Not as great an economic hazard results from Zootermopsis as from drywood and subterranean termites. They can, however, at times, cause considerable damage in a structure, particularly since they are associated with decay. The dampwood termites of the desert southwest and southern Florida are rarely of any economic importance in structures. Paraneotermes most often enters and attacks wood below ground and thus has few points of entry in a reasonably constructed building. Prorhinotermes only attacks decaying wood, so it is of little economic concern. The decay would be of greater importance than the termites.

Sources of Infestation. The dampwood termites locate their colonies in damp, decaying wood. Once they become established, however, some species can extend their activities into sound and even relatively dry wood if they maintain contact with damp wood. Zootermopsis and Prorhinotermes do not require contact with damp ground, but do require wood with a high moisture content. Infestations are generally found in buildings with wood-to-earth contact, a condition contrary to modern construction standards. The paired reproductives usually enter the wood directly to establish colonies. Once a colony is established, its members can move rather long distances through wood, but do not forage outside of wood. Although some species of dampwood termites have been transported long distances inside infested wood, it is not likely that this is a primary source of infestation in buildings. The infested lumber would have to be incorporated into the structure in such a way that it remained in contact with a constant source of moisture.

Paraneotermes infests wood at or below the soil surface and remains either in wood or in the soil immediately surrounding the wood. Although this species nests mainly in the soil, it does not build shelter tubes from the soil to wood above ground. This species also girdles and sometimes kills trees and vines below the soil line.

Signs of Infestation. The most obvious sign of infestation is the presence of alates. There is little external evidence of the presence of dampwood termites in wood. The most obvious places to look for evidence are places where wood is in contact with the ground, or where there is obviously a plumbing or rain leak that provides a constant supply of moisture. Because of the close association of this type of termite with decaying wood, it is reasonable to look primarily for evidence of decay, and for these termites secondarily. Cracks and crevices in the infested wood might be sealed with fecal pellets and soft fecal material and, in drier wood, there might be an accumulation of fecal pellets under the infested wood.

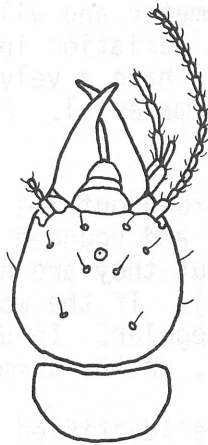
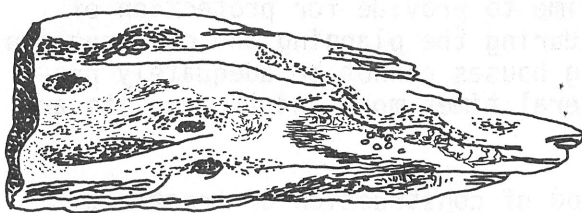
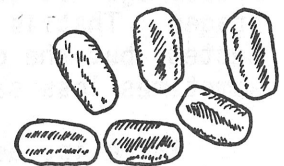


Figure 15. Head of Prorhinotermes simplex soldier. (Adapted from National Pest Control Association source. Used with permission.)



A



B

Figure 16. Dampwood termite damage: (a) wood (b) fecal pellets. (Used with permission of the Center for Continuing Education, California Polytechnic University. See Figure 3.)

Characteristics of Damaged Wood. The appearance of wood damaged by Zootermopsis will vary according to the amount of decay present in the wood. If the wood is comparatively sound, the tunnels or galleries will tend to follow the annual rings with the soft, early wood being eaten first. If the wood has a considerable amount of decay, the galleries or tunnels will be much larger in diameter and will pass through both early wood and late wood. There is much variation in size and shape of galleries. The surfaces of the galleries have a velvety appearance and they are sometimes covered with dried fecal material. Figure 16a shows typical feeding damage on a piece of wood.

Fecal pellets may be found throughout the workings. They are usually hard, elongated (about 1 mm long), and rounded at both ends. There are traces of 6 longitudinal ridges, but they are not as distinct as those of drywood termite pellets (Fig. 16,b). If the wood is extremely damp, the pellets are often spherical or irregular. In drier conditions, the pellets collect in the bottom of galleries, or the termites may throw them outside.

Damage by Paraneotermes can be identified by the presence of numerous, hard, conical, dark fecal pellets. The wood is not usually plastered with feces; however, the soil and galleries surrounding the wood is usually blackened with feces. Damage by Prorhinotermes is similar to subterranean termite damage.

TERMITES: PREVENTION AND CONTROL

The building contractor or homeowner can play an active role in preventing or controlling attack by termites through proper construction or correction of improper construction. Homeowners are limited, however, in what they can do to chemically control any wood-destroying insects because certification by State regulatory agencies will soon be required to use the necessary pesticides. Prevention and control of termites (as well as all the other wood-destroying insects), therefore, will be reviewed briefly in this chapter. The major aspects of prevention and control of termites are discussed in great detail by Spear (1970).

Subterranean Termites: Prevention

The most effective and economical time to provide for protection of houses against subterranean termites is during the planning and construction stages. That is not to say that existing houses cannot be adequately protected, but the cost of treatment is several times more and the results are sometimes less satisfactory.

There is, as yet, no foolproof method of construction or treatment which will prevent infestation by subterranean termites. Many measures, however, can be taken to decrease the likelihood of initial attack and to control existing infestations. Good design, conscientious construction procedures with supplemental use of chemically treated wood, and soil treatment can provide adequate protection at a reasonable cost.

Whatever methods are used to prevent or control subterranean termites, one rather simple principle is involved. It is, to prevent their simultaneous access to food and moisture (Mampe 1973). This principle includes the

following kinds of procedures: (1) The elimination of food through proper design and construction (or modification of existing conditions) and through the removal of cellulosic debris at building sites; (2) The control of moisture through adequate drainage and ventilation; the exposure of termite shelter tubes through the use of impenetrable barriers between the soil and the structural wood; and (3) The use of chemicals for direct control, for establishment of barriers by soil treating, and for the preservative treatment of wood.

Wherever subterranean termites are found, consideration should be given to the hazard they represent. This hazard will vary with the geographic location (Fig. 4), the type of construction, and the building site itself. In areas where subterranean termites represent only a moderate hazard on the average, the probability of attack is increased when houses are erected where woodland (the natural habitat of termites) formerly stood, or where old, infested buildings have been torn down. It is well to keep this in mind when determining the extent of preventive measure needed.

Good Design. The first consideration, of course, comes in the design of the structure. It is important to be aware of the potential points of entry by termites (Fig. 7). No current type of construction in and of itself forms an adequate physical barrier to subterranean termite entry.

A. *Foundations.* All foundations should be constructed as termite resistant as possible to prevent hidden attack on wood above them. Foundations are rated in decreasing order of relative resistance to penetration by subterranean termites by Johnston et al. (1972).

1. Poured concrete foundations (Fig. 17), properly reinforced, prevent large shrinkage or settlement cracks.
2. Hollow-block or brick foundations and piers:
 - a. Capped with a minimum 10 cm of reinforced poured concrete (Fig. 18).
 - b. Capped with precast solid concrete blocks, and joints completely filled with cement mortar or poured lean grout.
 - c. Top course of blocks and all joints completely filled with concrete. (Where hollow blocks are not filled, no protection is provided.)
3. Wooden piers, or posts used for foundation or piers, pressure treated with an approved preservative by a standard pressure process.

Only types 1 and 2a have any significant protective value. In considering any of these foundation types, keep in mind that, for every departure from an uninterrupted, smooth and solid concrete foundation, one or more access points for termites is introduced.

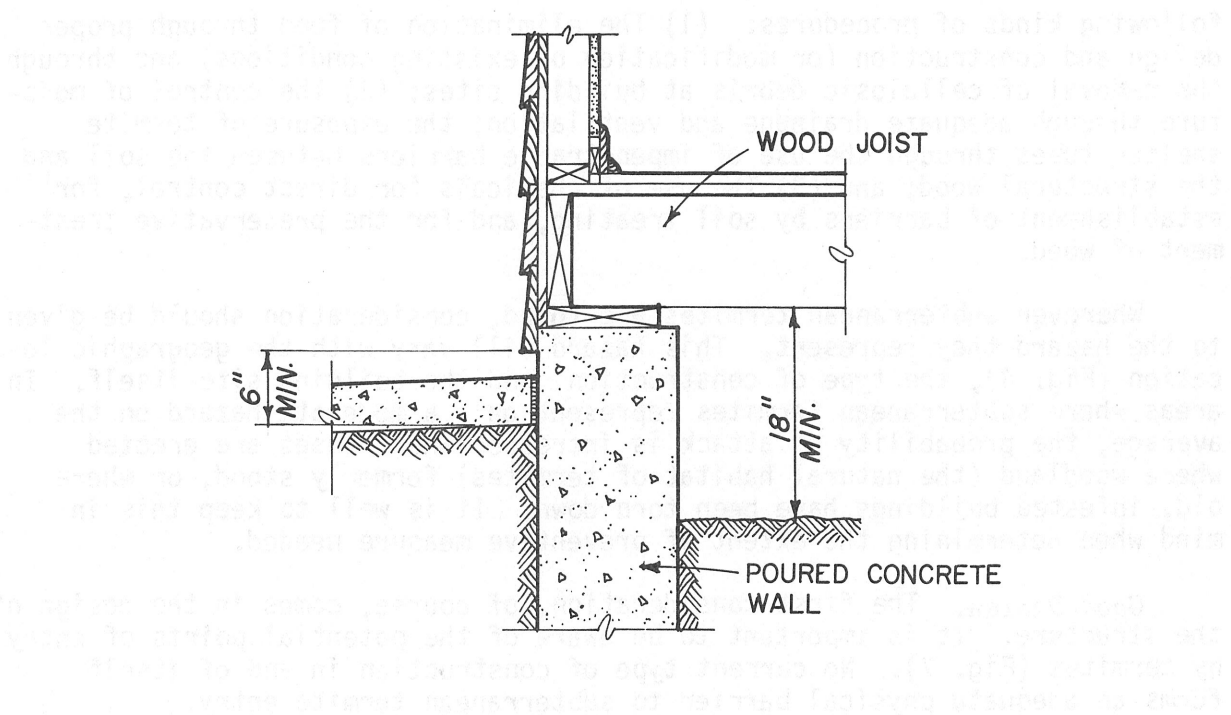


Figure 17. Poured concrete foundation.

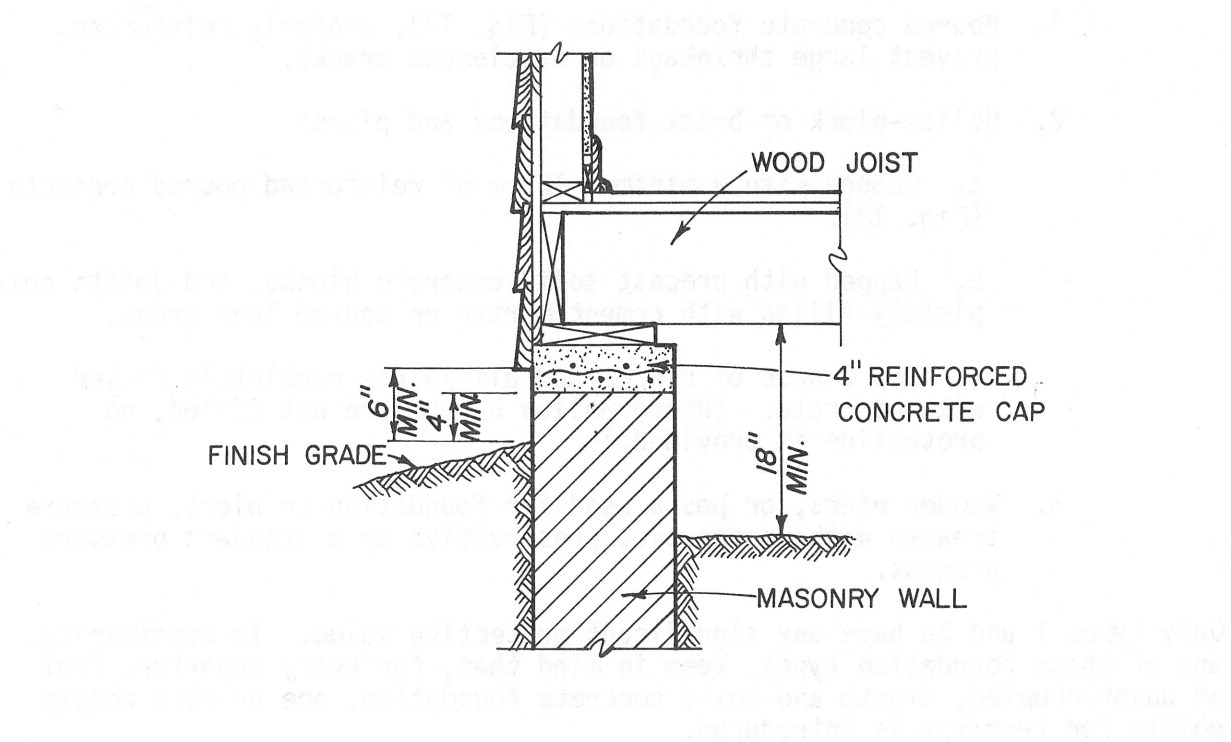


Figure 18. Capped masonry foundation.

For many years, concrete slab-on-ground construction was considered to be safe from termites. To the contrary, it is one of the most susceptible types of construction. Termites can enter through cracks and joints and around pipe openings or they can build tubes over the edges of the slabs. There are 3 basic types of slab-on-ground construction, each varying in their susceptibility to invasion by subterranean termites (Johnston et al. 1972). The type most resistant to entry by termites is the monolithic slab (Fig. 19,a). In this type, the floor and footing are poured as one continuous operation, so that there are few points which might allow hidden termite entry. Termites may, however, find entry around plumbing and other utility pipes or through cracks which sometimes develop in spite of reinforcement. The second type is the suspended slab that extends across the top of the foundation wall (Fig. 19,b). This provides some protection from termite entry through voids or vertical cracks in the foundation, but there are other possible entry points as in the monolithic slab, as well as over the edge of the slab on the outside. The third type is the floating slab. In this type, the slab may rest on a ridge of the foundation (Fig. 19,c) or be independent of it (Fig. 19,d). This is the type most likely to be invaded by subterranean termites. The expansion joints where the slabs contact the foundations are often invaded.

B. *Attachments and appurtenances.* Attachments and appurtenances to the main foundation require special consideration. It has been a common practice in the past for many structures such as concrete steps, porches, patios, breezeways, carports, and terraces to be built over earth fills. Such construction brings the level of soil into close proximity to the wooden members of the structure (Fig. 7). Termite colonies in these fills appear to be the sources of over half the subterranean termite infestations of structures (Ebeling 1975). Structures should be constructed so as to be open for ventilation and inspection, or to expose the upper part of the concrete foundation or the cap of the masonry foundation. Attention to structural detail alone would significantly reduce the access of most subterranean termites to buildings and save many millions of dollars in repair costs (Spear 1970).

Ornamental attachments to buildings such as porte cocheres, trellises, buttresses, and others, should be constructed so as to rest on concrete or masonry foundations that extend at least 15 cm above exterior grade or any adjoining soil. This clearance prevents hidden access to the wood by termites in the soil.

Planters attached to houses should have a clear gap of at least 5 cm between the planter and the house structure. If they must be attached, they should be firmly anchored and constructed as an integral part of the foundation to provide no hidden access between the planter and the house. The soil level should not reach within 20 cm of the lowest wooden structural members of the house.

C. *Heating System.* Perimeter heat ducts also create problems in termite control, even when no insulation is involved. These heat ducts are incorporated into the slab or are placed just beneath the slab (Fig. 20). If termites make entry through cracks in the ducts or through openings around the heat registers, it is extremely difficult to adequately treat the soil, especially without contaminating the heat ducts.

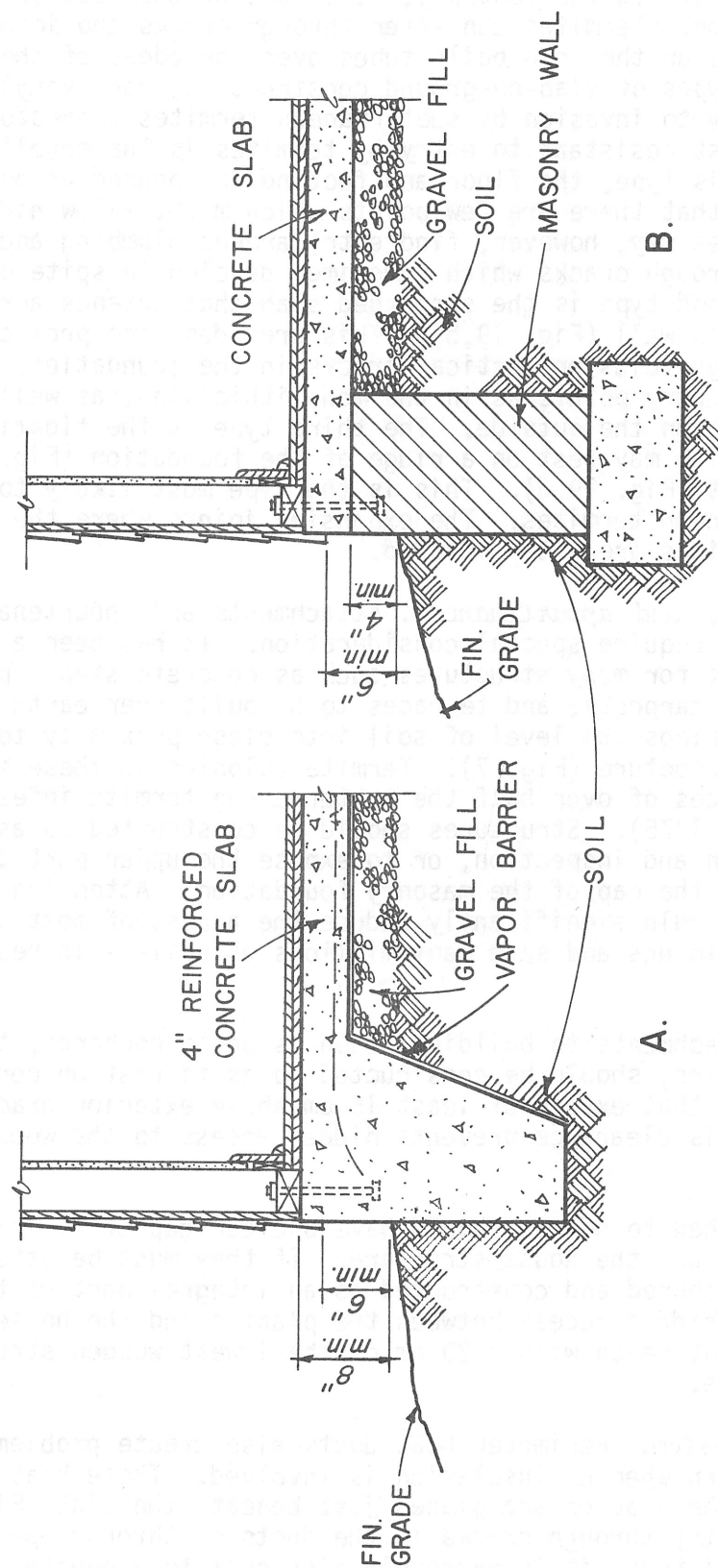


Figure 19. Types of slab-on-ground construction: (a) monolithic slab, (b) supported slab.

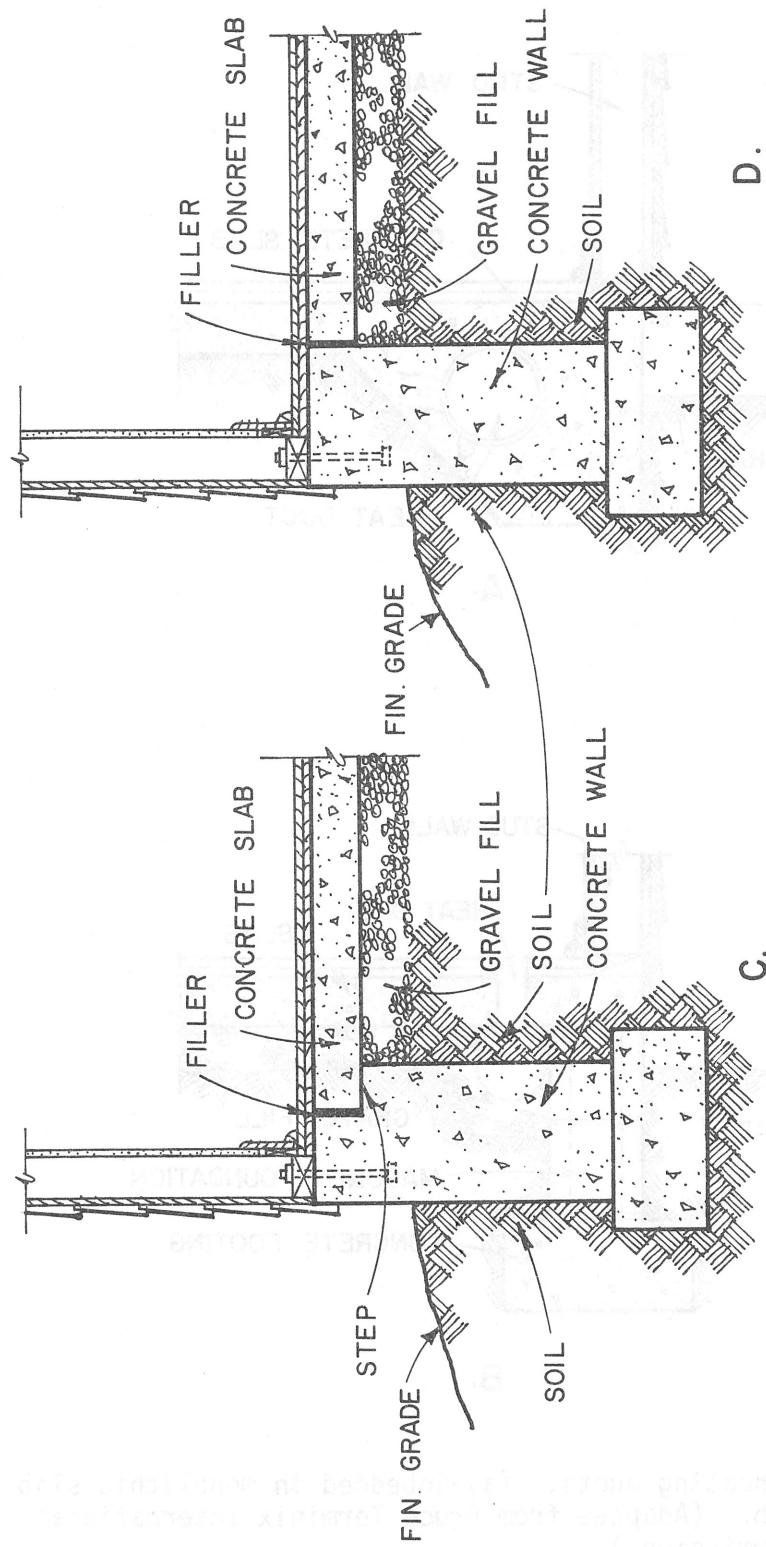


Figure 19. Types of slab-on-ground construction: (c) floating slab resting on foundation ledge, and (d) floating slab independent of foundation.

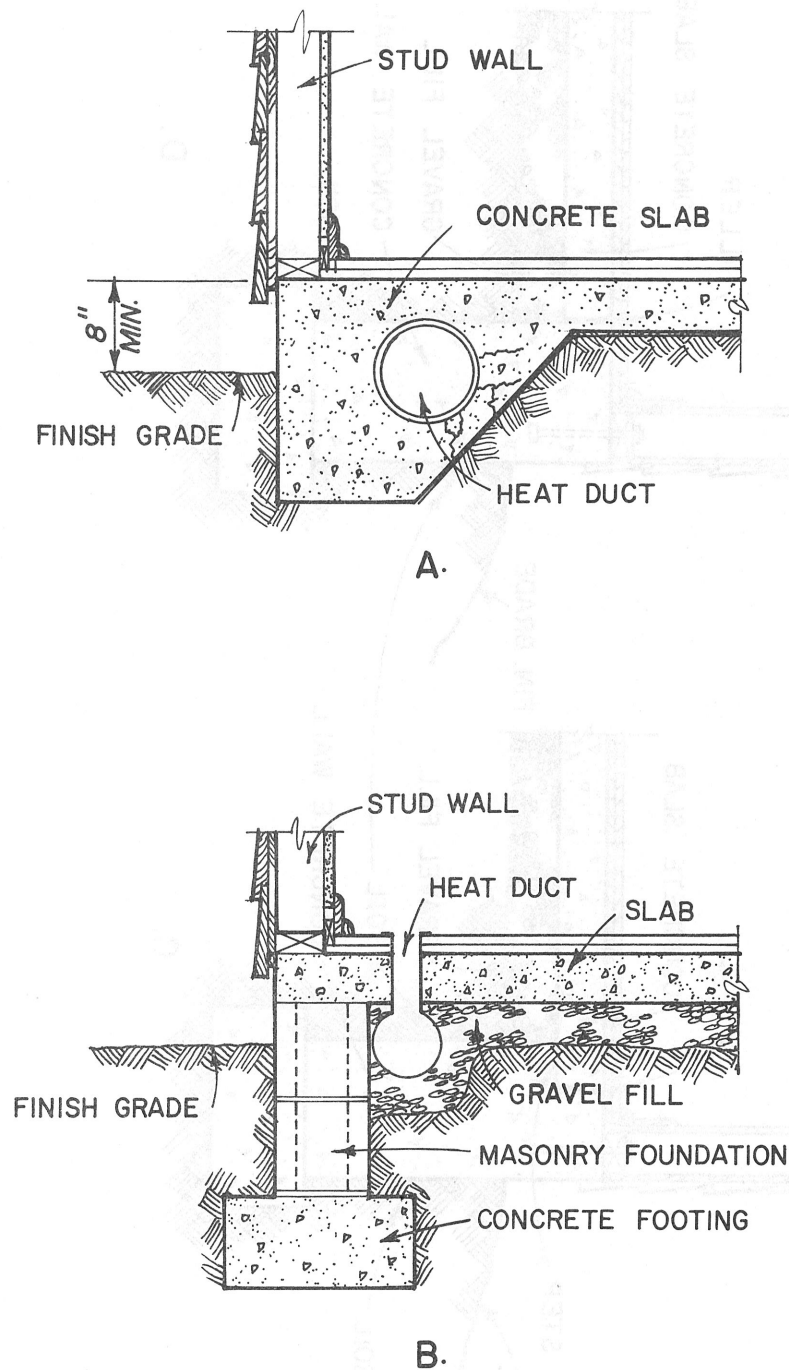


Figure 20. Subfloor heating ducts: (a) inbedded in monolithic slab and (b) under a supported slab. (Adapted from Bruce Terminix International, Inc., source. Used with permission.)

D. *Soil-wood clearance.* Clearance between wood and soil is an often neglected aspect of construction. The minimum clearance between outside finish grade and the top of a floor slab should be 20 cm with at least 15 cm exposed. In crawl spaces, the minimum clearance between the ground and the bottoms of floor joists should be 45 cm. Clearance for beams and girders should be at least 30 cm. The outside grade lines of houses with crawl spaces or basements should be at least 15 cm below all exterior woodwork. Where the superstructure is of brick or other masonry, the grade line should be 20 cm below the top of the foundation. If a masonry foundation is capped with 10 cm of reinforced concrete, the grade line should be at least 10 cm below the uppermost horizontal joint. These clearance requirements provide a means of visual inspection for termite shelter tubes and often expose these tubes to adverse environmental conditions. An added advantage to all such clearance between wood and soil is that it reduces the danger of decay.

E. *Moisture control.* Concrete carport, garage, porch, and entrance slab floors attached to houses should be sloped to drain water away from the foundation. The level of soil fill under all such slabs should be at least 20 cm below framing members and 15 cm below any wood siding.

Proper ventilation under buildings with crawl spaces is important in reducing subterranean termite activity by lowering humidity and drying the soil. It has the added advantages of reducing risk of decay and beetle attack. The ventilators should be large enough and so distributed to prevent dead air pockets from forming. Shrubbery and other plantings should be placed far enough from ventilator openings to permit free circulation of air. Additionally, in areas of high humidity and high water tables, it is advisable to cover the ground under crawl space construction with a vapor barrier. This will help reduce termite activity by reducing crawl space humidity.

F. *Porches.* Porch supports, such as piers adjacent to a house, should be separated from the foundation proper by a clear gap of 5 cm to prevent hidden access by termites. Where wooden steps are used, they should not rest directly on the ground. The carriages should rest on a concrete base that extends at least 15 cm above grade (Fig. 21).

G. *Wood imbedded in concrete.* It has been common practice in the past for exterior door frames and jambs to be placed before concrete floors of garages, basements, etc., have been poured. Very often the frame or jamb is partially imbedded in the concrete or even extends through it to the soil. This makes a perfect hidden entry point for termites. When this is done on the outside, the pockets formed around the wood collect water and make ideal conditions for subterranean termites and decay fungi. Whenever window frames or other openings near or below outside grade are made of wood, particular attention should be paid to making the foundation wall surrounding the wood as impervious to termites as possible. Also, the level of the bottom of the window well should be at least 15 cm below the nearest wood. Wooden support posts, stair carriages, or partition walls used in a basement should be put into place after the slab floor is poured. If they extend into or through the concrete, they are subject to hidden attack by termites (Fig. 22).

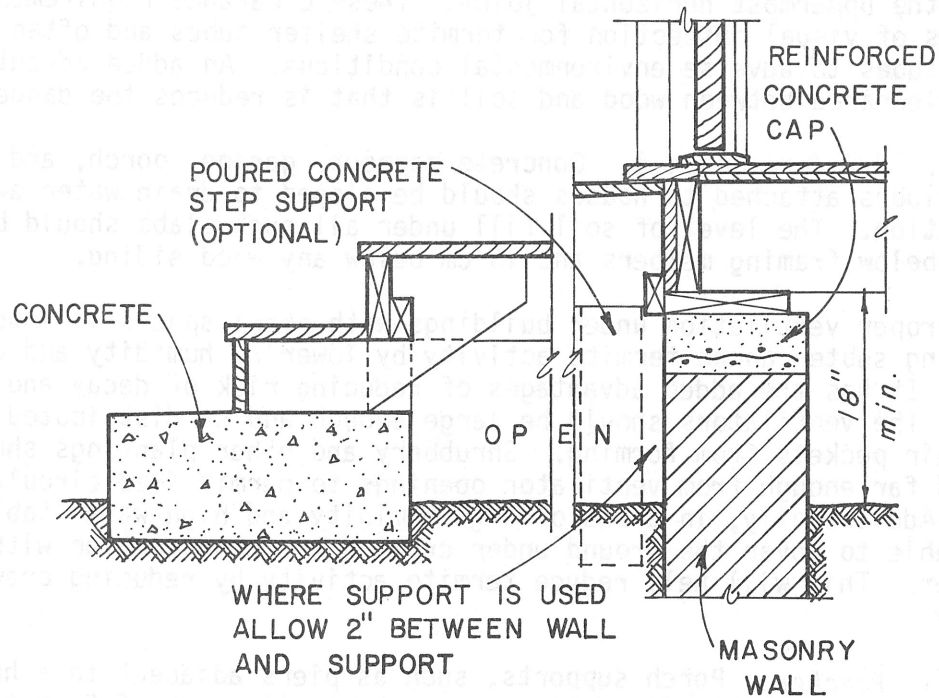


Figure 21. Wooden porch and steps.

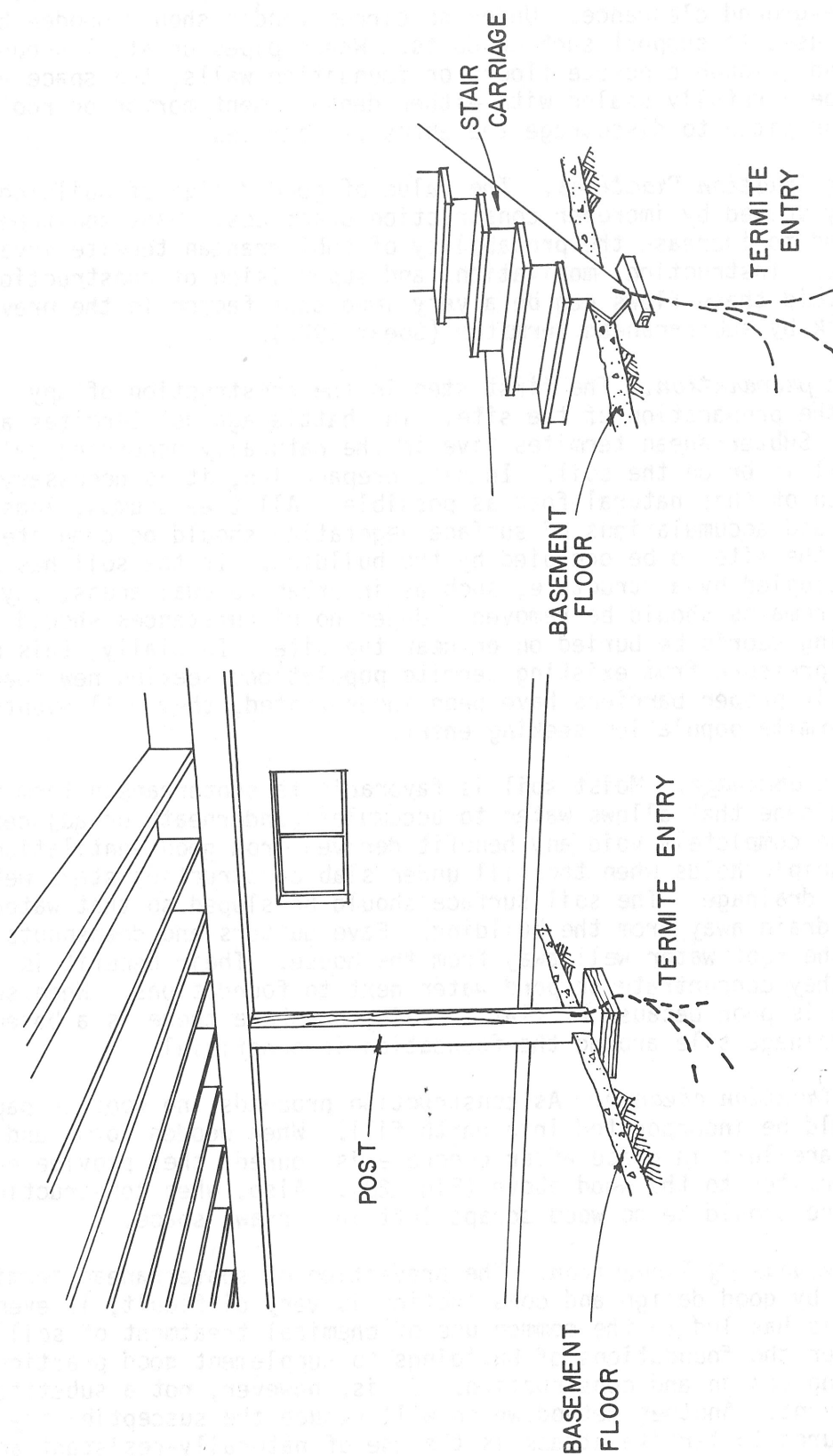


Figure 22. Wooden basement steps and posts extending through concrete floor. (Adapted from National Pest Control Association source. Used with permission.)

H. *Pipes and conduit.* Plumbing and other utility conduits in crawl spaces need to be installed carefully. All such conduits should be suspended clear of the ground, preferably from girders and joists to provide maximum above-ground clearance. Under no circumstances should wooden blocks or stakes be used to support such conduits. Where pipes or steel support columns extend through concrete floors or foundation walls, the space around them should be carefully sealed with either dense cement mortar or roofing grade coal tar pitch to discourage the entry of termites.

Good Construction Practices. The value of good design of buildings can be completely voided by improper construction practices. Many construction practices tend to increase the probability of subterranean termite invasion of structures. Instruction, motivation, and supervision of construction workers to avoid these flaws can be a very important factor in the prevention of attack by subterranean termites (Spear 1970).

A. *Site preparation.* The first step in the construction of any building is the preparation of the site. The battle against termites also begins here. Subterranean termites live in the naturally occurring cellulosic material in or on the soil. In site preparation, it is necessary to remove as much of this natural food as possible. All tree stumps, logs, large roots, and accumulations of surface vegetation should be completely removed from the site to be occupied by the building. If the soil has been previously occupied by a structure, such as in urban renewal areas, any wood debris which remains should be removed. Under no circumstances should any wood-containing debris be buried on or near the site. Initially, this may increase the pressure from existing termite populations seeking new food sources, but if proper barriers have been incorporated, they will eventually reduce the termite population seeking entry.

B. *Water drainage.* Moist soil is favorable to subterranean termites. Poor site drainage that allows water to accumulate underneath or adjacent to a house can completely void any benefit derived from good ventilation. The same principle holds when the fill under slab construction stays wet because of poor drainage. The soil surface should be sloped so that water will quickly drain away from the building. Eave gutters and downspouts should take the roof water well away from the house. Their benefit is voided when they concentrate or pond water next to foundations. When surface drainage is poor because of flat terrain, or where there is a basement, the use of drainage tile around the foundation is beneficial.

C. *Construction cleanup.* As construction proceeds, no wood or paper products should be incorporated into earth fill. When wooden forms and grade stakes are left in place after concrete is poured, they provide easy access for termites to the wood above (Fig. 23). Also, when construction is complete, there should be no wood scraps left in a crawl space.

Direct Methods of Prevention. The prevention of subterranean termites in structures by good design and construction is very difficult, if even possible. This has led to the common use of chemical treatment of soil around or under the foundations of buildings to supplement good practice in modern building design and construction. It is, however, not a substitute, only a supplement. Another method which will reduce the susceptibility of wooden structures to termite attack is the use of naturally-resistant and chemically-treated woods.

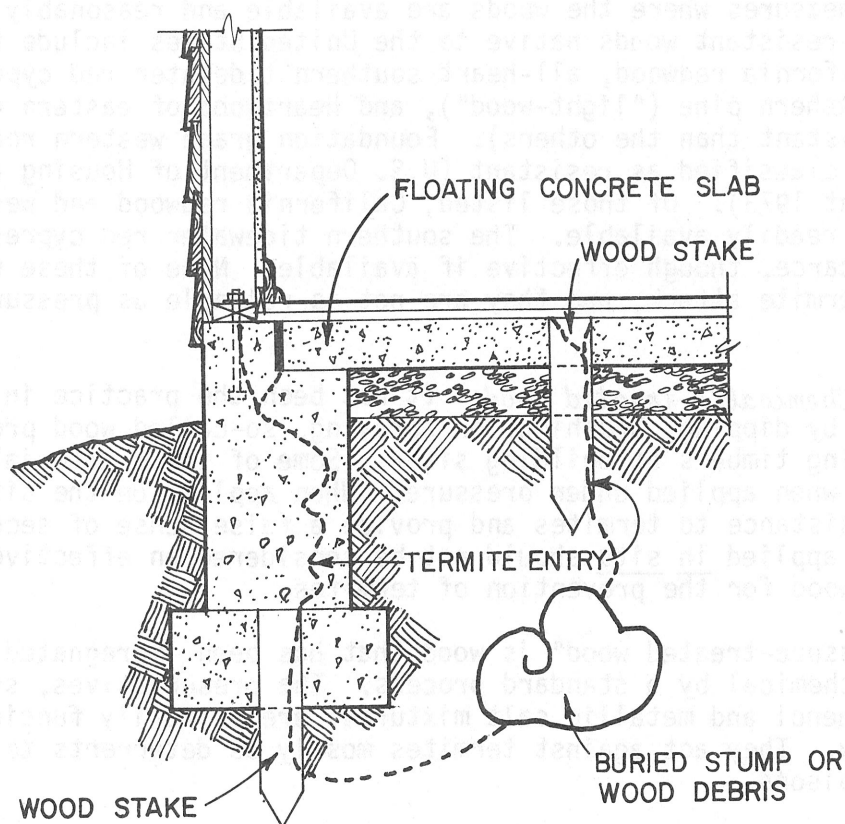


Figure 23. Grade stakes left in concrete.

A. *Naturally-resistant wood.* These woods contain extractives which are toxic or repellent to termites. Only the heartwood is resistant. In most cases, the wood must be used above ground and protected from weathering to remain resistant. The practice of using these woods in construction is very old and, until recently, in many parts of the world was the sole means of defense against termites. Use of naturally-resistant wood has largely been replaced by wood preservatives, soil poisons, and more durable construction materials and methods. It still has a minor place as a supplement to other measures where the woods are available and reasonably priced. The naturally-resistant woods native to the United States include foundation grade California redwood, all-heart southern tidewater red cypress, very pitchy southern pine ("light-wood"), and heartwood of eastern red cedar (less resistant than the others). Foundation grade western red cedar has also been classified as resistant (U.S. Department of Housing and Urban Development 1973). Of those listed, California redwood and western red cedar are readily available. The southern tidewater red cypress is extremely scarce, though effective if available. None of these woods is immune to termite attack, and they are not as reliable as pressure-treated wood.

B. *Chemically-treated wood.* It has been the practice in the past to apply, by dipping, brushing, or spraying, so-called wood preservatives to wood framing timbers at building sites. Some of these materials are quite effective when applied under pressure. When applied on the site they offer little resistance to termites and provide a false sense of security. Preservative applied in situ should not be considered an effective means of treating wood for the prevention of termites.

"Pressure-treated wood" is wood that has been impregnated with an approved chemical by a standard process. The preservatives, such as pentachlorophenol and metallic salt mixtures, are primarily fungicides to prevent decay. They act against termites mostly as deterrents to feeding or as stomach poisons.

Naturally-resistant or pressure-treated wood should not be considered a termite barrier, but only protection for those parts of the structure actually constructed from these woods. Termites will build shelter tubes over resistant or treated wood to get at untreated wood above it. In the contiguous states, the use of pressure-treated or resistant wood as a part of termite prevention can only be justified when drywood termites are a serious problem, and protection from them is deemed necessary. In Hawaii, where drywood termites are a serious threat, it is feasible to use pressure-treated wood for all framing lumber.

Chemical Soil Treatment. The soil under concrete slabs and in crawl spaces is usually habitable by termites, even in reasonably drained and ventilated construction. Long experience has shown that termites are quite capable of penetrating or by-passing most, or all, of the physical barriers erected as a defense against their assault on wood in buildings. This knowledge led to the development of methods to render the soil adjacent to house foundations toxic and/or repellent to termites. Many synthetic organic insecticides have been tested for their effectiveness against subterranean termites by the Forest Service, U. S. Department of Agriculture, in southern Mississippi (Johnston et al. 1971). Chlorinated hydrocarbons have

been found to be outstanding in their persistence and effectiveness. Among all of the insecticides tested thus far, 4 are outstanding and are presently suggested for soil treatment. Aldrin, chlordane, dieldrin and heptachlor have to this date (1978) been 100 percent effective for 30, 31, 29, and 27 years, respectively. Since none of them has yet failed in the tests, the exact duration of effectiveness is not known. These 4 insecticides may be regarded as equal in effectiveness and longevity when applied at their recommended application rates (Johnston *et al.* 1972). Recent restrictions by the Environmental Protection Agency on the use of the chlorinated hydrocarbon insecticides has placed their continued availability for termite control in question. Alternate chemicals are being tested for this purpose and will presumably become available.

The purpose of soil treatment is to establish a barrier of chemically treated soil adjacent to all surfaces of the building foundation over which, or through which, termites might gain entry into the wood of the structure. Obviously, the barrier must be applied very thoroughly and uniformly to block all routes of termite entry. This requires that treatment must also be applied around all pipes or utility conduits making contact with the ground and the wood. When this soil treatment is performed during construction of the foundation as a preventive measure, it is called "pre-treatment." This is the most economical and effective time to apply soil insecticides. The rates and methods of application vary with the type of construction (Johnson *et al.* 1972).

Inspection. All structures built entirely or in part of wood in areas where subterranean termites are found should be inspected at least annually for active infestations, regardless of physical and chemical preventive measures employed in construction. Even the best physical barriers currently used may be breached by termites. In addition, there may have been structural changes which have occurred subsequent to construction that have altered the integrity of termite barriers. For example, one or more service or repair persons may have left termite-prone conditions after working underneath or around the structure. The homeowner may have disturbed treated soil or placed wood on the ground near or under the structure. Settlement may have resulted in cracks in foundation walls or concrete floors.

If property is inspected annually, or in some cases semiannually, little serious damage will result from subterranean termites before they are discovered and treated. They work slowly enough that their presence can be detected and the infestation controlled before structural weakness results. Spear (1970) provides a detailed guide for inspecting homes for subterranean termites.

Subterranean Termites--Control

When a careful inspection has revealed that termites are infesting a structure, or that conditions exist which will, in all likelihood, lead to eventual infestation, control measures should be taken. The purposes of such measures are to (1) terminate attack on the structure and its contents, and (2) to provide protection from future attack by subterranean termites. In practice, control measures tend to be based more on chemical treatment

than on structural alterations. Chemical treatment and mechanical alteration are essential phases of termite control, however, and both should be used.

Mechanical Alterations. Mechanical alterations, as related to termite control, include sanitation, breaking earth-to-wood contacts, installing physical barriers to termites, replacement and repair of damaged wood, providing adequate drainage, clearance and ventilation, and providing access for inspection of all vulnerable areas, and others. It would not be practical, or even necessary, to provide detailed information on such a complex subject. A very excellent and definitive reference on the subject in the form of the "Approved Reference Procedures for Subterranean Termite Control," published by the National Pest Control Association (Mampe 1973), provides the details needed by those interested.

Chemical Treatment of the Soil. Chemicals are probably the most important factor in corrective termite control in all parts of this country. The insecticides used, concentrations and their rates of application are the same for control as for pretreating (Johnston *et al.* 1972). The methods of application to soil in crawl spaces and adjacent to the outside of foundations are essentially the same as in pretreating. A combination of shallow trenching and grout rodding to the footing is the most common method. The thoroughness of dispersal is still the essential feature.

The chemical treatment of slab-on-ground construction, or of dirt-filled extensions of raised construction, presents the greatest challenge to the pest control operator. These types of construction are the most expensive to treat and leave more room for uncertainty than any others. The best way to treat the soil is by drilling a series of holes vertically through the slab. The holes should allow injection of the chemical into the soil below all joints and cracks and penetration of slabs by plumbing. The distance between holes is determined by the type of soil, its moisture content and the experience of the applicator. Again, the chemical barrier must be complete in order to be effective. The advantage of vertical drilling is that the chemical may be flooded over the surface of the soil and, by using a grouting rod, may also be injected as deeply as needed into the soil to saturate the soil to the footing (Fig. 24).

In drilling vertically through slabs, there are hazards of drilling through radiant-heat pipes, hot air ducts and plumbing, or the possibility of ruining a vapor barrier, as well as the expense and liability incurred in removing tile or parquet. Because of this, many applicators prefer to treat under slabs by drilling horizontally through the foundation at a height that allows rods to be inserted immediately below the slab. Horizontal rodding is accomplished by using long treating pipes (up to 6 m long) which are inserted and pushed through the fill as the chemical is applied. This method is inferior to vertical drilling for several reasons. There is little downward movement of the chemical below the application point, except in very loose, sandy soil. Also, if the holes in the foundation are too low, there may be untreated soil above the point of application. If the rods remain in the proper horizontal and vertical plane, accuracy of application is good. Unfortunately, such long pipes are sometimes deflected in the soil and may move into areas far removed from those anticipated. A series of horizontal holes at rather close intervals will allow "short rodding" by inserting rods

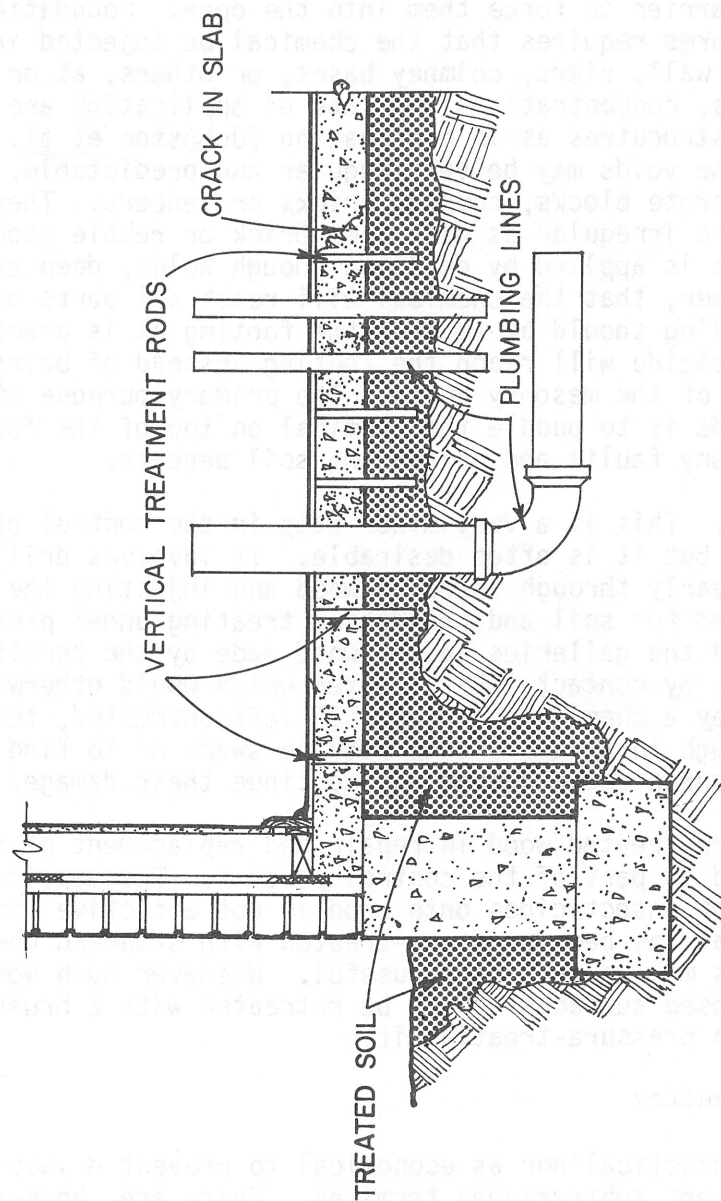


Figure 24. Treatment under concrete by vertical rodding.

only a short distance into the fill and injecting the chemical so that the soil between the application points is flooded. This method also has the disadvantage of not assuring deep treatment below the point of injection. Sometimes it is necessary to use a combination of horizontal or vertical rodding to reach critical areas.

Chemical Treatment of Foundations. Termites use voids in foundations and flaws in footings to pass from the soil to the wood above the foundation. They are often able to accomplish this completely undetected when there is no physical barrier to force them into the open. Foundation treating of existing structures requires that the chemical be injected into all voids in the foundation wall, piers, chimney bases, or others, at or near the footing. The chemicals, concentrations and rate of application are the same for treating existing structures as in pretreating (Johnston et al. 1972). With some foundations the voids may be very regular and predictable, as in the case of hollow concrete blocks, coursed bricks or veneers. They may also be disconnected and irregular as with some brick or rubble stone foundations. The treatment is applied by drilling enough holes, deep enough, and close enough together, that the chemical will reach all parts of the footing surface. Drilling should be as near the footing as is practical so that most of the insecticide will reach the footing instead of being absorbed by the surfaces of the masonry units. The primary purpose of treating the foundation voids is to puddle the chemical on top of the footing so that it may seep into any faults and poison the soil beneath.

Treatment of Wood. This is a very minor step in the control of subterranean termites, but it is often desirable. It involves drilling small diameter holes nearly through infested wood and injecting the same insecticides as are used for soil and foundation treating under pressure. The purpose is to flood the galleries in the wood made by the termites. This will quickly kill, by contact, the termites which would otherwise be cut off from the soil by a chemical barrier. If left untreated, termites might survive long enough in slightly damp wood to swarm or to find an alternative moisture source above ground and continue their damage.

The use of pressure-treated wood in repair and replacement of damaged wood is also considered as part of the control process. The application of spray- or spray-coats of insecticides onto wood is not effective for termite control. Only wood that has been pressure-treated with standard chemicals and standard procedures may be considered useful. Whenever such wood is cut into or sawed, the exposed surfaces should be retreated with 2 brush coats of the chemical used in pressure-treating it.

Drywood Termites--Prevention

It is neither as practical nor as economical to prevent drywood termite attack as it is to prevent subterranean termites. There are, however, several measures that can be taken to reduce the chances of attack. The effectiveness of these measures is variable and probably none of them used alone would be sufficient for entirely effective prevention.

Exclusion. Some authors in the past have recommended screening of vents to attics and crawl spaces to exclude drywood termite swarms (Snyder 1966). This has been proven to be unsatisfactory because the screening must

be 18 to 20 mesh to exclude the termites. A mesh of this small size greatly restricts normal movement of air even when it is new, and it quickly becomes clogged with dust and cobwebs.

Keeping a good continuous coat of paint or varnish on all outside wood surfaces and keeping all cracks and joints tightly caulked might help to some degree in preventing new infestations. Although drywood termites can penetrate through a flat surface, they much prefer to wedge themselves into a crevice to start boring. There are so many routes of entry other than exterior surfaces, however, that painting and caulking should not be relied upon very heavily. Drywood termites can enter under siding, through wood shingles, or between and underneath shingles or tiles and sheathing.

Chemical Treatment of Wood. In the past there have been reports of the successful prevention of drywood termite infestation in framing timbers by soaking them in vats of wood preservative before construction. Other reports have suggested spraying or brush-coating all of the wood framing in a structure after it is erected but before it is closed in. These methods have a degree of benefit, but in the long run probably would not be as economical or as effective as using pressure-treated wood. The thin, treated shell of wood could be easily penetrated by bruises or cracks in the surface during the construction process and thus open avenues of entry for drywood termites. All cut surfaces of pre-treated wood would also have to be brush-coated with preservative to renew the protective surface. These methods have not been in wide and general use.

Pressure-treated wood is protected against drywood termite attack. Its use for all framing members, and possibly even for sheathing, subflooring, exterior doors and windows, and exterior trim, might well be justified in the high-hazard areas mentioned previously. Even with this method, there are limitations. Every place on the surface of the pressure-treated wood that is cut, bored, notched, or split during the construction process must be retreated with a brush or spray application of the preservative. The difficulty of ensuring adequate treatment of such places has been a great limitation to the value of pressure-treated wood in the prevention of drywood termites.

Desiccating Dust Application. Certain fluoridated silica aerogel dusts (Dri-die 67) have been found to be effective in preventing drywood termite attack. Ebeling and Wagner (1964) described a system of applying such dusts during construction in attics, crawl spaces, and wall voids to prevent drywood termites. The silica aerogel has a monomolecular layer of ammonium or magnesium fluosilicate that gives it an electrostatic charge. This results in a more efficient deposit on dusted surfaces and efficient "pickup" by insects crawling over them. Insects are protected from desiccation by a very thin waxy layer on the surface of the exoskeleton. Sorptive dusts, such as the silica aerogels, absorb enough of the protective wax layer to induce a lethal rate of water loss. For termites, a film of such dust which is barely visible is enough to protect wood.

Drywood Termites: Inspection and Control

Structures should be inspected annually for the presence of drywood termites. The longer these termites have infested a building, the more

difficult their control. At first their galleries are extended rather slowly and may be easily accessible for treatment. Later they may extend their workings into framing within walls, and control becomes much more difficult and expensive. Many of the same principles and procedures for inspection for subterranean termites apply equally for drywood termites (Spear 1970).

The extent of drywood termite infestation in a building needs to be determined as fully as possible. An appropriate control method can only be chosen when this is known. Unless a general fumigation of the whole structure is planned, the extent of each of the one or more infestations in the building needs to be carefully delimited for treatment. Only in this way can the correct remedial control technique, other than complete fumigation, be chosen.

The Drill-and-Treat Method. If the infestation has been carefully delimited by sounding and probing and it all appears to be accessible to treatment, the drill-and-treat method can provide satisfactory control if the applicator is skilled and conscientious. The traditional method involves drilling 7-mm holes at 30-cm intervals into the infested wood so that access to all termite galleries is provided. An insecticide is then applied into the holes. In years past, several poisonous dusts were used. Only small amounts should be applied. Too much dust will plug the galleries, and they will be walled off by the termites and isolated. This method relies on the grooming habit of termites. Only a few termites with insecticidal dust, usually stomach poisons, on their bodies can spread it to all of the colony through grooming. The availability of the dusts commonly used is uncertain, at present, and this method has been replaced almost entirely by other methods.

Holes drilled into galleries can also be treated with small amounts of a liquid fumigant such as ethylene-dibromide mixed with a residual insecticide in a petroleum solvent. Formulations of this type are still available and can be used effectively. The fumigant reaches parts of the galleries not otherwise reached. This method is, however, difficult to use safely, especially in hot, cramped attic spaces.

Oil solutions of residual insecticides alone have also been used by this method. Fuel oil solutions of 2 percent chlordane, 5 percent pentachlorophenol, or 0.5 percent lindane will all leave residual deposits in treated galleries. The disadvantage is that the fuel oil itself or pentachlorophenol may leave a long lasting odor. The availability of these insecticides for this purpose is doubtful at present.

Fumigation. Although fumigation is generally recognized as the most effective treatment for drywood termites, there are some negative factors that should be considered. Fumigation is a hazardous procedure and can be undertaken only by experienced and licensed fumigators. It offers no protection against future infestation of the treated structure. It is necessary for the occupants of buildings being fumigated to vacate the premises for at least a day and, in some cases, for several days. Finally, it is an expensive procedure that, in some areas, must be repeated at intervals of 5-7 years because of reinfestation.

The basic procedure is to enclose the entire structure in a gas-tight tarpaulin (Fig. 25). Stucco structures with flat roofs are sometimes sealed with special gas-tight paper over outer doors, windows, and ventilators if the fumigator believes a satisfactory seal can be obtained without the labor of "tarping." By whatever method the building is enclosed, the exterior wood such as window and door frames, siding and trim must be effectively exposed to the fumigant. These exterior members could support small infestations that might not be controlled if the fumigant were applied only to the interior of the building.

The fumigants most commonly used for drywood termites are sulfuryl fluoride and methyl bromide. They are introduced into structures through long plastic or copper tubes leading from large cylinders of compressed gas. Electric fans circulate the fumigant to prevent stratification. The gas usually remains in the building for 24 hours.

In those situations where an entire building is not to be fumigated and there are drywood termite-infested articles in the building, they can be removed and fumigated separately. They should be either wrapped in a gas-proof tarpaulin or placed in a fumigation vault when they are exposed to the fumigant.

Application of Silica Aerogel after other Treatment. Following treatment, many termite control technicians recommend attic dusting with silica aerogel to prevent reinfestation (Ebeling 1975). Where termites survived treatment or were not detected for localized treatment, attic dusting provides a means of limiting the spread of surviving colonies. Also, during the swarming season, houses are subject to reinfestation from colonies outside the building. Any wood coated with the silica aerogel film would be protected from new infestation.

Dampwood Termites: Prevention, Inspection, and Control

Prevention, inspection for, and control of dampwood termites is primarily a matter of following the same measures used against wood decay. Because these termites must maintain contact with damp wood, and damp wood decays, it follows that preventing or eliminating dampness in wood will prevent or control dampwood termites. Because some species of these termites may enter wood through the soil, it is helpful in those locations where such species are found, to treat the soil as for subterranean termites.

WOOD-BORING BEETLES

Three families contain species that are commonly considered to be pests of seasoned wood. Other families have a few species of significance as pests of seasoned wood. Several other families have representatives which damage wood during seasoning and might later be encountered in structures. Still other families have species that do all of their damage to wood before it is seasoned. When the wood has been milled and placed into use, however, the damage done earlier is still visible and must be recognized.

The damage to wood by beetles varies according to the species involved, but all types of beetle damage differ from that done by termites. When beetles have completed their development and have become adults inside wood,



Figure 25. House covered with a gas-tight tarpaulin during fumigation for control of drywood termites.

they bore exit or flight holes to the outside. These holes vary in size and shape according to the beetle species involved. The real damage to the wood is discovered only after the surface is split or pried open to expose the interior. With the more important wood-boring species, there are many galleries of different diameters running primarily with the grain of the wood. They are most often packed with wood fragments and fecal matter.

The amount of damage inflicted to wood by beetles in any given location will vary as a result of many factors. Some of these factors include the presence or absence of certain beetle types, the type of wood (hardwood or softwood), the part of the wood involved (sapwood or heartwood) and the environmental conditions. As each type of beetle is discussed, these factors will be considered and related to the problem of evaluating the potential for damage to wood in structures.

The most important group of beetles that attack seasoned wood are collectively known as the powderpost beetles. The term "powderpost" refers to damage in which the inner portion of wood is eventually converted to a mass of powdery or pelletized frass held together by a thin outer shell of surface wood penetrated by numerous exit holes. Damage of such an extent usually requires that several succeeding generations of beetles reinfest the same piece of wood.

Anobiidae--Powderpost Beetles

About 280 species in the family Anobiidae are found in the United States. Many of them are wood-borers. Two common species, the drugstore beetle (Stegobium paniceum Linnaeus) and the cigarette beetle (Lasioderma serricorne Fabricius) are important pests of stored products. The adults of species that are commonly found attacking wood in buildings range from 3 to 7 mm in length. They are elongate and very convex. The pronotum is hoodlike and, when viewed from above, completely conceals the head (Fig. 26, a,b). Their color ranges from reddish-brown to nearly black. Some have short hairs of lighter color covering their bodies. Most have conspicuous grooves and/or rows of pits on their elytra.

The larvae are grublike, C-shaped, and nearly white except for a brownish head and mouthparts. They are hirsute and have rows of small spines on the top of most segments (Fig. 26,c). The largest species when fully grown are nearly 11 mm long when extended.

Distribution. Various species are found as pests of wood in houses in all of the contiguous states. They are not reported as pests in Alaska or in tropical areas. They are rather minor pests within heated, occupied dwellings in most parts of the country except the southeastern states, where they are most common. Here they are particularly common in coastal areas where the relative humidity is always high. In general, the drier the environment, the less the problem. One species has been reported as common on the West Coast. In the Northeast, they are primarily found in unheated houses or outbuildings.

Biology and Habits. Some anobiid species will attack both hardwoods and softwoods, others only one type of wood. They will also feed on both sapwood and heartwood, though sapwood is usually preferred. Both freshly

seasoned and older wood are attacked. Unlike the lyctid powderpost beetles, the anobiids can digest the cellulose of wood cell walls. The wood cell contents, however, such as starches, sugars and proteins, are the more critical nutrients.

The females of anobiid powderpost beetles lay their eggs on the surface of wood under splinters, in cracks, under debris, or in old exit holes. Relatively few eggs are laid, probably less than 50 for most species, and many of the first instar larvae die before they can successfully bore into the wood. After the larvae have bored straight into the wood a short distance, they turn at a right angle and begin to tunnel in the direction of the wood grain. At first they feed on the softer springwood, and if they have a choice, primarily in the outer sapwood. After each molt the gallery becomes larger to accommodate the increase in size of the larva. Often, the tunnels of many larvae intersect, and the wood may eventually become a mass of tightly packed wood fragments and fecal pellets.

It takes at least 2 or 3 years for a larva to complete its development. If the wood is dry (less than about 14% moisture content) or has very little food value (low protein or high resin content), the life cycle is prolonged, or development ceases and the larva dies. High temperatures are also unfavorable, both because of direct effect and because they tend to dry out the wood. If the wood is slightly decayed or has a relatively high moisture content, even near the fiber saturation point (30%), development proceeds at its maximum rate. Damp, cool conditions in crawl spaces or outbuildings are particularly suitable.

When larval development is complete, pupation takes place in an enlarged portion of the gallery which is clear of frass. This usually occurs in the spring. The adults bore holes straight up to the surface of the wood and emerge. Most species of anobiids are active as adults during the spring and summer months. Most of the activity occurs during the first half of the warm season of the year. The adults do not feed. Most species of anobiids are strong fliers. In spite of this ability, a large proportion of eggs are likely to be deposited on the same piece of wood from which the beetles emerged. This results in constant reinfestation of wood until little is left except the outer surface.

Signs of Infestation. Before the emergence of the first generation of adults, the early stages of an infestation are all but impossible to detect. Because the development time is long and there is no external evidence of the attack, one or more generations may occur before there is enough evidence to be readily detected. This evidence is powdery frass and tiny pellets which accumulate underneath infested wood or are found streaming from the exit holes (Fig. 27,a). The exit holes are round and vary from 1.6 to 3 mm in diameter. If there are large numbers of holes and the powder is bright and light-colored, like freshly-sawed wood, the infestation is both old and active. Sometimes infestations die out naturally and the frass which remains is yellowed and partially caked on the surface. Anobiid pellets (Fig. 27,b) differ from those excreted by drywood termites in that they are smaller and taper toward each end.

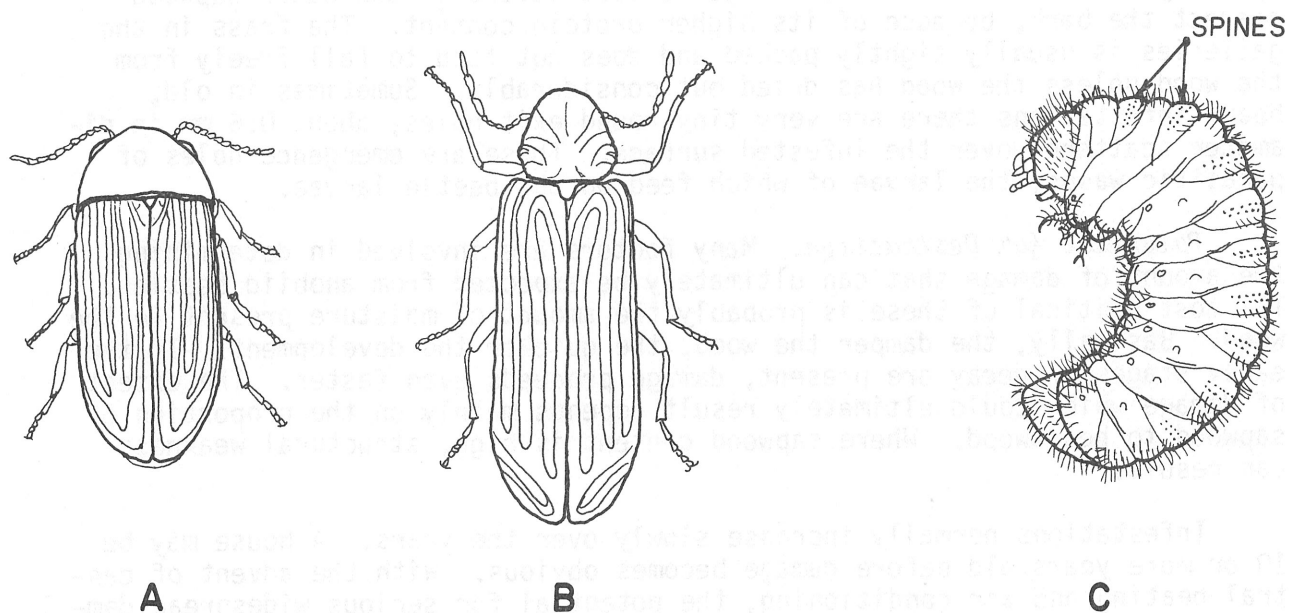


Figure 26. Anobiid beetles: (a) species common in the eastern part of the United States, (b) species common on the West Coast, and (c) typical larva of an anobiid powderpost beetle.

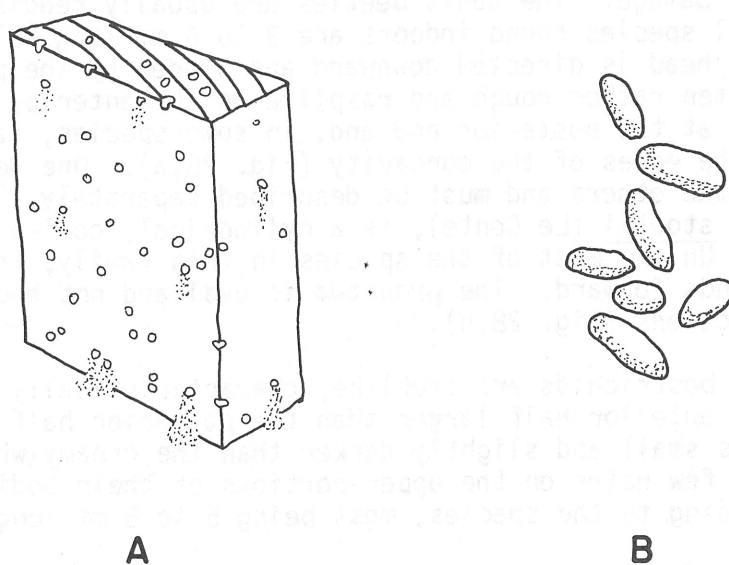


Figure 27. (a) Wood infested with anobiid beetles, and (b) fecal pellets of anobiid beetles. Used with permission of the Center for Continuing Education, California Polytechnic University. See Figure 3.)

Characteristics of Damaged Wood. Tunneling is most extensive in sapwood, though it may extend into heartwood, particularly if it is partially decayed. In sound timber, damage is most severe in the outer sapwood nearest the bark, because of its higher protein content. The frass in the galleries is usually tightly packed and does not tend to fall freely from the wood unless the wood has dried out considerably. Sometimes in old, heavy infestations there are very tiny round exit holes, about 0.6 mm in diameter scattered over the infested surface. These are emergence holes of parasitic wasps, the larvae of which feed on the beetle larvae.

Potential for Destruction. Many factors are involved in determining the amount of damage that can ultimately be expected from anobiid beetles. The most critical of these is probably the amount of moisture present in the wood. Basically, the damper the wood, the quicker the development. If the early stages of decay are present, damage proceeds even faster. The extent of damage which could ultimately result depends mainly on the proportion of sapwood to heartwood. Where sapwood content is high, structural weakness can result.

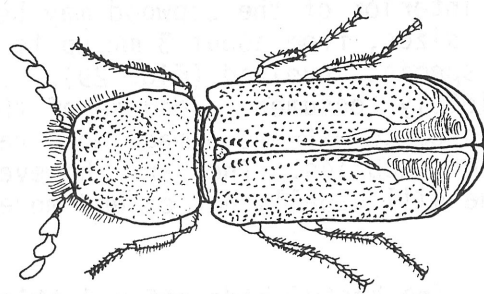
Infestations normally increase slowly over the years. A house may be 10 or more years old before damage becomes obvious. With the advent of central heating and air conditioning, the potential for serious widespread damage in houses has decreased. The heat in the living areas, and that which rises to the attic, tends to dry out the wood of wall and roof framing and of interior trim. If a house has no excess moisture in the basement or crawl space, is centrally heated and does not remain closed and unoccupied for long periods, the extent of damage by anobiid powderpost beetles is greatly reduced.

Bostrichidae--Powderpost Beetles

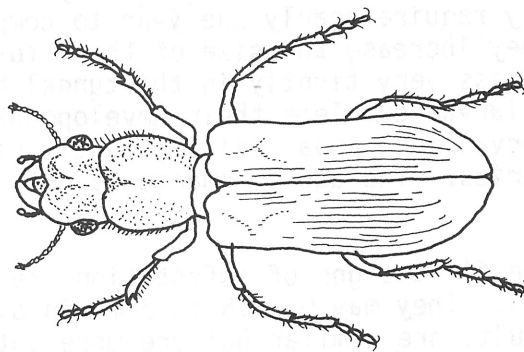
This family contains many species whose larvae bore into wood and cause typical powderpost damage. The adult beetles are usually reddish-brown to black. The typical species found indoors are 3 to 6 mm long, elongate, and cylindrical. The head is directed downward and hidden by the pronotum. The pronotum is often rather rough and rasplike on the anterior edge. The elytra are concave at the posterior end and, in some species, have projecting spines along the edges of the concavity (Fig. 28,a). One destructive species is unlike the others and must be described separately. The black polycaon, *Polycaon stoutii* (Le Conte), is a cylindrical, coal-black beetle 12 to 25 mm long. Unlike most of the species in this family, the head is prominent and extends forward. The pronotum is oval and not hoodlike, and has no rough projections (Fig. 28,b).

The larvae of bostrichids are grublike, characteristically curved and wrinkled, with the anterior half larger than the posterior half (Fig. 28,c). The head is small and slightly darker than the creamy-white body. These beetles have few hairs on the upper portions of their bodies. They vary in size according to the species, most being 5 to 8 mm long.

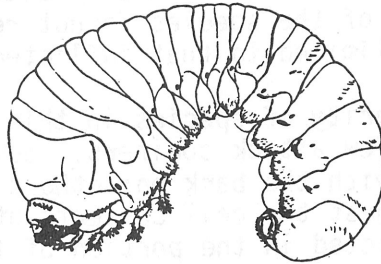
Distribution and Economic Importance. Most of the contiguous states have recorded bostrichid species in wood indoors. One pest species native to India, *Heterobostrychus aequalis* (Waterhouse), has become established in Florida and is encountered in imported hardwoods elsewhere. The black



A



B



C

Figure 28. (a) Typical bostrichid, (b) Black polycaon, *Polycaon stoutii* (LeConte), an atypical bostrichid, (c) typical bostrichid larva. (28b used with permission of the Center for Continuing Education, California State Polytechnic University. See Figure 3.)

polycaon occurs naturally in the West Coast states and, to a lesser extent, in the Rocky Mountain states. It is shipped to other parts of the country in infested wood products.

The bostrichid powderpost beetles in houses are of much less economic importance than the Anobiidae or Lyctidae. They are important as pests in hardwoods. Those that attack wood of conifers rarely cause serious damage. Most of the hardwoods attacked are not those commonly used for interior floors, woodwork, and trim. Many of the species do not reinfest wood after it is seasoned, so the damage is limited to that inflicted by one generation.

Biology and Habits. The majority of species in this family feed on the sapwood of hardwoods; however, a few attack conifers. Some attack freshly cut and partially seasoned woods with the bark on; others attack relatively dry wood. The larvae can only digest the cell contents of wood, primarily starch, so they are greatly restricted in the portion of the wood that can be utilized, the outer sapwood.

Bostrichids differ from the anobiids and lyctids in that the females bore into the wood and prepare "egg tunnels" for oviposition. The eggs are very slender and are inserted into pores in the wood that have been exposed by the cross-grain tunnel. The adults are active primarily during the summer months. The larvae usually require nearly one year to complete their development. As they grow, they increase the size of their tunnel with each molt. The larvae pack their frass very tightly in the tunnel behind them. Under most circumstances, the larvae complete their development the spring following oviposition. The larvae make pupal cells slightly nearer the wood surface than the feeding galleries. The adults emerge by cutting straight through to the surface.

Signs of Infestation. The first signs of infestation are the circular egg tunnels made by the females. They may be 2.5 to 7 mm in diameter. The exit holes made by emerging adults are similar but are more apt to be filled with frass. The frass is meal-like and contains no pellets. It is tightly packed in the galleries and does not sift out of the wood easily. The adults are not often seen unless there is a very heavy infestation and the inspection is made by coincidence at a time of beetle activity.

Characteristics of Damaged Wood. In addition to the egg-laying and exit holes in the surface, the interior of the sapwood may be filled with very round tunnels of different sizes, from about 3 mm up to 10 mm in diameter, depending on the beetle species involved (Fig. 29). If damage is extreme, the sapwood may be completely consumed. Because of the shorter life cycle of bostrichids, they often cause extreme damage more rapidly than would an equivalent population of anobiids. They are, however, restricted to the outer sapwood, and damage will usually not extend more than an inch or two into a board.

Potential for Destruction. The bostrichids offer little likelihood of causing serious damage to softwood framing in a home. Because of the speed and completeness of their attack on portions of wood having a high starch content, they might cause serious damage to individual pieces of hardwood flooring or trim. There is little danger of reinfestation after the first generation emerges.

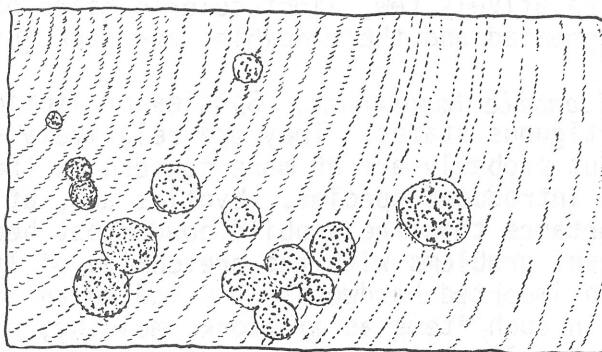


Figure 29. Damage of the Black polyaon. (Used with the permission of the Center for Continuing Education, California State Polytechnic University. See Figure 3.)

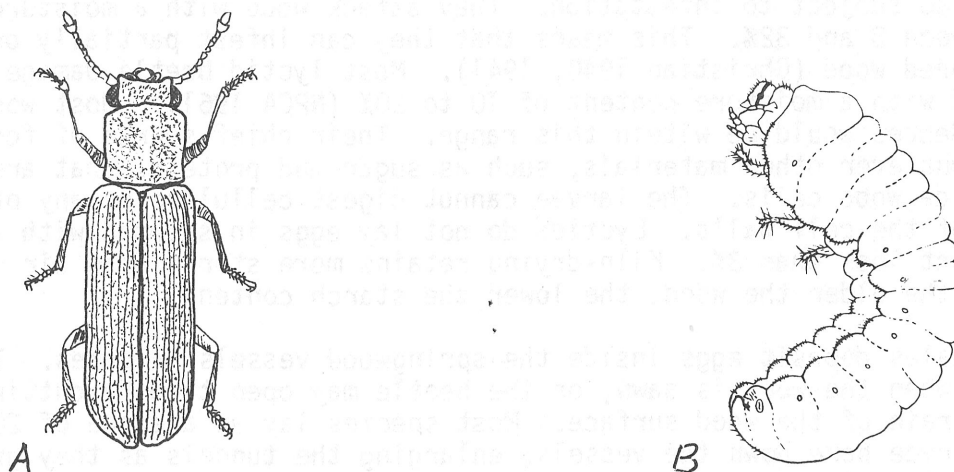


Figure 30. (a) Typical lyctid adult and (b) larva.

Lyctidae - Powderpost Beetles

Most of the native species are quite similar in appearance and biology. They are small, slender, somewhat flattened, elongate, reddish-brown to black, and vary in length from about 3 mm to slightly over 7 mm. The head is prominent and not covered by the pronotum (Fig. 30,a). Mature larvae vary in size but are usually less than 6 mm long. They are enlarged at the thorax and have relatively few, light-colored hairs on their bodies. The head is slightly pigmented and the mandibles are dark (Fig. 30,b).

Distribution and Economic Importance. Species of lyctid beetles are found in all of the contiguous states. They are relatively common in all parts of the country, but probably are of more concern in the South. Some are native and some are introduced species. Lyctids are, at present, of much less economic importance than the anobiid powderpost beetles as pests of wood in houses. Recent problems with the prevention of lyctid powderpost beetles, particularly in imported hardwoods, has led to an increase in the number of infestations in such items as millwork, molding, picture frames, and hardwood paneling, as well as in furniture stock, etc. This could lead to a change in their relative importance in houses. Proper handling of hardwood lumber and the use of contact insecticides had reduced the lyctid problem to one of comparative unimportance in relation to its status 30 or more years ago (Bletchly 1967). Because of a present lack of readily available residual insecticides to treat stored hardwood products, and because of much infested hardwood now being imported, the problem is likely to increase before adequate preventive and control programs are developed.

Biology and Habits. These beetles attack the sapwood of hardwoods only. Ring-porous hardwoods such as oak, hickory and ash are most susceptible. Some diffuse-porous hardwood that are often attacked include walnut, pecan, poplar, sweetgum, and wild cherry. Many species of tropical hardwoods are also subject to infestation. They attack wood with a moisture content between 8 and 32%. This means that they can infest partially or wholly seasoned wood (Christian 1940, 1941). Most lyctid beetle damage occurs in wood with a moisture content of 10 to 20% (NPCA 1961). Most wood within residences would be within this range. Their chief source of food is starch and whatever other materials, such as sugar and protein, that are present inside wood cells. The larvae cannot digest cellulose or any other components of the cell walls. Lyctids do not lay eggs in sapwood with a starch content less than 3%. Kiln-drying retains more starch than air drying. Also, the older the wood, the lower the starch content.

The females deposit eggs inside the springwood vessels or pores. These are exposed when the wood is sawn, or the beetle may open them by cutting across the grain of the wood surface. Most species lay an average of 20 to 50 eggs. Larvae bore down the vessels, enlarging the tunnels as they grow. At first the tunnels are straight and with the grain, but later become more irregular and often intersect other tunnels. The mature larvae bore to a point just under the wood surface and form pupal chambers. The adult beetles cut their way to the surface, forming circular exit holes. Some of the very fine, flour-like frass is pushed out as the adult emerges.

The greatest period of adult activity occurs in late winter or early spring. They conceal themselves in cracks and holes in the wood during the

day and become active at night. They are strong fliers and may be attracted to lights. Indoors, they may be seen crawling on windowsills, floors, furniture, and other surfaces. The entire life cycle for most species requires 9 to 12 months. One common native species routinely completes a cycle in about 4 months. Any of them will develop more quickly if temperature and starch content of the wood are favorable.

Signs of Infestation. Wood which has been infested only a short time will show no external evidence of beetle attack. If the first generation has emerged there will be circular exit holes on the surface which are 0.8 to 1.6 mm in diameter. The presence of small piles of fine flour-like frass on or under the wood is an even more conspicuous evidence of infestation (Fig. 31). There are no pellets in the frass and it falls easily from the wood rather than being tightly packed. Even a slight jarring of the wood makes the frass sift from the holes. It is not likely that the adult beetles will be seen.

Characteristics of Damaged Wood. The sapwood of infested wood has longitudinal, cylindrical galleries of various sizes, most of them about 1.6 mm in diameter. They are loosely packed with fine frass. If the damage is severe, the sapwood may be completely converted to frass held together by a very thin veneer of surface wood which has beetle exit holes in it. In heavy infestations there may be circular holes in the wood surface even smaller than the adult exit holes. This indicates that small wasps, which are parasitic on the beetle larvae, have also emerged.

Potential for Destruction. The amount of damage that an infestation of lyctid powderpost beetles can inflict is based on several factors:

(1) The extent of infestation and subsequent damage is proportional to the starch content of the sapwood. Because heartwood is practically free of starch it is immune from attack.

(2) The width of the sapwood portion of a given piece of wood will, within the limitations of the starch content, determine how much of the wood might ultimately be destroyed.

(3) The diameter of the pores or vessels in the wood can also be a limiting factor. If they are not large enough ($>.076$ mm) to allow the female to insert the eggs, no infestation is likely to result.

(4) Softwoods do not have pores and usually have a low starch content; therefore, softwoods are essentially immune to infestation.

Cerambycidae - Round-Headed Borers.

This is one of the largest and most important of the families of wood-boring beetles. More than 1,200 species have been recorded in the United States. The larvae of all but a few members of the family live as borers in the tissues of trees and other woody plants. Species that feed under the bark of living trees may weaken and kill them, or cause defects and stains which seriously degrade lumber values. Species that attack recently felled trees, logs, or seasoned lumber also cause heavy losses.

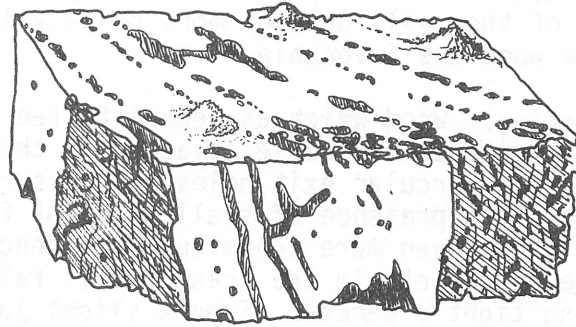
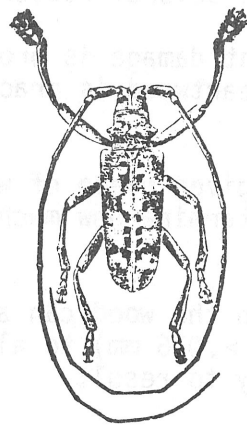
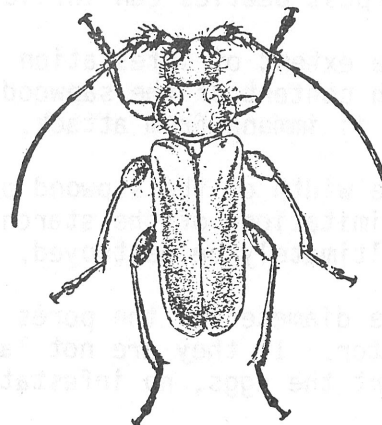


Figure 31. Wood damaged by lyctids. (Used with permission of the Center for Continuing Education, California Polytechnic University. See Figure 3.)



A



B

Figure 32. (a) A typical sawyer Monochamus sp.: several similar species attack coniferous wood in most parts of the country. (b) The blackhorned pine beetle Callidium antennatum hesperum Casey, a species found on the West Coast. Another species common in the western states, the newhouse borer, Arhopalus productus, is slightly more slender and black in color. (From Forest Insects by R. W. Doane, et al. Copyright 1939 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.)

The adults vary considerably in length; those encountered in seasoned wood vary from about 8 mm to 50 mm or more in length. They are elongate, and usually more or less cylindrical in cross-section (some are flattened). The antennae are long, sometimes much longer than the body. Hence, the adults are referred to as "long-horned beetles." The coloration of those attacking softwoods is often drab (Fig. 32a,b). Some species attacking hardwoods are brightly colored and conspicuously marked.

The larvae are whitish to cream-colored. They are long and narrow and very markedly segmented (Fig. 33,b). The anterior part of the body is never abruptly and conspicuously larger than the posterior; and they are straight, never C-shaped. When fully grown, they vary in length from 9 mm to over 50 mm. The head is usually partly withdrawn into the first thoracic segment, and is inconspicuous except for the dark brown mandibles. Many of the larvae are legless, but some have three pairs of very small legs.

Distribution and Economic Importance. Species of this family are found in all of the states. It is important to understand, however, that they are not all of economic importance, nor are there representatives found attacking wood in houses in all of these states. The actual economic losses to wood caused by round-headed borers is probably greater from the down-grading of hardwood lumber than from their attack on softwoods. Very often their attack on framing lumber is of little importance and to a great extent does not restrict its use. Most species cease their attack on wood after it is seasoned and do not usually cause enough damage during their development to reduce its strength. Borer-damaged wood is often classified as utility grade and used with no problems.

Some species begin their development in dying or fire-, disease-, or insect-killed trees, in logs or in unseasoned lumber (particularly if it has any bark edges left on it) and are able to complete their development as the wood seasons. If this wood is not kiln-dried, the beetles can be distributed to any location where the wood is shipped. The adults of these borers will emerge from the wood after it has been incorporated into a structure. They will not reinfest the wood because of its dryness, but they are of great concern to property owners who find them or evidence of their activity. It is not uncommon for the adults of various species to emerge from firewood logs brought indoors. This can lead to a false impression of structural attack.

General Biology and Habits of Family. The eggs are laid singly or in small groups on or in the bark. The eggs hatch within a few days and the larvae begin feeding into the wood. Many species feed extensively directly under the bark before descending into the sapwood and, in some cases, the heartwood. The larval stage may last from a few months to several years. This stage is always prolonged if the wood has been cut into dimension lumber, which dries more rapidly. The pupal stage is passed in a cell near the surface and the adult chews its way straight out of the wood. Outdoor emergence can occur anytime, from early spring to fall. Indoors, the climatic conditions are so different that emergence might occur during almost any season. Outdoors, the adults would mate, lay eggs, and die. Indoors, there are only two species that can reinfest dry, seasoned wood. These will be discussed separately and in more detail.

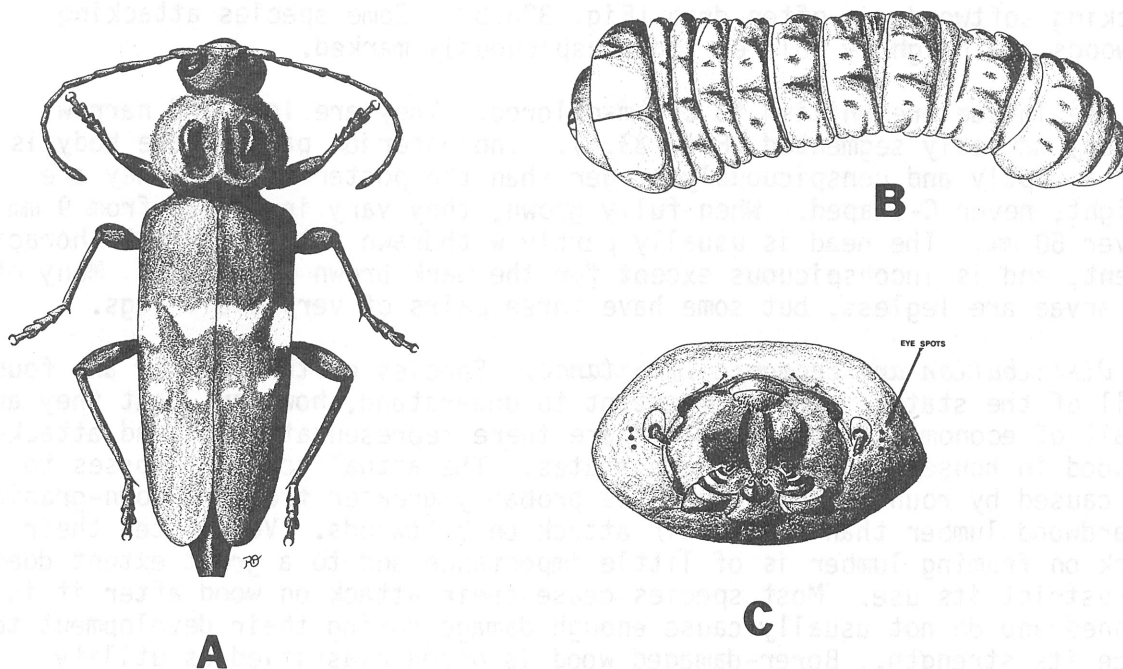


Figure 33. Old house borer; (a) adult, (b) larva, (c) closeup of head of larva showing eye spots.

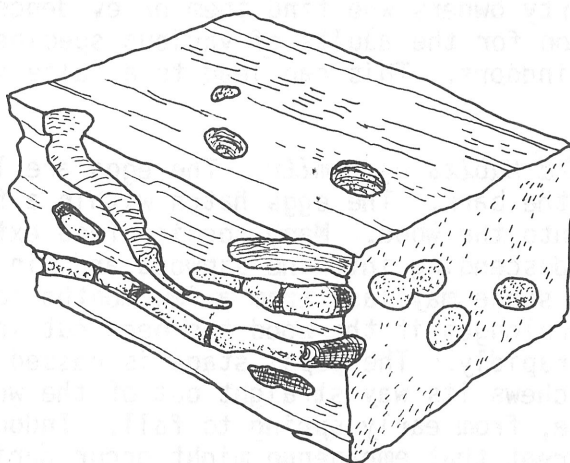


Figure 34. Wood damaged by round-headed borers. (Used with permission of the Center for Continuing Education, California State Polytechnic University. See Figure 3.)

Signs of Infestation. When long-horned beetles emerge from wood, they make slightly oval to nearly round exit holes (Fig. 34). If the points of exit are covered by building components, they will cut through such things as plasterboard, hardboard, hardwood flooring, insulation, roofing felt and shingles, plywood, and others. The size and shape of the holes varies with the species and they can be from 3 mm to as much as 9 mm or more in diameter. In some instances, there is coarse, even stringy, frass in evidence inside or around the exit holes.

Characteristics of Wood Damaged by Nonreinfesting Round-headed Borers. The damage of these beetles is known in the lumber trade as "worm holes." The galleries wind irregularly from directly below the bark into the sapwood. Many common species attacking softwoods feed primarily in the outer sapwood and damage is not severe. The frass produced by the larvae is packed into the galleries once the feeding has proceeded below the wood surface. If bark edges have been left on lumber, there is often much frass in evidence underneath. The texture of the frass varies from rather fine and meal-like in some species to very coarse and almost excelsior-like in other species. Figure 34 shows the sort of damage that is typical.

Potential for Destruction. The amount of damage that can be expected from nonreinfesting round-headed borers is usually not significant. Most of the damage occurs before the wood is sawn and ceases almost immediately when the wood dries. Several common species, however, often infest wood being salvaged from fire or insect-killed trees. They may survive the processing of the wood, and will continue to develop for a year or more after the wood has been utilized. The amount of structural damage that they inflict during this time is not enough to require any treatment. The major problem that they cause is the production of exit holes when they emerge. Most of these beetles will emerge during the first year to 18 months of a house's existence.

Round-headed Borers that Reinfest: Old House Borer. The old house borer, *Hylotrupes bajulus* (L.), probably ranked next to termites with respect to the frequency with which it was encountered in buildings in the eastern United States in 1957 (St. George 1957). This is probably still true today with the possible exception of the northeastern states. It attacks not only well-seasoned coniferous wood found in old buildings (as the name implies), but also relatively unseasoned pine and other coniferous construction material. It does not attack hardwoods.

The adult beetle is 16 to 25 mm long, slightly flattened, brownish-black in color, with many gray hairs on its head and thorax. The pronotum has a ridge down the middle with raised knobs on each side. The elytra sometimes bear four patches of gray that form two indistinct cross bands or spots (Fig. 33,a).

The larva is a typical round-headed borer up to 31 mm long (Fig. 33,b). There are three black ocelli, in a row, on each side of the small head (Fig. 33,c). These ocelli can be seen with a hand lens and will separate this species from others of similar appearance. The other species found boring in softwoods have no more than one ocellus on each side.

A. *Distribution and Economic Importance.* The species is thought to have originated in North Africa but has spread to the eastern half of the United States. The heaviest infestations occur in the states on the Atlantic seaboard, particularly the mid-Atlantic states. It is strictly a pest of structures and, although it is found in barns, fence posts, and rustic buildings, it has not yet been found in logs and stumps.

It is very difficult to determine the economic importance of the old house borer. Although it is very common, particularly in new construction on the East Coast, the amount of actual damage that it does in houses is limited. It is common to find that only a few boards in an entire house are infested. Evidence indicates that, in heated, well-ventilated, occupied dwellings, the chance of reinfestation beyond the first generation is rare. Unfortunately, this is not widely recognized and a great deal of unnecessary treatment, particularly fumigation, is done.

B. *Biology and Habit.* The eggs are laid in cracks and crevices in wood. Stacks of lumber are ideal sites. The larvae may crawl over the surface of the wood until they find a suitable point of entry. The young larvae feed near the surface but penetrate deeper into the sapwood as they grow. A minimum of 0.2% protein is required for development of old house borer larvae. The higher the protein level, the faster development proceeds. The wood has the highest protein near the bark; the deeper portions of wood have little protein. Also, as wood ages, its protein content declines. Consequently, the greatest damage is in the outermost sapwood of new wood. Heartwood is not attacked. Pine generally has a higher protein content than spruce and fir and so is more often attacked. The length of the larval period may be as short as 2 to 3 years in the southern part of its range, but is very commonly 3 to 5 years. In areas north of Washington, D.C., the larval period usually requires 2 to 3 years longer. In very dry wood, such as in attics, it may take 12 to 15 years for one generation.

The larvae can digest the wood cell walls (primarily cellulose) as well as the cell contents (mostly starches, sugars, and proteins). Unlike the anobiid beetles and termites, they do not require the help of yeasts or protozoa in their gut. The moisture content of the wood also plays an important role in the speed of development. At moisture contents below 10%, the larvae develop very slowly and it is doubtful that newly hatched larvae can survive. They develop most rapidly at wood moisture contents between 15 and 25%.

Pupation occurs near the surface of the wood in the spring. Adults sometimes remain in the wood for extended periods before they emerge. Their flight season extends from April to October in the South and from June to September in the North. The greatest adult activity is in June and July in most areas. The adults are strong fliers and are capable of spreading infestations from one building to another.

C. *Signs of Infestation.* An infestation is all but impossible to detect in its early stages. The larvae are small and develop rather slowly for the first year. There are no external signs of infestation. This is why infested wood is so often used in construction. As the infestation progresses, the larvae can be heard boring in the wood. They make a rhythmic ticking or rasping sound. They seldom break through the surface, even

though the interior of the wood may be severely damaged. In severe infestations, the loosely packed frass occupies a greater volume than the wood from which it was produced. When it is in tunnels near the surface of the wood, the thin surface layer may bulge out, giving the wood a blistered appearance. These "blistered" areas are best discovered with a light shining parallel to the surface.

When enough time has passed for the adults to have emerged (3 to 5 years in the South; 5 to 7 years in the North), there may be small piles of frass beneath or on top of infested wood. The frass is composed of very fine powder and tiny, elongate, blunt pellets that often split lengthwise when dry. The exit holes made by the adults are irregularly oval and 6 to 10 mm maximum diameter (Fig. 35,a).

D. *Characteristics of Damaged Wood.* In the southern portion of this species' range, damage is most often found in wood framing in crawl spaces, basements, and storage areas. In northern areas, damage is more commonly found in attic framing. The sapwood may be completely reduced to powdery frass with a paper thin outer veneer. The galleries are loosely filled with the frass which falls freely from the wood when the surface is pried away. The surfaces of most galleries have a rippled pattern much like sand over which water has washed (Fig. 35,b). Most other wood borers do not make such marks on gallery surfaces. The galleries are oval in cross-section and may be up to 9 mm in their broadest dimension.

E. *Potential for Destruction.* If the building is centrally heated, has no moisture problems resulting from poor drainage or ventilation, and does not stay closed and unoccupied for long periods, there is probably little chance that an infestation will become any worse than when it was first discovered. Other than the nuisance which they create by the gnawing sounds of the larvae and the few holes made by the adults, they are often of no real economic concern.

If portions of houses have enough humidity to allow reinfestation after the first and subsequent generations, serious damage can result. Virtually all sapwood of infested boards may be disintegrated. The extent of structural damage depends upon the proportion of sapwood to heartwood. In small-dimensioned timbers, where the amount of sapwood is extensive, structural collapse may occur. This sort of serious damage is most likely to happen in (1) unheated storage areas, (2) in recreational structures which are intermittently occupied and rarely heated for long periods, or (3) in occupied structures with relatively high moisture content.

Round-headed Borers that Reinfest: Flat Oak Borer. The flat oak borer, *Smodicum cucujiforme* (Say) is much less common and of much less economic importance than the old house borer. Because they can infest dry wood in houses, however, it is important that they be recognized. The adults are small, elongate flattened, dull yellowish, shiny beetles about 8 to 10 mm long (Fig. 36). The larvae are typical round-headed borers that reach a length of about 12 mm. They have very small legs and a smooth white triangular arc on the underside of the first thoracic segment. The larvae excavate long meandering tunnels in the dry heartwood of oak and hickory. The tunnels are about 3 mm in diameter and tightly packed with fine granular frass. The larvae may continue to feed in the wood until it is totally riddled.

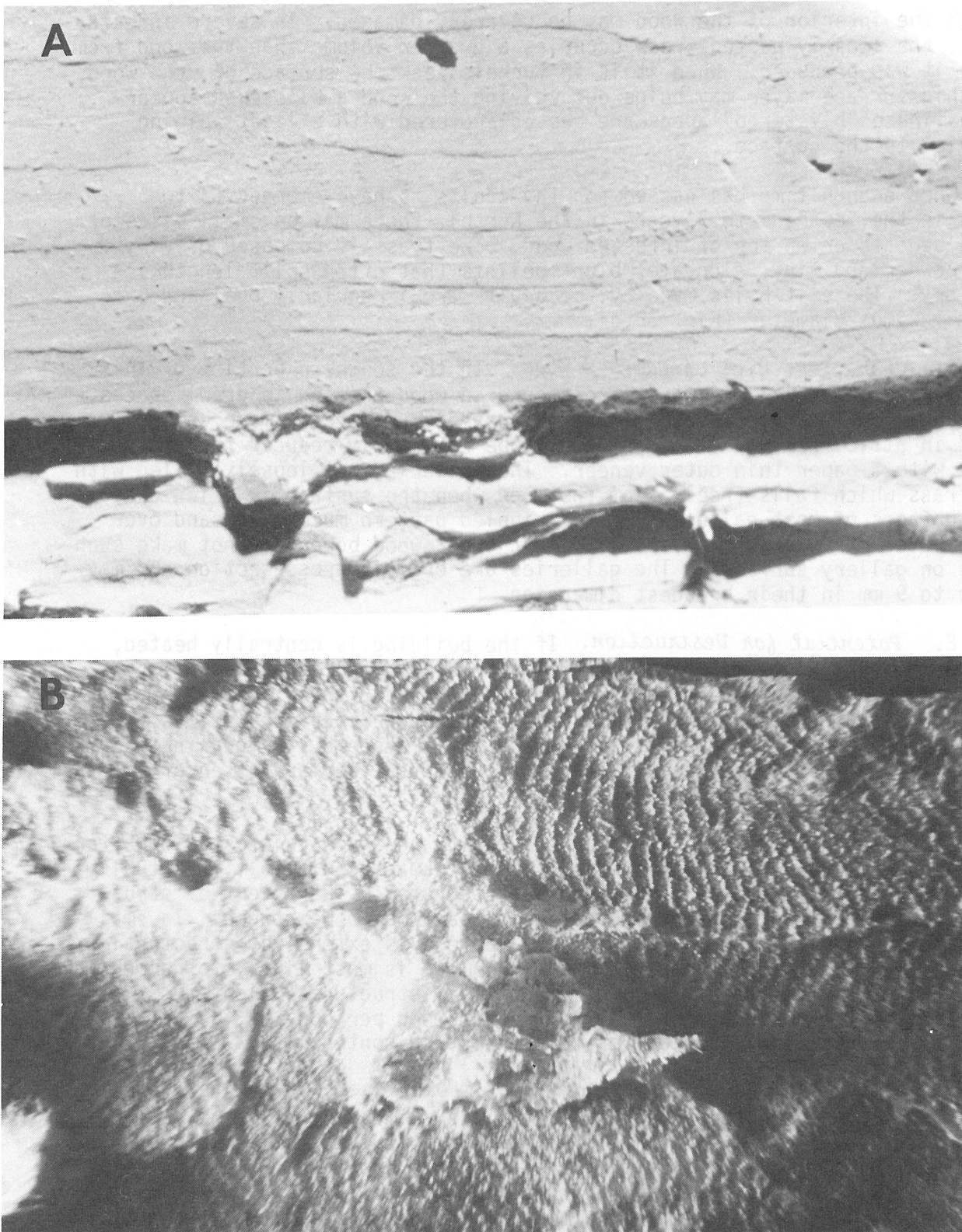


Figure 35. Old house borer: (a) Adult exit hole and larval galleries in wood damaged by old house borer, (b) Close-up of old house borer gallery surface showing ripples.

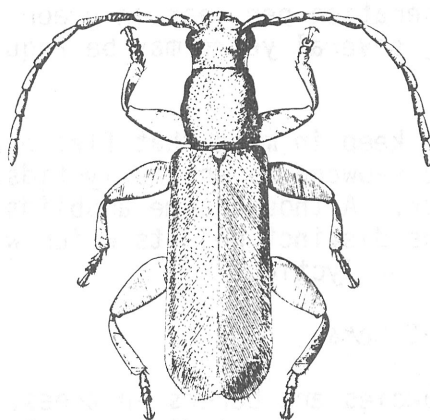


Figure 36. Adult flat oak borer, Smodicum sp.

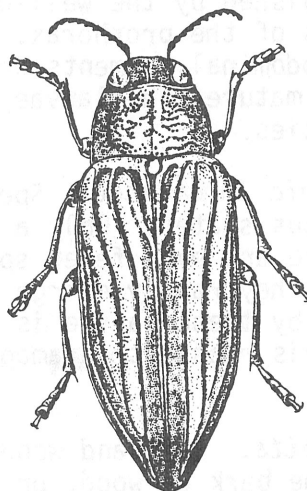


Figure 37. Adult of the golden buprestid, Buprestis aurulenta L., a typical flat-headed borer. (Used with permission of McGraw-Hill Book Company. See Figure 32.)

This species is found in the entire eastern United States from New York to Florida and as far west as Texas. They often attack stored lumber and have caused serious damage, especially in the Gulf States. The adults are active in mid- to late-summer, laying eggs in crevices of exposed wood. There is normally one generation per year in green logs under natural conditions. In dry wood, several years may be required to complete one generation.

It is significant to keep in mind that flat oak borers attack the heartwood of oak, not the sapwood as do the lyctids. Their frass is granular and not fine like flour. Although some anobiids will attack oak heartwood, their frass contains distinct pellets which will distinguish them from the flat headed oak borer or lyctids.

Buprestidae - Flatheaded Borers

The larvae of all species are borers in trees. Some mine leaves, twigs, branches, and roots. Most excavate winding tunnels in inner bark. Some of the more important species tunnel through sound and decaying sapwood and heartwood. These wood-boring species are highly destructive to newly cut logs and can seriously reduce their value as lumber. Attack of dry wood is not common.

The adults of those encountered in seasoned wood vary in length from 6 mm up to 33 mm or more. They are boat-shaped and somewhat flattened (Fig. 37). Many are beautifully marked or metallic in color. The adults are, for this reason, often referred to as "metallic wood borers." The elytra are usually ridged or roughened. Those that are found in softwoods in structures are usually dark-colored but have a metallic sheen, particularly on the ventral side.

The larvae are distinguished by the well-developed, flattened plates on the upper and lower surfaces of the prothorax. They are whitish to yellowish, have no legs and the abdominal segments are much smaller than those of the thorax (Fig. 38). When mature, the larvae may reach a length of 25 to 50 mm, depending on the species.

Distribution and Economic Importance. Species of this family are found in all parts of the contiguous states. Only a few species, however, are of concern in structures. There are even fewer species that are active after wood has been seasoned, and they rarely emerge within buildings. Wood that has been previously damaged by these larvae is sometimes used for structural timbers, however, and for this reason the damage attributable to these beetles must be recognized.

General Biology and Habits. Bark and wood-boring buprestids deposit their eggs in crevices in the bark or wood, or under the bark at the edges of wounds. Weakened, injured, dead or dying trees are usually attacked. The young larvae bore first under the bark and then into the sapwood or heartwood. Most require 1 to 2 years to complete their development. The larvae construct elongate pupal cells near the surface of the wood. As adults, the beetles chew their way out of the wood. Upon emerging, they feed, mate, lay their eggs, and die by the end of the season.

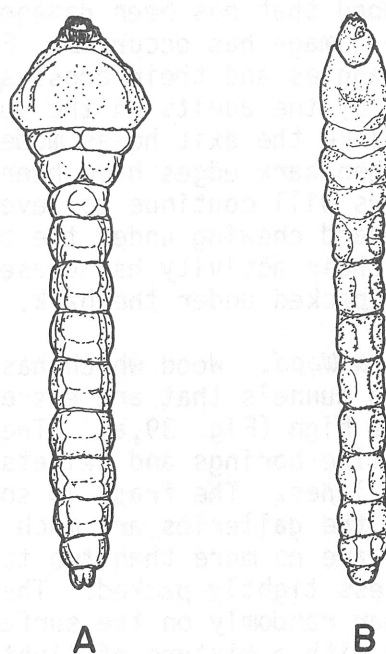


Figure 38. Larva of the golden buprestid Buprestis aurulenta L.; (a) dorsal view, (b) lateral view.

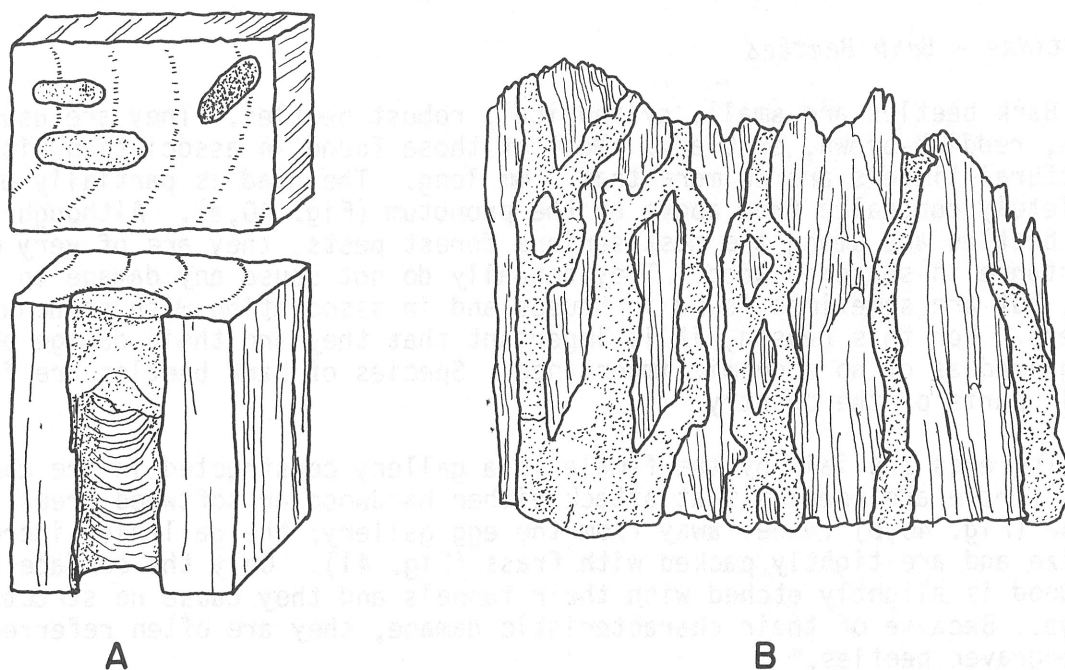


Figure 39. Flat-headed borer damage; (a) in wood, (b) under bark. (Used with permission of the Center for Continuing Education, California State Polytechnic University. See Figure 3.)

Signs of Infestation. Wood that has been damaged by flat-headed borers is most often sawed after the damage has occurred. For this reason, the galleries are cut at oblique angles and their cross-sections are distorted. Sometimes exit holes are made by the adults on the surface of the wood. They are elongate-oval, much like the exit holes made by some of the flattened long-horned beetles. When bark edges have been left on structural timbers, the flat-headed borers will continue to develop until the wood becomes too dry. They can be heard chewing under the bark in houses that are only a few months old. When their activity has ceased, only the frass which they produce is found tightly packed under the bark.

Characteristics of Damaged Wood. Wood which has been damaged by flat-headed borers has winding tunnels that are extremely flat, at least three to four times as wide as high (Fig. 39,a). They are very tightly packed with layers of sawdustlike borings and pellets, and their walls are scarred with fine, transverse lines. The frass is somewhat like that of some round-headed borers, but the galleries are much more flattened. Galleries of round-headed borers are no more than two to three times broader than high, and the frass is less tightly packed. The galleries under bark edges are serpentine and appear randomly on the surface of the outer sapwood (Fig. 39,b). They are packed with a mixture of light, wood-colored frass and brown, bark-colored frass.

Potential for Destruction. No serious damage to structural timbers is caused by flat-headed borers. They have usually completed their development before the wood is sawed and their damage is evaluated at the time the wood is graded. Those that might remain active in the wood for a short time rarely cause any significant additional damage.

Scolytidae - Bark Beetles

Bark beetles are small, cylindrical, robust beetles. They are usually brown, reddish-brown, or black. Most of those found in association with structural timbers are no more than 3 mm long. The head is partially or completely concealed from above by the pronotum (Fig. 40,a). Although the bark beetles are among the most serious forest pests, they are of very minor importance in seasoned wood. They actually do not cause any damage to the wood, but are sometimes found in houses and in association with structural timbers. For this reason, it is important that they and their damage be recognized as of no economic importance. Species of bark beetles are found in all parts of the country.

The eggs are laid by the female in a gallery constructed in the cambial zone. There are species that attack either hardwood or softwood trees. The larvae (Fig. 40,b) tunnel away from the egg gallery; the galleries increase in size and are tightly packed with frass (Fig. 41). Only the surface of the wood is slightly etched with their tunnels and they cause no structural damage. Because of their characteristic damage, they are often referred to as "engraver beetles."

When larval development is complete, they pupate at the ends of the tunnels. The adults tunnel straight out through the bark. The surface of the bark is sometimes riddled with round exit holes 1.5 to 3 mm in diameter. Bark beetles cannot live in seasoned wood, and thus do not reinfest.

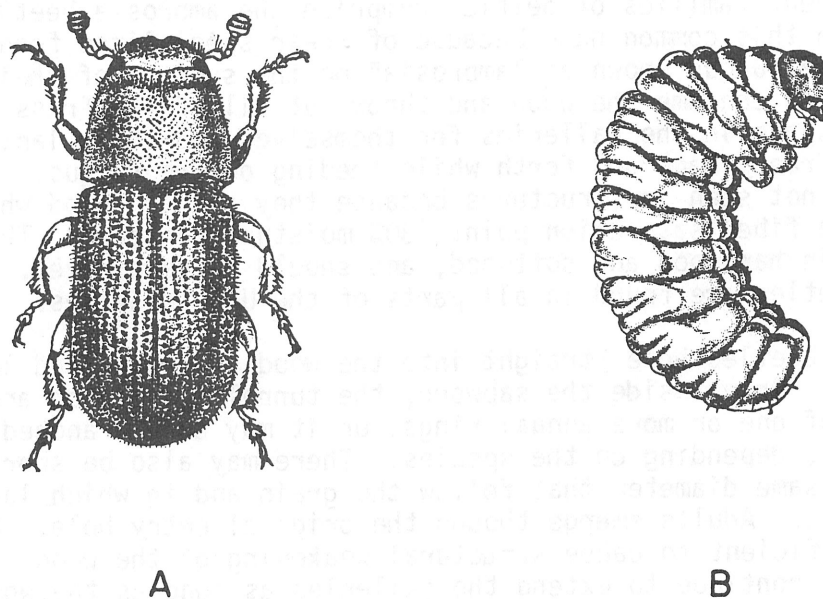


Figure 40. Typical bark beetle: (a) adult, (b) larva. (Used with permission of the McGraw-Hill Book Company. See Figure 32.)

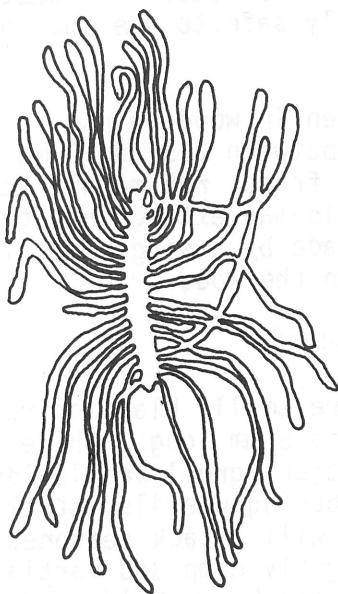


Figure 41. An example of bark beetle egg and larval galleries which are found between bark and wood. (Used with permission of the Center for Continuing Education, California Polytechnic University. See Figure 3.)

Scolytidae and Playtopodidae - Ambrosia beetles

Two different families of beetles comprise the ambrosia beetles. They have been given this common name because of their specialized food. These beetles "grow" a fungus known as "ambrosia" on the surface of their galleries. They do not consume the wood and throw out all of the frass. They maintain open space in the galleries for themselves and their larvae in order to move freely back and forth while feeding on the fungus. The adults and larvae are not seen in structures because they abandon wood which has dried below the fiber saturation point (30% moisture content). Their damage is often seen in hardwood and softwood, and should be recognized. Species of ambrosia beetles are found in all parts of the United States.

The adult beetles bore straight into the wood of unseasoned logs for several inches. Once inside the sapwood, the tunnel may branch and follow the curvature of one or more annual rings, or it may be unbranched and relatively straight, depending on the species. There may also be short side tunnels of the same diameter that follow the grain and in which larvae feed and later pupate. Adults emerge through the original entry hole. Damage is not usually sufficient to cause structural weakening of the wood. Several generations may continue to extend the galleries as long as the wood remains moist enough to sustain the fungus growth. Some species extend galleries into the heartwood. Freshly cut lumber may be attacked while it is stacked and before it has dried.

As the tunnels are constructed, the walls are inoculated with the fungus by the adult beetles. The fungus stains the gallery walls black, blue, or brown. The staining often spreads through the surrounding wood and is particularly obvious in lighter colored wood. This staining is often a greater defect than the holes themselves. The beetle attack ceases when the wood dries out. It is perfectly safe to use the wood without fear of further deterioration.

Ambrosia beetle damage seen in wood in use is characterized by circular holes and portions of tunnels between 0.5 and 3 mm in diameter (Fig. 42). The tunnels, which are free of frass, run mainly across the grain and have darkly stained walls. The stain may extend into the wood in patches or streaks. All of the tunnels made by a single species are the same size since only the adults tunnel in the wood.

Curculionidae - Wood-boring Weevils

The wood-boring weevils are small, black or reddish-brown, cylindrical in cross section, and about 3 to 5 mm long. The elytra are heavily pitted (Fig. 43). The larvae are whitish, grublike, legless, and 3 mm long when mature. Many species of wood-boring weevils attack unseasoned wood only. There are several species that will attack seasoned wood, but they are most often seen in wood that is slightly damp and partially decayed. Their damage is very similar to that caused by anobiid powderpost beetles, and both types of beetles are sometimes present in the same piece of wood. They are found in all parts of the country and have been transported, even overseas, in infested lumber.

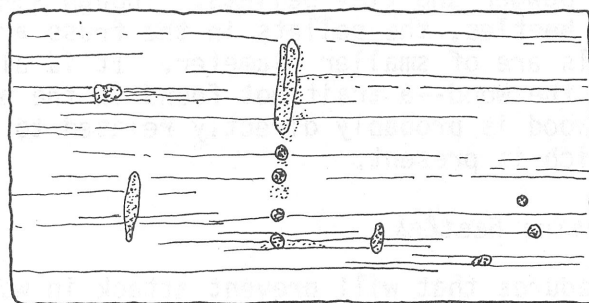


Figure 42. Wood damaged by ambrosia beetles. (Used with permission of the Center for Continuing Education, California Polytechnic University. See Figure 3.)

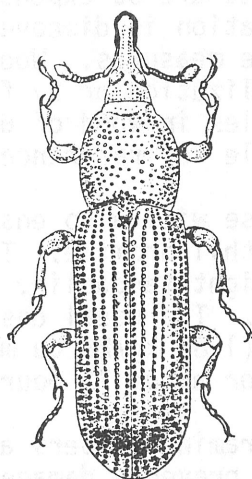


Figure 43. Adult wood-boring weevil. (Used with permission of the McGraw-Hill Book Company. See Figure 32.)

The eggs are laid in holes excavated by the female or in cracks and crevices. The larvae enter the wood and tunnel primarily with the grain. In some species the tunnels are completely random in direction. The life cycle usually takes less than a year. Adults emerge through exit holes that are raggedly round, approximately 1.5 mm in diameter, or elongate, irregularly shaped holes 1.5 to 2 mm in diameter.

These beetles attack hardwood, softwood, and plywood. When damage is heavy, the interior of the wood, including sapwood and heartwood, is honey-combed. The galleries, which are up to 1.5 mm in diameter, are made by the feeding of both adults and larvae. The frass is packed in the galleries and composed of very fine powder and tiny pellets. Though similar to the damage of anobiid powderpost beetles, the pellets in the frass are much smaller, and the largest tunnels are of smaller diameter. It is also common to find the adults feeding in the wood--a trait not found in the anobiids. Potential for damage to the wood is probably directly related to the amount of dampness and decay which is present.

Prevention of Wood-boring Beetles

Most of the procedures that will prevent attack in wood before it is placed into use are the responsibility of those who harvest, mill, and store the wood. Those who use this wood must take precautions that will reduce the chances of building a beetle infestation into a home. Specification that all wood be kiln-dried or air-dried before its use will prevent the introduction of beetle-infested wood into a home. This eliminates or severely restricts the development of most beetle species. This is also the cheapest and most practical preventive measure. Some beetles, however, will attack and re-attack wood after it is put into use so this will not eliminate all concern for beetle infestations.

If there is any reason to suspect that incipient infestations may be present, or if the wood components are so expensive or will be so difficult to treat or replace if an infestation is discovered later, it may be feasible to require further preventive measures. Wood may be positively freed of beetle infestation by heat sterilization or by fumigation. Times and temperatures necessary to kill beetles in wood of different thicknesses have been established and are available for reference (Ebeling 1975).

Fumigation of wood before use will also ensure that it is beetle-free. The gas most commonly used is methyl bromide. The wood should be stacked loosely and covered with a gas-tight tarpaulin. The bottom edges of the cover should be sealed with sand. The usual dosage of methyl bromide for such purposes is 3 lb/100 cu ft (1.82 kg/28 cu m) of air space. The gas should be held under the cover for about 72 hours (St. George 1973).

In areas where structural framing members are subject to beetle attack, the use of pressure-treated wood prevents damage. It is doubtful that there are any areas in the contiguous states that have enough beetle attack to justify the extra expense for such a preventive measure. If drywood termite and/or subterranean termite attack potential would justify pressure-treated wood, then the prevention of beetle attack would be an added benefit.

Brushing or spraying the wood with a 0.5% lindane oil solution before it is used will protect it from attack by beetles for 10 years or more. Lindane is applied at the rate of 1 gal/100 sq ft (4 liters/100 sq m) of surface or until no more is absorbed. The current availability of lindane is limited and its future is questionable. Replacement insecticides may, however, become available.

For the beetles that begin their attack under bark, the removal of any bark edges from lumber before it is used in construction is a good preventive measure. Many of the round-headed and flat-headed borers feed for extended periods under bark before they enter the wood. Bark beetles confine their attack to the inner bark and are thus eliminated by bark removal.

Use of good building design, as outlined for subterranean termite prevention, also applies to beetles. Good ventilation, drainage, and proper clearance between wood and soil will tend to reduce the equilibrium moisture content of wood and thus render conditions less favorable for beetle development. When the building is centrally heated, the drying process after construction is speeded up and the house becomes less susceptible to beetle attack. Proper attention to good attic ventilation is important in the prevention of beetle attack. If attics are well ventilated, they tend in most regions to dry out below the level of moisture needed for vigorous beetle activity.

Inspection

Most of the beetles that cannot reinfest seasoned wood show evidence of their presence within 2 or 3 years. Infestations of wood by beetles that can reinfest seasoned wood often do not become evident for several years after a house is constructed. Anobiid powderpost beetles and the old house borer may not become evident for 10 or more years, if the initial infestation was small and limited. The external signs of their presence do not become evident until sufficient adults have emerged to provide numerous exit holes and large quantities of accompanying frass. Where damage occurs, it is seldom widespread unless the property has been neglected for a number of years. Most commonly, only a very few boards are found to be infested when inspections have been performed at reasonable intervals. When an infestation is discovered (during a routine inspection rather than as a result of the sudden collapse of a wooden member) there is rarely any need for extreme haste in providing treatment.

Evidence of a beetle infestation is often not as easily seen as is evidence of a termite infestation. It is necessary to examine visually all exposed surfaces of painted and unpainted wood. Rapping on the surface to locate hollow-sounding areas and probing into the surface at close intervals with a sharp instrument will identify areas of internal damage. In its early stages, the extent of infestation by beetles is more difficult to determine than that of termites. There are no telltale shelter tubes or fecal pellets to reveal early beetle activity. Exit holes occur at the end of the first generation of beetle attack. In many cases larvae do not expel any frass to reveal their presence until there are exit holes from which the frass can sift. Minor exceptions include the bark beetles and some of the flat-headed borers that push frass from underneath bark edges left on structural timbers.

The characteristics of beetle damage found in wood in houses is summarized (Table 1). This table also indicates the type of wood and the portion of the wood attacked by the various kinds of beetles. This is important in determining the potential areas which might be infested by a particular species, and in evaluating the likelihood of serious structural weakening.

Control

Treatment for the control of wood-boring beetles is really only necessary when an inspection has revealed an active infestation by a species that will reinfest seasoned wood. The method or methods that should be used in the control of an active infestation of wood-boring beetles depends on many factors. Often it is necessary to consider the possibility of damage by the treatment as well as the probability of achieving control. Each problem must be analyzed in the light of severity of infestation, possibility of reinfestation, type of wood product being attacked, the area of the structure where attack is occurring, the speed of control needed, and the cost to the property owner.

Nonchemical Control.

Alteration of environmental conditions in the house might one day be the only procedure necessary to eliminate some infestations of wood boring beetles.

A. *Reduction of wood moisture.* It is a well-established fact that there are no infestations of wood-boring beetles that develop rapidly in wood that is very dry. There are indications that the most common anobiid beetles cannot establish an infestation in wood below 15% moisture content. For the old house borer, the moisture requirement for establishment is probably more than 10%. If the use of vapor barriers, ventilation, and central heat can dry wood and keep it dry enough, the use of other control measures may not be necessary. This method would not be a rapid means of control and probably would not completely replace others. At the present time, it can only be recommended that every effort be made to reduce the moisture content of the wood to be protected. If wood-boring weevils are the attacking species, they can be controlled completely by removing the cause of decay and dampness in the wood. Because they depend on the dampness for their survival, they will be controlled indirectly.

B. *Replacement of infested wood.* Before any chemical control procedures are considered, thought should be given to the feasibility of simply removing and replacing the infested wood. Under certain circumstances, this is more effective and economical than other methods. It would, of course, not be practical except in limited infestations. Wood in contact with the pieces removed should be carefully inspected to ensure that it has not become infested also, and if not removed, would remain as a source of future damage.

C. *Replacement of structurally-weakened wood.* Any wood in the building which has been damaged sufficiently for it to be structurally weakened should be replaced or reinforced. If the weakened wood, or that with which it is in contact, is actively infested with beetles, it should be

Table 1. Characteristics of damage caused by common wood-boring beetles in houses.

Type of borer	Wood attacked		Recognition of damage			Reinfestation
	Portion and type	Condition	Exit holes	Galleries (tunnels)	Frass	
Anobiid powder-post beetles	Mostly sapwood of hardwoods and softwoods; some in heartwood	Seasoned	Circular, 1.6 - 3 mm diameter	Circular, up to 3 mm diameter; numerous; random	Fine powder with elongate pellets conspicuous; usually loosely packed	Yes
Bostrichid powderpost beetles	Sapwood of hardwoods primarily; minor in softwoods	Seasoning and newly seasoned	Circular, 2.5 - 7 mm diameter	Circular 1.6 - 10 mm diameter; numerous; random	Fine to coarse powder; tightly packed, tends to stick together	Rarely
Lyctid powder-post beetles	Sapwood of ring-porous and diffuse-porous hardwoods	Newly seasoned with high starch content	Circular, 0.8 - 1.6 mm diameter	Circular, 1.6 mm diameter; numerous; random	Fine, flourlike, loose in tunnels	Yes
Round-headed borers (general)	Sapwood of softwoods and hardwoods; some in heartwood	Unseasoned, logs and lumber	Oval to circular, 3-10 mm long diameter	Oval, up to 13 mm long diameter; size varies with species	Coarse to fibrous; mostly absent	No
Old house borer	Sapwood of softwoods, primarily pine	Seasoning to seasoned	Irregular oval 6 - 10 mm long diameter	Oval, up to 10 mm long diameter; numerous in outer sapwood, ripple marks on walls	Very fine powder and tiny pellets; tightly packed in tunnels	Yes
Flat oak borer	Sapwood and heartwood of hardwoods, primarily oak	Seasoning and newly seasoned	Slightly oval, 1.6 - 2 mm long diameter	Oval, up to 2 mm long diameter	Fine granules	No

1/ Pellets may be absent and frass tightly packed in hardwoods

Table 1 (continued)

Flat-headed borers	Sapwood and heartwood of softwoods and hardwoods	Seasoning	Oval, 3 - 13 mm long diameter	Flat oval, up to 10 mm long diameter; winding	Sawdust-like, No may contain light and dark portions if under bark; tightly packed	No
Bark beetles	Inner bark and surface of sapwood only	Unseasoned, under bark only	Circular, 1.6 - 2.5 mm diameter	Circular, up to 2.5 mm diameter; random	Coarse to fine powder, bark-colored, tightly packed in some tunnels	No
Ambrosia beetles	Sapwood and heartwood of hardwoods and softwoods	Unseasoned, logs and lumber	Circular, 0.5 - 3 mm diameter	Circular, same diameter as holes; across grain, walls stained	None present	No
Wood-boring weevils	Sapwood and heartwood of hardwoods and softwoods	Slightly damp, decayed	Raggedly round or elongate, 1.6 - 2 mm diameter	Circular, up to 1.6 mm diameter	Very fine powder and very tiny pellets, tightly packed	Yes

replaced with pressure-treated wood or the replacement wood and the adjacent infested wood should be treated by surface application of a residual insecticide.

Residual Insecticides. At the time of this writing (1979), the availability and use of residual insecticides for wood-boring beetle control in buildings is in question. The insecticides most commonly used in the past, chlordane and dieldrin, have had their registrations for this purpose suspended or canceled by the Environmental Protection Agency. The only effective residual insecticide currently registered for control of wood-boring beetles is lindane. The future of lindane is also in doubt. Pentachlorophenol in an oil solution is also registered for use against wood-boring beetles, but is not an effective residual insecticide for this purpose. It is possible that some new insecticides will be registered for use and the situation will improve.

Most infestations of wood-boring beetles in houses are neither widespread nor inaccessible. For that reason, the treatment most commonly used in the past has been the surface application of residual insecticides to infested wood. When infestations were widespread in attics, crawl spaces and other unfinished areas, all exposed wood members were treated. This is still the preferred method of control when it is possible to obtain properly labeled insecticides, and there is no requirement that control be immediate. It sometimes takes from several months to a year or more for an infestation treated in this manner to be controlled completely. This is because it is not possible in most cases to get complete penetration of the insecticide into all of the infested wood. The larvae in unsaturated areas tend to avoid the treated outer layer of wood until they complete their development, pupate and attempt to emerge as adults. Most adults are killed while attempting to chew through the treated wood layer. If there are surfaces that are insufficiently treated or untreated because of inaccessibility, some adults may emerge. These adults are usually killed, however, in the process of crawling over the treated surfaces of exposed wood. Larvae hatching from eggs successfully laid on treated surfaces do not survive their attempt to bore into the wood. Thus, a high degree of success results after sufficient time has passed. Proper treatments with residual insecticides should remain effective for 10 or more years.

A. *Treatment of unfinished wood.* There are some differences in the way a treatment is applied to unfinished wood as compared to wood with a finish on its surface. When raw, unfinished wood has been heavily damaged by beetles, the powdered portion should be removed completely. The frass and wood fragments should be carefully cleaned up. If replacement or reinforcement is needed, this should be done before completing the treatment.

Where damage is not severe, the surfaces to be treated should be carefully brushed to remove frass and dust clinging to the surface. Suspended wood should be pounded with a rubber mallet before brushing to vibrate loose frass from exit holes. Clean wood allows better penetration of insecticides and new activity to be more easily spotted during subsequent inspections.

As of 1979, the only effective residual insecticide currently labeled in 20 states is lindane. It should be applied as a 0.5% water emulsion. In

the past, oil solutions as well as water emulsions, of dieldrin and chlordane, successfully controlled anobiid powderpost beetles in unfinished wood.

If powderpost beetles are the problem, the insecticide solution is applied to all exposed wood surfaces by brush, or as a wet spray, to the point of runoff. Two applications should be made, the second before the first is completely dry. The amount varies with the amount of damage and the smoothness of the wood surface. If a sprayer is used, very low pressure and a fan-shaped spray pattern should be used. This will prevent excessive misting and bounce-back from the surface, thus reducing hazard and waste.

Old house borers can also be treated by brushing or spraying 0.5% lindane water emulsion on infested areas. Repeated applications are made until the infested areas are heavily saturated.

Treatments as heavy as this should not be applied to all exposed surfaces but only to known infested areas and slightly beyond. The lower rate of application described for powderpost beetles would serve as an adequate treatment to prevent infestations in areas outside the infested ones. This type of treatment should be effective for 10 or more years.

B. *Treatment of finished wood surfaces.* Beetles that attack hardwoods, the type of wood most often infested on the interior of houses, will not usually lay their eggs on finished wood surfaces. Such wood is physically protected from reinfestation, except for the old exit holes or cracks and crevices that allow beetles access to unfinished areas. Finished wood surfaces greatly reduce the potential for reinfestation beyond the first generation.

The problem of treating finished surfaces of wood is rather complex. Many types of wood finishes may react to the chemicals. Because the treatment might damage the wood finish, it is advisable to treat a small, inconspicuous area for preliminary observation. It is seriously doubted that the insecticide solutions penetrate through finished surfaces, but simply evaporate on the surface (Bletchly 1967). Unless the finish can be removed, the only beneficial treatment is to repeatedly inject an insecticide oil solution (none of which are currently labeled), into the beetle exit holes in the surface of the wood and into open joints and crevices between boards. Because this would result in good penetration of the wood only if there were many exit holes, it would be feasible only when heavy damage has occurred. If interior trim can be removed, it might be successfully treated through the unfinished surfaces by applying the lindane emulsion, as described previously for unfinished wood surfaces.

Fumigation. Infestations of wood-boring beetles are controlled most rapidly and completely by fumigation. This is a very expensive process and it offers no residual protection from reinfestation. It is also necessary for the residents to leave the premises for one or more days. But because of the current uncertainty over the availability and use of residual insecticides and the large turnover in home ownership requiring certification that structures are insect-free, fumigation has recently become a more common control procedure in spite of its drawbacks. In addition to acting rapidly, fumigants are useful when an infestation is very extensive, or is in building locations that make other control procedures impractical.

Methyl bromide is the fumigant most widely used in houses. Fumigation for wood-boring beetles is similar to that for drywood termites. Sulfuryl fluoride, commonly used for drywood termite fumigation, is not generally recommended for wood-boring beetles because it is not very effective against the egg stage. Because of some other advantages, sulfuryl fluoride has been used by fumigators for beetle control when eggs are not present. The gas needs to be retained in the building under the tarpaulin for only 24 hours if the space is properly sealed. Because of the expense involved in fumigating entire structures, attempts have been made to treat localized portions of buildings by covering them with plastic. These procedures are not usually successful because of the rapid loss of gas through wall voids and other places.

WOOD-ATTACKING WASPS, ANTS AND BEES

The insects to be discussed in this section all belong to the order Hymenoptera. The type and amount of damage done to wood by hymenopterans vary with the particular family. Only the horntails (family Siricidae) bore in wood and make galleries packed with frass. The carpenter ants (family Formicidae) and carpenter bees (family Apidae) make hollows in the wood for nesting purposes only and keep them clean and free of frass. Although the amount of damage done to wood in use cannot rank these insects as major pests, they are common enough and conspicuous enough to warrant their consideration.

Horntails or Wood Wasps

The horntails, because of their superficially wasplike appearance, are often called wood wasps. In both sexes the last segment of the abdomen bears a hornlike projection (Fig. 44,a,b). This distinctive structure gives them the widely used common name of horntails. There are about 50 different species of horntails in the family Siricidae, approximately 20 of them are found in the United States. They belong to four different genera, one of which infests hardwood. All of the other genera attack softwoods, and some are common pests of coniferous trees used for construction lumber.

The adults are large, usually 25 mm or more in length. The females are usually larger than the males and have a long ovipositor (Fig. 44,a). Sizes of individuals even in the same species vary. The adults of the species attacking softwoods are usually black or dark metallic blue, sometimes in combination with markings which are yellowish, reddish, or brown. The larvae are whitish to creamy yellow in color, usually cylindrical, have very short legs and a small dark horny spine on their posterior end. This they use for packing frass behind them (Fig. 44,c). When larvae are removed from their galleries, they tend to take on a slight S-shape with their heads bent down and their tails turned up. Depending on the size of the species, they may be up to 45 mm long.

Horntails are discussed, not because they are very common pests of wood or do a significant amount of damage to structural timbers, but rather, because they occasionally appear in large numbers in houses constructed of infested wood. Adults make conspicuous exit holes in finished surfaces and are very conspicuous and noisy when they fly about indoors. Equally important is the fact that wood showing evidence of past attack by horntails is

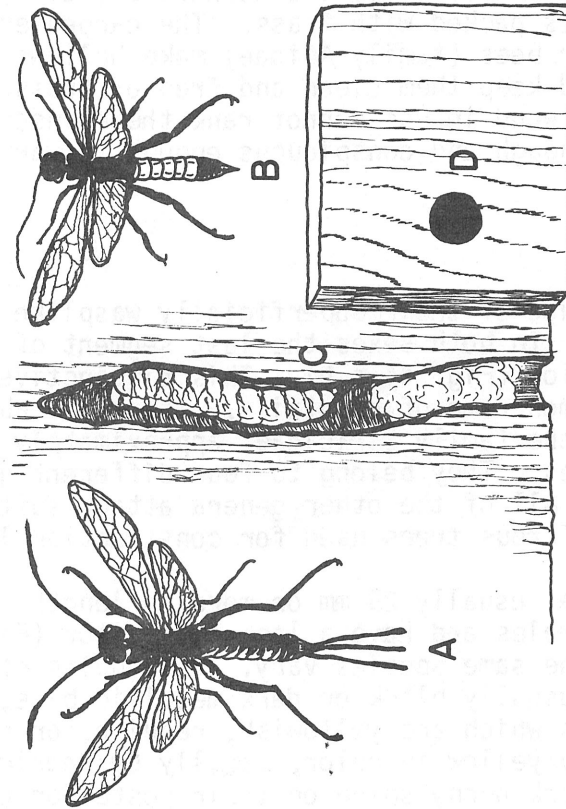


Figure 44. Horntails or wood wasps: (a) adult female, (b) adult male, (c) larva in gallery, and (d) exit hole made by adult. (Courtesy of the University of California, Berkeley.)

sometimes included in structures. The significance of such damage should be understood by those concerned with the soundness of buildings constructed with such wood.

Distribution and Economics Importance. Species of horntails are found naturally in all parts of the contiguous states where the host trees grow. Those that attack softwoods have been dispersed in infested lumber to many areas where they do not occur naturally. There are, therefore, no parts of the United States that are not subject to the possibility of horntails in wood in houses. One species, Tremex columba (L.), with several color phases, attacks hardwoods. This species is widely distributed in the United States and southern Canada. Indoors, it is found emerging from hardwood fireplace logs, but is a nuisance only and not a pest of structural wood.

The major economic losses caused by horntails are the result of boring by adults and larvae in trees. This results in the down-grading of lumber. Instances of damage in houses have not been very frequent, but infestations may be very serious when they do occur.

Biology and Habits. Little is known of the biology of North American species of horntails. Morgan (1968) has provided a comprehensive review of available literature and much of the information reported here has come from that source. The female inserts her slender ovipositor into the bark and the wood to a depth of 8 to 20 mm, and deposits several eggs. Fungal spores, which are stored in special glands at the base of the ovipositor, are also introduced into the egg tunnel. The fungus grows rapidly before egg hatch and provides the larvae with nourishment. The larvae do not swallow any wood but secrete saliva which digests the fungal tissue in the wood. They then ingest the predigested nutrients. The wood fragments that they have chewed off are passed behind them after the fungal nourishment has been ex- tracted. Because larvae depend on the fungal growth for food, wood that is attacked must be in a condition to support its growth. This generally means that the moisture content must be above the fiber saturation point (30%).

The young larvae bore cylindrical tunnels at right angles to the oviposition tunnel. They feed at first in the sapwood but, as they become larger, they bore into the heartwood. After feeding for some time in the heartwood, the larvae turn outward and tunnel back into the sapwood. Thus, the larval tunnel is roughly C-shaped and from 25 to 75 cm long, depending on the species. As the larvae tunnel back, they pack the frass tightly behind them.

The larval stage may require 2 or 3 years to complete. If the wood dries out quickly, as it does in lumber sawed from infested logs, the development time may be prolonged to 4 or 5 years. Pupation occurs in a silken cocoon spun toward the end of the larval tunnel. This is usually 18 to 25 mm below the surface. The adults make a perfectly round exit hole as they emerge. They have been reported emerging through hardwood floors, wood siding and paneling, plaster and plasterboard, and even sheet lead of considerable thickness.

Signs of Infestation and Characteristics of Damaged Wood. The most common manifestations of a horntail infestation are tunnels tightly packed with frass, which have been sawed through in the milling process and are visible on the surface of the wood. If the infestation has been active, there may be adult exit holes through the surface of structural members, or through any of the materials which have been applied over the infested wood. These usually appear within the first 3 years.

Both the exit holes and the larger tunnels are circular in cross section and 4 to 6 mm in diameter (Fig. 44,d). There is considerable variation in the size of the interior tunnels because some are made by young larvae. The tunnels exposed by milling may appear to be oval in cross section because of the angle at which they were cut. They wind in many directions, and are quite commonly surrounded by soft, decayed wood. Sometimes a faintly grayish staining is associated with the fungal attack. This is visible in light-colored wood as a thin "halo" a few mm from the tunnel, when viewed in cross section.

Potential for Destruction. The amount of horntail damage found in structural timbers is usually so small as to be of no practical concern. When a live infestation is incorporated into a new building, larval development may proceed and adult horntails eventually emerge. Because they are unable to reinfest seasoned wood, however, such live infestations and any resulting damage are usually unimportant.

Prevention and Control. Damage by horntails to wood in use can be prevented by proper kiln-drying of green lumber sawed from infested logs. If kiln-drying is not specified, some infested lumber will no doubt continue to be used in new construction and result in problems with adult emergence during the first 2 to 5 years of the structure's existence.

The presence of actively infested timbers cannot be detected until the adults have emerged. After emergence, there is no real need for any control measures. Exit holes that are exposed to the weather should probably be treated by injecting a 5% oil solution of pentachlorophenol to kill any fungi present, then sealed with an appropriate filler to prevent water seepage and subsequent decay.

Carpenter Ants

Ants that damage wood are known as carpenter ants. All of the carpenter ants of economic importance belong to one genus, *Camponotus*, and are very similar in habits. Carpenter ants are among the largest species of ants found in the United States. Several castes are found in mature colonies. The winged females may be up to 18 mm long, including the wings (Fig. 45,a). The males are considerably smaller, being up to 11 mm long (Fig. 45,b). There is usually only one functioning, wingless queen in a colony and she is up to 14 mm long (Fig. 46,a). There are several sizes of workers. The major workers are up to 11 mm long (Fig. 46,b) in the common species and may be slightly larger. The minor workers are the smallest, averaging 8 mm in length (Fig. 46,c), though some species may be smaller. There are also intermediate sized workers. The adults of those species found nesting in houses are predominantly black; however, some may be partially reddish brown to yellowish. The pupal stage is completed inside tan

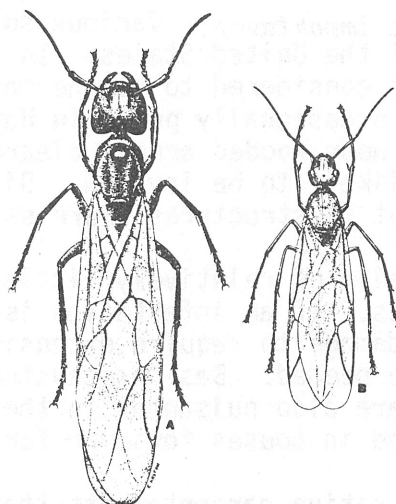


Figure 45. Carpenter ant adults: (a) female, (b) male. (Courtesy of Connecticut Agricultural Experiment Station.)

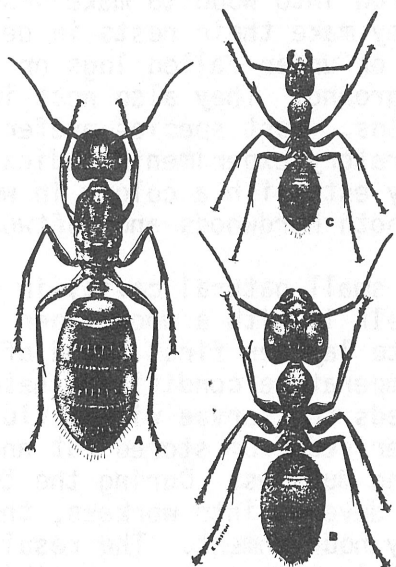


Figure 46. Wingless carpenter ant queen (a) and carpenter ant workers: (b) major worker and (c) minor workers. (Courtesy of Connecticut Agricultural Experiment Station.)

or cream-colored silken cocoons, which are often erroneously referred to as "ant eggs."

Distribution and Economic Importance. Various species of carpenter ants are found in all parts of the United States. In the Pacific Northwest and in the Northeast, they are considered to be the most common pests of wood in structures. They are occasionally pests in Hawaii in areas recently cleared of chaparral. Houses near wooded areas, cleared land, or brush-covered vacant lots are more likely to be invaded. Disturbing natural nesting areas triggers movement to structures (Furniss 1944).

Carpenter ants are generally of relatively little economic importance as destroyers of wood in houses. If an infestation is of long standing, however, there may be enough damage to require extensive repairs. Usually, only minor repairs at most are needed. Besides causing some damage to wood in buildings, carpenter ants are also nuisances in the same way that other ants are when they crawl around in houses foraging for food or water.

Biology and Habits. The native carpenter ant that has been most thoroughly studied is the black carpenter ant, Camponotus pennsylvanicus (DeGeer). It is very common in the eastern and central United States. Most of the information which follows applies to that species. Various reports on other native species indicate that their biology and habits are similar.

Any time from early spring until the mid-summer months, rather large numbers of winged males and females emerge from established colonies. After mating, females begin a search for a place to establish a new colony. Females break off their wings just before or just after a nesting site is selected. Carpenter ants burrow into wood to make nests. They do not use wood for food. In nature, they make their nests in dead portions of standing trees, stumps, logs, or under fallen logs or stones, sometimes with galleries extending into the ground. They also nest in structural timbers if they find suitable conditions. Most species prefer to nest in moist wood that has begun to decay. Laboratory experiments indicate that the black carpenter ant cannot successfully establish a colony in wood below 15% moisture (Simeone 1954). They attack both hardwoods and softwoods.

The mated female finds a small natural cavity in wood or soil, or excavates one, and seals herself in with a wood fiber and saliva mixture. Within a few days she begins to lay her first brood of eggs until there are 15 to 20. Under favorable temperature conditions these hatch in approximately 3 weeks. The queen feeds the larvae with a fluid secreted from her mouth. This nourishment is derived from stored fat and from metabolic conversion of the now useless wing muscles. During the two or more months required for the first brood to develop into workers, the female never leaves the brood chamber or takes any nourishment. The resulting adult workers are all very small. They immediately take over responsibility of caring for and providing food for the new brood and the queen. They enlarge the nest as the colony population increases. The queen's sole responsibility then becomes egg-laying.

In subsequent generations, workers of various sizes are produced. They are all females, but are undeveloped sexually and do not produce eggs. In general, the largest ants guard the nest, battle enemies, forage for food,

and bring food to the nest where it is transferred to the smaller workers. The smaller workers primarily expand the nest and care for the young. These ants cannot sting, but have the ability to inflict a painful bite.

The food of carpenter ants consists primarily of honeydew. The workers gather honeydew from aphids and other sucking insects that they find on foliage and roots of trees. They also feed on the remains of dead insects and on plant and fruit juices. When they forage inside houses for food, they are attracted to sweets and to most kinds of meats, grease, and fat. Most of the food gathered by the workers is consumed instead of being carried back to the nest. They feed the other colony members, adults and larvae, by regurgitation.

During the first year the colony remains small, consisting of the queen, about 10 to 20 workers, and some immature forms. In succeeding years, the population grows rapidly until it numbers from 2,000 to 3,000 individuals, at which time winged reproductives (swarmers) may be produced each year. They usually mature in late summer, but spend the winter in the nest, and emerge the following spring or summer. Colonies rarely grow larger at this point, but continue indefinitely to produce reproductives and replenish the workers which die.

Houses are commonly infested by the movement of a colony, or part of a colony, into the structure. Fertilized queens also establish new colonies in houses. In structures, timbers that are soft, damp, and partially decayed are selected most frequently as nesting sites. There are some species that are capable of nesting in sound wood, but even these prefer softened wood to start a nest. Once a nest is established, the workers will extend the galleries into sound wood adjacent to the partially decayed portion.

It is common for carpenter ants to nest in houses without attacking the timbers. They simply use existing cavities, including wall voids, hollow flush panel doors, termite galleries in wood, and other cavities in almost any part of a house. In undisturbed areas such as attics, inside stored furniture, and on seldom used shelves, they may establish a nest in debris or even out in the open. They sometimes nest in foamed plastic or fiberglass insulation.

Signs of Infestation. The most obvious sign of infestation is the presence of large workers inside the house. The ants are active all year if nesting in heated portions of houses; otherwise, they become inactive during cool weather. During very warm weather, the ants are most active at night, and daytime activity is reduced. During the spring or early summer, there may be swarmers inside or around the house. Those indoors tend to fly toward the windows and to congregate there.

There may be piles or scattered bits of frass which the ants have removed from the wood. This is very fibrous and sawdust-like. If from decayed wood, the pieces tend to be darker and square-ended. Carpenter ant frass can be distinguished from sawdust produced during construction, or from carpenter bee frass, because there are usually fragments of ants and other insects mixed with wood fibers. Frass is expelled from cracks and crevices or from slit-like openings, called "windows", made by the ants. It is quite often found in basements, dark closets, attics, under porches, and other out-of-the-way places.

Characteristics of Damaged Wood. The damage to wood is discovered when the surface is broken open. The only external evidence of attack is the small, inconspicuous "windows" made in the surface by the ants. The galleries extend both along the grain of the wood and around the annual rings. The softer spring growth tends to be removed first. The harder-grained summer wood is penetrated at frequent intervals, so there is complete access between the galleries (Fig. 47). The surfaces of the galleries are smooth and perfectly clean; though sometimes the wood has been discolored by decay fungi. The general appearance of the galleries is similar to those made by drywood termites. However, there are no fecal pellets and the frass is completely removed, except for occasional deposits in unused galleries.

Potential for Destruction. Carpenter ants do not pose a serious threat to the soundness of structural timbers unless they are ignored for long periods of time. Once the infestation is discovered, control is simple enough that the problem can be quickly ended. If the ants are ignored, serious destruction of wood may result and expensive repairs may be needed. This most often occurs in recreational structures that remain unoccupied for long periods of time.

Prevention, Inspection and Control. The prevention of attack by carpenter ants is in many ways similar to the prevention of subterranean termite attack. Because carpenter ants are most likely to initiate attack in damp wood that has been partially decayed, this condition should be avoided. Proper clearance between wood and soil, good drainage and ventilation, proper roof flashing, and tight exterior wood joints are all good preventive practices. If wood is likely to be wetted from time to time, it should be pressure-treated. Areas such as wooden porches and wooden support columns are particularly susceptible to ant attack.

The most difficult and most important part of carpenter ant control is locating the nest or nests. Once they have been found, control is relatively easy. Inspection procedures, therefore, should be aimed at finding the nest sites, both indoors and outdoors. The most obvious places to look for carpenter ants are those areas most likely to have a high moisture content. Inspection for this condition would require careful examination of the outside of the structure as well as in the attic and crawl space or basement. Because carpenter ants do not confine their nests to damp wood, it is equally important to examine the interior of the house for signs of ant activity. They have been found nesting in virtually every part of houses. The edges of floors and ceilings, and window and door trim should be carefully examined. Ants commonly nest in wall voids above windows and doors, and inside hollow doors.

When ants themselves are found, they should be observed long enough to determine the general direction in which they are traveling to follow them back to the nest area. Once the nests have been located, they should be treated with residual contact insecticides applied as a dust or spray. Dusts are particularly effective in the nests. All of the approaches and areas surrounding the nest should also be treated. Indoors, this is best accomplished by spraying. Simply treating the areas where ants are seen and not locating and treating the nests is seldom satisfactory. Some of the ants do not leave the nest and would not be affected by such a treatment. Considering that individual carpenter ants can live for 6 months or more without feeding, it is obvious that nest treatment is essential.

Any of the insecticides which are currently labeled for ant control should be effective if the nests are carefully treated. Examples of such insecticides are carbaryl (Sevin), chlorpyrifos (Dursban), diazinon, Ficam, and propoxur (Baygon). When the infestation is in an area exposed to wetting by rain or is in ground contact, the use of a 5% pentachlorophenol oil solution in the galleries is helpful in reducing decay activity as well as killing the ants. This should not be used in treating a nest in a living tree or inside structures. Indoor galleries and wall voids can be treated with Drione, a silica aerogel and pyrethrins mixture, which will provide long-term residual protection if the treated areas are dry.

Carpenter Bees

The common name, carpenter bee, is used for two closely related groups of bees in the family Apidae. One of the two groups consists of small, metallic-colored bees that nest in the stems and canes of pithy plants (genus *Ceratina*). Individuals in the other groups are all larger and belong to the single genus, *Xylocopa*. They construct nests in wood, occasionally in structural timbers.

Nine species of *Xylocopa* are found in the contiguous states (NPCA 1963) and at least one species in Hawaii. The adults are generally stocky, black or blue-black in color, and 25 mm in length. The thorax is covered with yellow, orange, or white hairs and the abdomen, especially on the dorsal surface, is bare and shiny (Fig. 48). Some species have greenish or purplish reflections and in some, the males are entirely buff or pale yellow. Carpenter bees can be distinguished from bumble bees by the lack of hairs on the dorsal surface of the abdomen. Also, female carpenter bees have a dense brush of hairs on the hind legs, as compared with the more openly constructed pollen baskets on the legs of bumble bees. The larvae are white, legless, and grublike, and remain entirely inside the wood. Pupae also remain entirely in the wood.

Distribution and Economic Importance. Only three species of wood-invading carpenter bees consistently nest in structural timbers (Hurd 1955, 1958). They are found in virtually all the contiguous states and Hawaii, and can be transported in infested wood from one area to another. Carpenter bees are most often simply nuisances in and around structures. They are confused with bumble bees by homeowners whose concern is being stung. The male bees are very aggressive, but harmless. The females are not aggressive and very seldom sting, unless handled or otherwise seriously molested.

Structural damage by carpenter bees to occupied buildings is seldom of any consequence. They are large, noisy insects and make rather conspicuous holes in wood. For these reasons, they attract much attention when present and should be recognized so that their relatively minor potential for damage can be properly evaluated.

Biology and Habits. *Xylocopa virginica* (L.) is the most prevalent wood-attacking species east of the Rocky Mountains. The biology of this species has been described in great detail (Chandler 1958; Balduf 1962) and will illustrate the life history of carpenter bees in general.

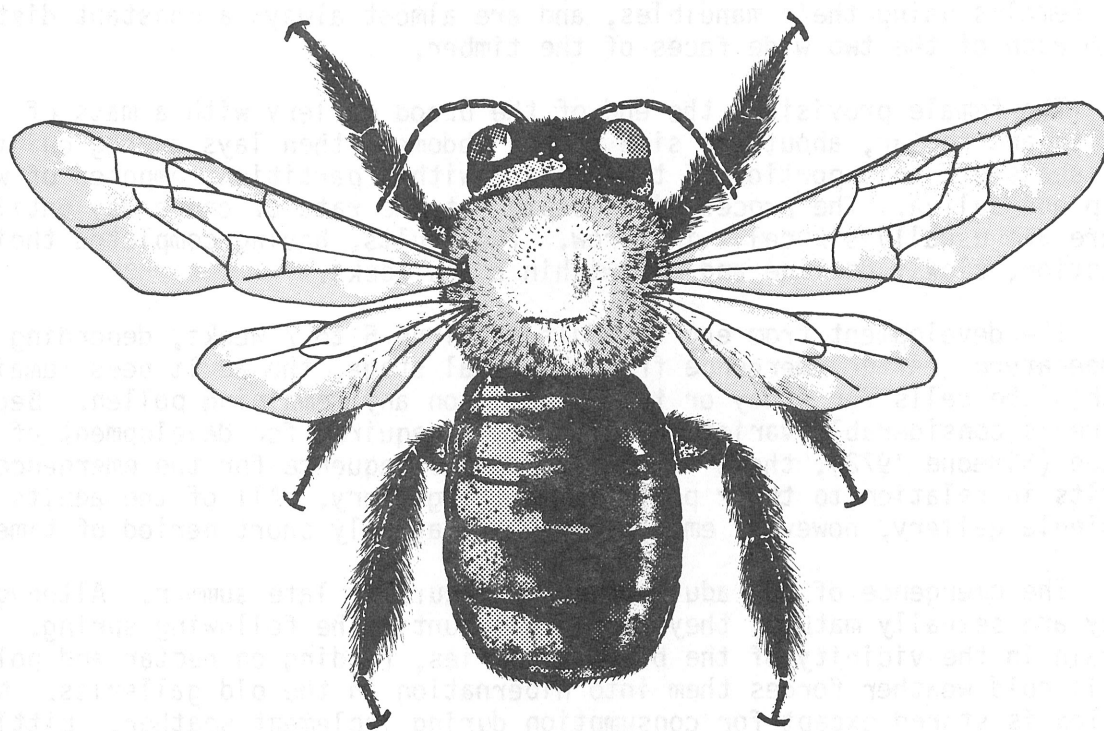


Figure 48. Adult Xylocopa spp.

The adults overwinter in abandoned nest tunnels. They emerge in the spring, usually April or early May, and feed on nectar. Mating occurs within a few weeks. Mated females begin to prepare nests either by excavating a new tunnel or more often, cleaning out and expanding an old gallery. Several females may share a common entry hole. When several generations of bees have shared a common nesting site, the galleries may become quite branched and interconnected (Fig. 49). The original entry is most commonly made by the female boring into the lateral face of a structural timber in a well-lighted but sheltered location. Entry is less often made on the underside or end of a board. The hole is perfectly round and approximately 12 mm in diameter. The tunnel usually turns abruptly at a right angle after being extended approximately the length of the female's body across the grain of the wood. The tunnel is extended with the grain from 10 to 15 cm in a new site. An old gallery may be extended or used without further burrowing. If an old gallery is repeatedly extended by succeeding generations, it may ultimately reach 2 to 3 m in length. The galleries are excavated solely by the females using their mandibles, and are almost always a constant distance from each of the two wide faces of the timber.

The female provisions the end of the brood gallery with a mass of pollen and nectar, about the size of her abdomen, then lays an egg on it. She seals off this portion of the gallery with a partition composed of wood pulp and saliva. The process is repeated at the rate of one a day until there are usually six cells in a row. The adults, having completed their function, slowly decline and die within a few weeks.

The development from egg to adult requires 5 to 7 weeks, depending on temperature. After emergence from the pupal stage, the adult bees remain within the cells for a day or two, feeding on any remaining pollen. Because there is considerable variation in the time required for development of each stage (Simeone 1972), there is no predictable sequence for the emergence of adults in relation to their position in the gallery. All of the adults from a single gallery, however, emerge over a relatively short period of time.

The emergence of the adults usually occurs in late summer. Although they are sexually mature, they do not mate until the following spring. They remain in the vicinity of the brood galleries, feeding on nectar and pollen, until cold weather forces them into hibernation in the old galleries. No pollen is stored except for consumption during inclement weather. Little, if any, boring is done before hibernation.

Signs of Infestation. There are several ways to determine the presence of carpenter bee attack in a structure. The most obvious one is the bees themselves. They are present around the outside of the house during the late spring and early summer and again in late summer and early fall. When the bees are not active, the only signs of infestation likely to be seen are the 12 mm, round entry holes made by the female bees. In addition, there will be rather coarse, sawdust-like frass being expelled from the entry holes that accumulates on surfaces below the site of activity. The frass is usually the color of freshly sawed wood which varies with the species of wood under attack. There are no fragments of insects mixed with this frass as is the case with carpenter ant frass, although it is otherwise similar.

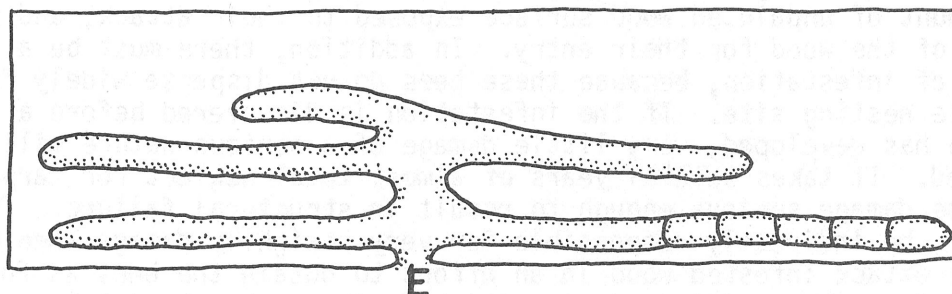


Figure 49. Carpenter bee nests in 1 x 4 board. E. Designates the entry hole on the narrow face of the board.

Characteristics of Damaged Wood. Carpenter bees usually choose wood that is soft and easy to work. They particularly like California redwood, cypress, cedar, white pine, and southern yellow pine. Other woods, even hardwoods, may be chosen if they have been softened as a result of being unprotected and exposed to the weather for extended periods of time. Bare wood is preferred and they avoid well-painted wood and wood with bark on it. If the surface is stained or has a very thin coating of paint on it, they will attack it. They will also tunnel wood that has been lightly pressure-treated with metallic salts for above-ground use, such as in decks.

The only external evidence of attack is the entry hole made by the females. If the wood is pried open, or has been damaged by woodpeckers subsequent to bee attack, the internal galleries can be seen. They are smooth-walled and tend to be a very uniform 12 mm in diameter. If they have been used for several generations, they become more irregular and up to 25 mm in diameter.

Potential for Destruction. In areas where carpenter bees are common, the amount of damage that they can do in a structure varies directly with the amount of unpainted wood surface exposed to their attack, and the suitability of the wood for their entry. In addition, there must be a nearby source of infestation, because these bees do not disperse widely from a suitable nesting site. If the infestation is discovered before a large population has developed, very little damage of a serious nature will have occurred. It takes several years of almost total neglect for carpenter bees to cause damage serious enough to result in structural failure. They can, however, be indirectly responsible for very unsightly damage when woodpeckers attack infested wood in an effort to obtain the bees as food. When thin wood, such as siding, is so attacked, it may be completely penetrated. Decay may follow such attack in wood exposed to rain.

Prevention, Inspection, and Control. The only way to prevent attack by carpenter bees is to keep all exposed wood surfaces well coated with paint. Wood pressure-treated with organic preservatives such as pentachlorophenol and with heavy loadings of metallic salts are resistant to carpenter bee attack. Even surface coatings of organic preservatives are helpful. The surface should be retreated when it has weathered for several years in order to maintain the repellent effect.

The nests of carpenter bees are not difficult to locate when the bees are active. When they are not, it is necessary to concentrate inspection efforts on those surfaces likely to be invaded (NPCA 1963). Those surfaces which are bare or poorly coated with stain or paint should be inspected very carefully. Well-lighted but protected locations are also favored.

Five to 10% carbaryl (Sevin) dust, or any insecticide labeled for bee control, applied into the entry holes, will kill bees which come into contact with the residue. Several days after treatment, the holes should be plugged with short length dowel rods of the proper diameter, or with plastic wood. Plugging the holes without applying insecticide can lead to the production of new holes next to the plugs, when bees inside attempt to emerge or when nesting females seek reentry into galleries in use. Treating the external surfaces in the vicinity of the entry holes with any insecticide labeled for bee control will discourage continued bee activity for the season.

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