Chapter 4: Disease Vectors and Pests

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"Sometimes poor housing is a shorthand way of describing living conditions of poor people. The poor include the aged, deprived, ethnic minority groups, the infirmed, and families headed by unemployed women. In other words, the people most at risk for illness often live in inferior housing. Therefore, it is a matter of conjecture whether many people live in poor housing because they are sick or are sick because they live in poor housing."

Carter L. Marshall, M.D.
Dynamics of Health and Disease
Appleton, Century Crofts 1972

Introduction

The most immediate and obvious link between housing and health involves exposure to biologic, chemical, and physical agents that can affect the health and safety of the occupants of the home. Conditions such as childhood lead poisoning and respiratory illnesses caused by exposure to radon, asbestos, tobacco smoke, and other pollutants are increasingly well understood and documented. However, even 50 years ago, public health officials understood that housing conditions were linked to a broader pattern of community health. For example, in 1949, the Surgeon General released a report comparing several health status indicators among six cities having slums. The publication reported that:

- the rate of deaths from communicable disease in these areas was the same as it was for the rest of the country 50 years ago (i.e., around 1900);
- most of the tuberculosis cases came from 25% of the population of these cities; and
- the infant mortality rate was five times higher than in the rest of the country, approximately equal to what it was 50 years ago.

Housing-related health concerns include asthma episodes triggered by exposure to dust mites, cockroaches, pets, and rodents. The existence of cockroaches, rats, and mice mean that they can also be vectors for significant problems that affect health and well-being. They are capable of transmitting diseases to humans. According to a 1997 American Housing Survey, rats and mice infested 2.7 million of 97 million housing units. A CDC-sponsored survey of two major American cities documented that nearly 50% of the premises were infected with rats and mice.
This chapter deals with disease vectors and pests as factors related to the health of households.

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Disease Vectors and Pests

Integrated pest management (IPM) techniques are necessary to reduce the number of pests that threaten human health and property. This systems approach to the problem relies on more than one technique to reduce or eliminate pests. It can be visualized best as concentric rings of protection that reduce the need for the most risky and dangerous options of control and the potential for pests to evolve and develop. It typically involves using some or all of the following steps:

- monitoring, identifying, and determining the level of threat from pests;
- making the environment hostile to pests;
- building the pests out by using pest-proof building materials;
- eliminating food sources, hiding areas, and other pest attractants;
- using traps and other physical elimination devices; and
- when necessary, selecting appropriate poisons for identified pests.

The above actions are discussed in more detail in the following section on the four basic strategies for controlling rodents.
Most homeowners have encountered a problem with rodents, cockroaches, fleas, flies, termites, or fire ants. These pests destroy property or carry disease, or both, and can be a problem for rich and poor alike.

Rodents

Rodents destroy property, spread disease, compete for human food sources, and are aesthetically displeasing. Rodent-associated diseases affecting humans include plague, murine typhus, leptospirosis, rickettsialpox, and rat-bite fever. The three primary rodents of concern to the homeowner are the Norway rat (*Rattus norvegicus*), roof rat (*Rattus rattus*), and the house mouse (*Mus musculus*). The term “commensal” is applied to these rodents, meaning they live at people’s expense. The physical traits of each are demonstrated in **Figure 4.1**.

Barnett **[1]** notes that the house mouse is abundant throughout the United States. The Norway rat **(Figure 4.2)** is found throughout the temperate regions of the world, including the United States. The roof rat is found mainly in the South, across the entire nation to the Pacific coast. As a group, rodents have certain behavioral characteristics that are helpful in understanding them. They are perceptive to touch, with sensitive whiskers and guard hairs on their bodies. Thus, they favor running along walls and between objects that allow them constant contact with vertical surfaces. They are known to have poor eyesight and are alleged to be colorblind. Contrastingly, they have an extremely sharp sense of smell and a keen sense of taste. The word “rodent” is derived from the Latin verb *rodere*, meaning “to gnaw.” The gnawing tendency leads to structural damage to buildings and initiates fires when insulation is chewed from electrical wires. Rodents will gnaw to gain entrance and to obtain food.

The roof rat **(Figure 4.3)** is a slender, graceful, and very agile climber. The roof rat prefers to live aboveground: indoors in attics, between floors, in walls, or in enclosed spaces; and outdoors in trees and dense vine growth. Contrasted with the roof rat, the Norway rat is at home below the ground, living in a burrow. The house mouse commonly is found living in human quarters, as suggested by its name. Signs indicative of the presence of rodents—aside from seeing live or dead rats and hearing rats—are rodent droppings, runways, and tracks **(Figure 4.4)**. Other signs include nests, gnawings, food scraps, rat hair, urine spots, and rat body odors. Note that waste droppings from rodents are often confused with cockroach egg packets, which are smooth, segmented, and considerably smaller than a mouse dropping.

According to the *Military Pest Management Handbook (MPMH)* **[2]**, rats and mice are very suspicious of any new objects or food found in their surroundings. This characteristic is one reason rodents can survive in dangerous environments. This avoidance reaction accounts for prebaiting (baiting without poisoning) in control programs. Initially, rats or mice begin by taking only small amounts of food. If the animal becomes ill from a sublethal dose of poison, its avoidance reaction is strengthened, and a poisoning program becomes extremely difficult to complete. If rodents are hungry or exposed to an environment where new objects and food are commonly found, such as a dump, their avoidance reaction may not be as strong; in extreme cases of hunger, it may even be absent.

The first of four basic strategies for controlling rodents is to **eliminate food sources**. To accomplish this, it is imperative for the homeowner or occupant to do a good job of solid waste management. This requires proper storing, collecting, and disposing of refuse.

The second strategy is to **eliminate breeding and nesting places**. This is accomplished by removing rubbish from near the home, including excess lumber, firewood, and similar materials. These items should be stored above ground with 18 inches of clearance below them. This height does not provide a habitat for rats, which have a propensity for dark, moist places in which to burrow. Wood should not be stored directly on the ground, and trash and similar rubbish should be eliminated.

The third strategy is to **construct buildings and other structures using rat-proofing methods**. *MPMH* notes that it is much easier to manage rodents if a structure is built or modified in a way that prevents easy access by rodents. Tactics for rodent exclusion include building or covering doors and windows with metal. Rats can gnaw through wooden doors and windows in a very short time to gain entrance. All holes in a building's exterior should be sealed. Rats are capable of enlarging openings in masonry, especially if the mortar or brick is of poor quality. All openings more than ¾-inch wide should be closed, especially around pipes and conduits. Cracks around doors, gratings, windows, and other such openings should be covered if they are less than 4 feet above the ground or accessible from ledges, pipes, or wires **(Figure 4.5)**.

Additional tactics include using proper materials for rat proofing. For example, sheet metal of at least 26-gauge, ¼ inch or ½-inch hardware cloth, and cement are all suitable rat-resistant materials. However, ½-inch hardware cloth has little value against house mice. Tight fittings and self-closing doors should be constructed. Rodent runways can be behind double walls; therefore, spaces between walls and floor-supporting beams should be blocked with fire stops. A proper rodent-proofing strategy must bear in mind that rats can routinely jump 2 feet vertically, dig 4 feet or more to get under a foundation, climb rough walls or smooth pipes up to 3 inches in diameter, and routinely travel on electric or telephone wires.

The first three strategies—good sanitation techniques, habitat denial, and rat proofing—should be used initially in any rodent management program. Should they fail, the fourth strategy is **a killing program**, which can vary from a family cat to the professional application of rodenticides. Cats can be effective against mice, but typically are not useful against a rat infestation. Over-the-counter rodenticides can be purchased and used by the homeowner or occupant. These typically are in the red squill or warfarin groups.

A more effective alternative is **trapping**. There is a variety of devices to choose from when trapping rats or mice. The two main groups of rat and mouse traps are live traps **(Figure 4.6)** and kill traps **(Figure 4.7)**. Traps usually are placed along walls, near runways and burrows, and in other areas. Bait is often used to attract the rodents to the trap. To be effective, traps must be monitored and emptied or removed quickly. If a rat caught in a trap is left there, other rats may avoid the traps. A trapping strategy also may include using live traps to remove these vermin.

Cockroaches

Cockroaches have become well adapted to living with and near humans, and their hardiness is legendary. In light of these facts, cockroach control may become a homeowner's most difficult task because of the time and special knowledge it often involves. The cockroach is considered an allergen source and an asthma trigger for residents. Although little evidence exists to link the cockroach to specific disease outbreaks, it has been demonstrated to carry *Salmonella typhimurium, Entamoeba histolytica*, and the poliomyelitis virus. In addition, Kamble and Keith [6] note that most cockroaches produce a repulsive odor that can be detected in infested areas. The sight of cockroaches can cause considerable psychologic or emotional distress in some individuals. They do not bite, but they do have heavy leg spines that may scratch.

According to *MPMH* [2], there are 55 species of cockroaches in the United States. As a group, they tend to prefer a moist, warm habitat because most are tropical in origin. Although some tropical cockroaches feed only on vegetation, cockroaches of public health interest tend to live in structures and are customarily scavengers. Cockroaches will eat a great variety of materials, including cheese and bakery products, but they are especially fond of starchy materials, sweet substances, and meat products.

Cockroaches are primarily nocturnal. Daytime sightings may indicate potentially heavy infestations. They tend to hide in cracks and crevices and can move freely from room to room or adjoining housing units via wall spaces, plumbing, and other utility installations. Entry into homes is often accomplished through food and beverage boxes, grocery sacks, animal food, and household goods carried into the home. The species of public health interest that commonly inhabit human dwellings **(Figures 4.8, 4.9, 4.10, 4.11, 4.12, 4.13)** include the following: German cockroach (*Blattella germanica*); American cockroach (*Periplaneta americana*); Oriental cockroach (*Blatta orientalis*); brown-banded cockroach (*Supella longipalpa)*; Australian cockroach (*Periplaneta australasiae*); smoky-brown cockroach (*Periplaneta fuliginosa*); and brown cockroach (*Periplaneta brunnea*).

Four management strategies exist for controlling cockroaches. The first is **prevention**. This strategy includes inspecting items being carried into the home and sealing cracks and crevices in kitchens, bathrooms, exterior doors, and windows. Structural modifications would include weather stripping and pipe collars. The second strategy is **sanitation**. This denies cockroaches food, water, and shelter. These efforts include quickly cleaning food particles from shelving and floors; timely washing of dinnerware; and routine cleaning under refrigerators, stoves, furniture, and similar areas. If pets are fed indoors, pet food should be stored in tight containers and not left in bowls overnight. Litter boxes should be cleaned routinely. Access should be denied to water sources by fixing leaking plumbing, drains, sink traps, and aquaria. Elimination of shelter can be partially accomplished by purging clutter, such as papers and soiled clothing and rags. The third strategy is **trapping**. Commercially available cockroach traps can be used to capture roaches and serve as a monitoring device. The most effective trap placement is against vertical surfaces, primarily corners, and under sinks, in cabinets, basements, and floor drains. The fourth strategy is **chemical control**. The use of chemicals typically indicates that the other three strategies have been applied incorrectly. Numerous insecticides are available and appropriate information is obtainable from EPA.

Fleas

The most important fleas as disease vectors are those that carry murine typhus and bubonic plague. In addition, fleas serve as intermediate hosts for some species of dog and rodent tapeworms that occasionally infest people. They also may act as intermediate hosts of filarial worms (heartworms) in dogs. In the United States, the most important disease related to fleas is the bubonic plague. This is primarily a concern of residents in the southwestern and western parts of the country **(Figure 4.14)**.

Of approximately 2,000 species of flea, the most common flea infesting both dogs and cats is the cat flea *Ctenocephalides felis*. Although numerous animals, both wild and domestic, can have flea infestations, it is from the exposure of domestic dogs and cats that most homeowners inherit flea infestation problems. According to *MPMH*, **[2]** fleas are wingless insects varying from 1 to 8½ millimeters long, averaging 2 to 4 millimeters, and feed through a siphon or tube. They are narrow and compressed laterally with backwardly directed spines, which adapt them for moving between the hairs and feathers of mammals and birds. They have long, powerful legs adapted for jumping. Both sexes feed on blood, and the female requires a blood meal before she can produce viable eggs. Fleas tend to be host-specific, thus feeding on only one type of host. However, they will infest other species in the absence of the favored host. They are found in relative abundance on animals that live in burrows and sheltered nests, while mammals and birds with no permanent nests or that are exposed to the elements tend to have light infestations.

MPMH **[2]**, notes that fleas undergo complete metamorphosis (egg, larva, pupa, and adult). The time it takes to complete the life cycle from egg to adult varies according to the species, temperature, humidity, and food availability. Under favorable conditions, some species can complete a generation in as little as 2 or 3 weeks. **Figure 4.15** shows the life cycle of the flea.

Flea eggs usually are laid singly or in small groups among the feathers or hairs of the host or in a nest. They are often laid in carpets of living quarters if the primary host is a household pet. Eggs are smooth, spherical to oval, light colored, and large enough to be seen with the naked eye. An adult female flea can produce up to 2,000 eggs in a lifetime. Flea larvae are small (2 to 5 millimeters), white, and wormlike with a darker head and a body that will appear brown if they have fed on flea feces. This stage is mobile and will move away from light, thus they typically will be found in shaded areas or under furniture. In 5 to 12 days, they complete the three larval stages; however, this may take several months depending on environmental conditions. The larvae, after completing development, spin a cocoon of silk encrusted with granules of sand or various types of debris to form the pupal stage. The pupal stage can be dormant for 140 to 170 days. In some areas of the country, fleas can actually survive through the winter. The pupae, after development, are stimulated to emerge as adults by movement, pressure, or heat. The pupal form of the flea is resistant to insecticides. An initial treatment, while killing egg, larvae, and adult forms, will not kill the pupae. Therefore, a reapplication will often be necessary. The adult forms are usually ready to feed about 24 hours after they emerge from the cocoon and will begin to feed within 10 seconds of landing on a host. Mating usually follows the initial blood meal, and egg production is initiated 24 to 48 hours after consuming a blood meal. The adult flea lives approximately 100 days, depending on environmental conditions.

Following are some guidelines for controlling fleas:

- The most important principle in a total flea control program is simultaneously treating all pets and their environments (indoor and outdoor).
- Before using insecticides, thoroughly clean the environment, removing as many fleas as possible, regardless of the form. This would include indoor vacuuming and carpet steam cleaning. Special attention should be paid to "source points" where pets spend most of their time.
- Outdoor cleanup should include mowing, yard raking, and removing organic debris from flowerbeds and under bushes.
- Insecticide should be applied to the indoor and outdoor environments and to the pet.
- Reapplication to heavily infested source points in the home and the yard may be needed to eliminate pre-emerged adults.

Flies

The historical attitude of Western society toward flies has been one of aesthetic disdain. The public health view is to classify flies as biting or nonbiting. Biting flies include sand flies, horseflies, and deerflies. Nonbiting flies include houseflies, bottleflies, and screwworm flies. The latter group is often referred to as synanthropic because of their close association with humans. In general, the presence of flies is a sign of poor sanitation. The primary concern of most homeowners is nonbiting flies.

According to *MPMH* **[2]**,the housefly (*Musca domestica*) **(Figure 4.16)** is one of the most widely distributed insects, occurring throughout the United States, and is usually the predominant fly species in homes and restaurants. *M. domestica* is also the most prominent human-associated (synanthropic) fly in the southern United States. Because of its close association with people, its abundance, and its ability to transmit disease, it is considered a greater threat to human welfare than any other species of nonbiting fly. Each housefly can easily carry more than 1 million bacteria on its body. Some of the disease-causing agents transmitted by houseflies to humans are *Shigella spp*. (dysentery and diarrhea = shigellosis), *Salmonella spp*. (typhoid fever), *Escherichia coli*, (traveler's diarrhea), and *Vibrio cholera* (cholera). Sometimes these organisms are carried on the fly's tarsi or body hairs, and frequently they are regurgitated onto food when the fly attempts to liquefy it for ingestion.

The fly life cycle is similar across the synanthropic group. *MPMH* [2] notes that the egg and larval stages develop in animal and vegetable refuse. Favorite breeding sites include garbage, animal manure, spilled animal feed, and soil contaminated with organic matter. Favorable environmental conditions will result in the eggs hatching in 24 hours or less. Normally, a female fly will produce 500 to 600 eggs during her lifetime.

The creamy, white larvae (maggots) are about ½-inch long when mature and move within the breeding material to maintain optimum temperature and moisture conditions. This stage lasts an average of 4 to 7 days in warm weather.

The larvae move to dry parts of the breeding medium or move out of it onto the soil or sheltered places under debris to pupate, with this stage usually lasting 4 to 5 days. When the pupal stage is accomplished, the adult fly exits the puparium, dries, hardens, and flies away to feed, with mating occurring soon after emergence. Figure 4.17 demonstrates the typical fly life cycle.

The control of the housefly is hinged on good sanitation (denying food sources and breeding sites to the fly). This includes the proper disposal of food wastes by placing garbage in cans with close-fitting lids. Cans need to be periodically washed and cleaned to remove food debris. The disposal of garbage in properly operated sanitary landfills is paramount to fly control.

The presence of adult flies can be addressed in various ways. Outside methods include limited placement of common mercury vapor lamps that tend to attract flies. Less-attractive sodium vapor lamps should be used near the home. Self-closing doors in the home will deny entrance, as will the use of proper-fitting and well-maintained screening on doors and windows.

Larger flies use homes for shelter from the cold, but do not reproduce inside the home. Caulking entry points and using fly swatters is effective and much safer than the use of most pesticides. Insecticide “bombs” can be used in attics and other rooms that can be isolated from the rest of the house. However, these should be applied to areas away from food, where flies rest.

The blowfly is a fairly large, metallic green, gray, blue, bronze, or black fly. They may spend the winter in homes or other protected sites, but will not reproduce during this time. Blowflies breed most commonly on decayed carcasses (e.g., dead squirrels, rodents, birds) and in droppings of dogs or other pets during the summer; thus, removal of these sources is imperative. Small animals, on occasion, may die inside walls or under the crawl space of a house. A week or two later, blowflies or maggots may appear. The adult blowfly is also attracted to gas leaks.

Termites

According to Gold et al. [11], subterranean termites are the most destructive insect pests of wood in the United States, causing more than $2 billion in damage each year. Annually, this is more property damage than that caused by fire and windstorms combined. In the natural world, these insects are beneficial because they break down dead trees and other wood materials that would otherwise accumulate. This biomass breakdown is recycled to the soil as humus. *MPMH* [2], on the other hand, notes that these insects can damage a building so severely it may have to be replaced. Termites consume wood and other cellulose products, such as paper, cardboard, and fiberboard. They will also destroy structural timbers, pallets, crates, furniture, and other wood products. In addition, they will damage many materials they do not normally eat as they search for food. The tunneling efforts of subterranean termites can penetrate lead- and plastic-covered electric cable and cause electrical system failure. In nature, termites may live for years in tree stumps or lumber beneath concrete buildings before they penetrate hairline cracks in floors and walls, as well as expansion joints, to search for food in areas such as interior door frames and immobile furniture. Termite management costs to homeowners are exceeded only by cockroach control costs.

Lyon [12] notes that termites are frequently mistaken by the homeowner as ants and often are referred to erroneously as white ants. Typical signs of termite infestations occur in March through June and in September and October. Swarming is an event where a group of adult males and female reproductives leave the nest to establish a new colony. If the emergence happens inside a building, flying termites may constitute a considerable nuisance. These pests can be collected with a vacuum cleaner or otherwise disposed of without using pesticides. Each homeowner should be aware of the following signs of termite infestation:

- Pencil-thin mud tubes extending over the inside and outside surfaces of foundation walls, piers, sills, joists, and similar areas **(Figures 4.18** and **4.19)**.
- Presence of winged termites or their shed wings on windowsills and along the edges of floors.
- Damaged wood hollowed out along the grain and lined with bits of mud or soil.

According to Oi et al. [15], termite tubes and nests are made of mud and carton. Carton is composed of partially chewed wood, feces, and soil packed together. Tubes maintain the high humidity required for survival, protect termites from predators, and allow termites to move from one spot to another.

Differentiating the ant from the dark brown or black termite reproductives can be accomplished by noting the respective wings and body shape. *MPMH* [2] states that a termite has four wings of about equal length and that the wings are nearly twice as long as the body. By comparison, ant wings that are only a little longer than the body and the hind pair is much shorter than the front. Additionally, ants typically have a narrow waist, with the abdomen connected to the thorax by a thin petiole. Termites do not have a narrow or pinched waist. **Figure 4.20** demonstrates the differences between the ant (A) and termite (B). Entomologists refer to winged ants and termites as alates.

Figure 4.21 shows the life cycle of the termite. In each colony, there are three castes or forms of individuals known as reproductives, workers, and soldiers. According to Lyon **[12]**, the reproductives can be winged or wingless, with the latter found in colonies to serve as replacements for the primary reproductives. The primary reproductives (alates) vary in color from pale yellow-brown to coal black, are ½-inch to ⅜-inch in length, are flattened dorsa-ventrally, and have pale or smoke-gray to brown wings. The secondary reproductives have short wing buds and are white to cream colored. The workers are the same size as the primary reproductives and are white to grayish-white, with a yellow-brown head, and are wingless. In addition, the soldiers resemble workers, in that they are wingless, but soldiers have large, rectangular, yellowish, and brown heads with large jaws.

MPMH **[2]** states there are five families of termites found in the world, with four of them occurring in the United States. The families in the United States are *Hodotermitidae* (rotten-wood termites), *Kalotermitidae* (dry-wood termites), *Rhinotermitidae* (subterranean termites) and *Termitidae* (desert termites). Subterranean termites typically work in wood aboveground, but must have direct contact with the ground to obtain moisture. Nonsubterranean termites colonize above the ground and feed on cellulose; however, their life cycles and methods of attack, and consequently methods of control, are quite different. Nonsubterranean termites in the United States are commonly called drywood termites.

In the United States, according to *MPMH* **[2]**, native subterranean termites are the most important and the most common. These termites include the genus *Reticulitermes*, occurring primarily in the continental United States, and the genus *Heterotermes*, occurring in the Virgin Islands, Puerto Rico, and the deserts of California and Arizona. The appearance, habits, and type of damage they cause are similar. The Formosan termite (*Coptotermes formosanus*) is the newest species to become established in the United States. It is a native of the Pacific Islands and spread from Hawaii and Asia to the United States during the 1960s. It is now found along the Gulf Coast, in California, and in South Carolina, and is expected to spread to other areas as well. Formosan termites cause greater damage than do native species because of their more vigorous and aggressive behavior and their ability to rapidly reproduce, build tubes and tunnels, and seek out new items to infest. They have also shown more resistance to some soil pesticides than native species. Reproductives (swarmers) are larger than native species, reaching up to ⅝-inch in length, and are yellow to brown in color. Swarmers have hairy-looking wings and swarm after dusk, unlike native species, which swarm in the daytime. Formosan soldiers have more oval-shaped heads than do native species. On top of the head is an opening that emits a sticky, whitish substance.

Dry-wood termites (*Cryptotermes spp.*) live entirely in moderately to extremely dry wood. They require contact with neither the soil nor any other moisture source and may invade isolated pieces of furniture, fence posts, utility poles, firewood, and structures. Dry-wood termite colonies are not as large as other species in the United States, so they can occupy small wooden articles, which are one way these insects spread to different locations. They are of major economic importance in southern California, Arizona, and along the Gulf Coast. The West Indian dry-wood termite is a problem in Puerto Rico, the U.S. Virgin Islands, Hawaii, parts of Florida and Louisiana, and a number of U.S. Pacific Island territories. Dry-wood termites are slightly larger than most other species, ranging from ½ inch to ⅝ inch long, and are generally lighter in color.

Damp-wood termites do not need contact with damp ground like subterranean termites do, but they do require higher moisture content in wood. However, once established, these termites may extend into slightly drier wood.

Termites of minor importance are the tree-nesting groups. The nests of these termites are found in trees, posts, and, occasionally, buildings. Their aboveground nests are connected to soil by tubes. Tree-nesting termites may be a problem in Puerto Rico and the U.S. Virgin Islands.

The risk for encountering subterranean termites in the United States is greater in the southeastern states and in southwestern California. In the United States, the risk for termite infestations tends to decrease as the latitude increases northward.

Figure 4.22 portrays the geographic risk of subterranean termites in the United States. Subterranean termites are found in all states except Alaska and are most abundant in the south and southeastern United States **[18]**.

According to Potter **[19]**, homeowners can reduce the risk for termite attack by adhering to the following suggestions:

- **Eliminate wood contact with the ground.** Earth-to-wood contact provides termites with simultaneous access to food, moisture, and shelter in conjunction with direct, hidden entry into the structure. In addition, the homeowner or occupant should be aware that pressure-treated wood is not immune to termite attack because termites can enter through the cut ends and build tunnels over the surfaces.

- **Do not allow moisture to accumulate near the home's foundation.** Proper drainage, repair of plumbing, and proper grading will help to reduce the presence of moisture, which attracts termites.
- **Reduce humidity in crawl spaces**. Most building codes state that crawl space area should be vented at a rate of 1 square foot per 150 square feet of crawl space area. This rate can be reduced for crawl spaces equipped with a polyethylene or equivalent vapor barrier to 1 square foot per 300 to 500 square feet of crawl space area. Vent placement design includes positioning one vent within 3 feet of each building corner. Trimming and controlling shrubs so that they do not obstruct the vents is imperative. Installling a 4- to 6-mil polyethylene sheeting over a minimum of 75% of the crawl space will reduce the crawl-space moisture. Covering the entire floor of the crawl space with such material can reduce two potential home problems at one time: excess moisture and radon (Chapter 5). The barrier will reduce the absorption of moisture from the air and the release of moisture into the air in the crawl space from the underlying soil.
- **Never store firewood, lumber, or other wood debris against the foundation or inside the crawl space.** Termites are both attracted to and fed by this type of storage. Wood stacked in contact with a dwelling and vines, trellises, and dense plant material provide a pathway for termites to bypass soil barrier treatment.
- **Use decorative wood chips and mulch sparingly.** Cellulose-containing products attract termites, especially materials that have moisture-holding properties, such as mulch. The homeowner should never allow these products to contact wood components of the home. The use of crushed stone or pea gravel is recommended as being less attractive to termites and helpful in diminishing other pest problems.
- **Have the structure treated by a professional pest control treatment.** The final, and most effective, strategy to prevent infestation is to treat the soil around and beneath the building with termiticide. The treated ground is then both a repellant and toxic to termites.

Figure 4.23 demonstrates some typical points of attack by subterranean termites and some faulty construction practices that can contribute to subterranean termite infestations. Click here for the key to Figure 4.23.

Lyon [12] notes the following alternative termite control measures:

- **Nematodes:** Certain species of parasitic round worms (nematodes) will infest and kill termites and other soil insects. Varying success has been experienced with this method because it is dependent on several variables, such as soil moisture and soil type.
- **Sand as a physical barrier:** This would require preconstruction planning and would depend on termites being unable to manipulate the sand to create tunnels. Some research in California and Hawaii has indicated early success.
- **Chemical Baits:** This method uses wood or laminated texture-flavored cellulose impregnated with a toxicant and/or insect growth regulator. The worker termite feeds on the substance and carries it back to the nest, reducing or eliminating the entire colony. According to HomeReports.com (http://www.homereports.com), [20] an additional system is to strategically place a series of baits around the house. The intention is for termite colonies to encounter one or more of the baits before approaching the house. Once termite activity is observed, the bait wood is replaced with a poison. The termites bring the poison back to the colony and the colony is either eliminated or substantially reduced. This system is relatively new to the market. Its success depends heavily on the termites finding the bait before finding and damaging the house.

Additional measures include construction techniques that discourage termite attacks, as demonstrated in **Figure 4.24**. Termites often invade homes by way of the foundation, either by crawling up the exterior surface where their activity is usually obvious or by traveling inside hollow block masonry. One way to deter their activity is to block their access points on or through the foundation. Metal termite shields have been used for decades to deter termite movement along foundation walls and piers on up to the wooden structure. Metal termite shields should extend 2 inches from the foundation and 2 inches down. Improperly installed (i.e., not soldered/sealed properly), damaged, or deteriorated termite shields may allow termites to reach parts of the wooden floor system. Shields should be made of noncorroding metal and have no cracks or gaps along the seams. If a house is being built with metal termite shielding, the shielding should extend at least 2 inches out and 2 inches down at a 45° angle from the foundation wall. An alternative to using termite shields on a hollow-block foundation is to fill the block with concrete or put in a few courses of solid or concrete-filled brick (which is often done anyway to level foundations). These are referred to as masonry caps. The same approach can be used with support piers in the crawl space. Solid caps (i.e., a continuously poured concrete cap) are best at stopping termites, but are not commonly used. Concrete-filled brick caps should deter termite movement or force them through small gaps, thus allowing them to be spotted during an inspection [21].

Fire Ants

According to *MPMH* **[2]**, ants are one of the most numerous species on earth. Ants are in the same order as wasps and bees and, because of their geographic distribution, they are universally recognized **(Figure 4.25)**.

The life cycle of the fire ant begins with the mating of the winged forms (alates) some 300 to 800 feet in the air, typically occurring in the late spring or early summer. The male dies after the mating; and the newly mated queen finds a suitable moist site, drops her wings, and burrows in the soil, sealing the opening behind her. Ants undergo complete metamorphosis and, therefore, have egg, larval, pupal and adult stages. The new queen will begin laying eggs within 24 hours. Once fully developed, she will produce approximately 1,600 eggs per day over a maximum life span of 7 years. Soft, whitish, legless larvae are produced from the hatching. These larvae are fed by the worker ants. Pupae resemble adults in form, but are soft, nonpigmented, and lack mobility. There are at least three distinct castes of ants: workers, queens, and males. Typically, the males have wings, which they retain until death. Queens, the largest of the three castes, normally have wings, but lose them after mating. The worker, which is also a female, is never winged, except as a rare abnormality. Within this hierarchy, mature colonies contain males and females that are capable of flight and reproduction. These are known as "reproductives," and an average colony may produce approximately 4,500 of these per year. A healthy nest usually produces two nuptial flights of reproductives each year and a healthy, mature colony may contain more than 250,000 ants. Though uncommon among ants, multiple queen colonies (10 to 100) occur somewhat frequently in fire ants, resulting in more numerous mounds per acre.

There are many species of fire ants in the United States. The most important are four species in the genus *Solenopsis*. Of these, the number one fire ant pest is the red imported fire ant (RIFA) *Solenopsis invicta* **(Figure 4.25)**. This ant was imported inadvertently from South America in the 1930s through the port of Mobile, Alabama. RIFAs are now found in more than 275 million acres in 11 southern states and Puerto Rico. The second most important species is the black imported fire ant, *S. richteri*, which was introduced into the United States in the 1920s from Argentina or Uruguay. It is currently limited in distribution to a small area of northern Mississippi and Alabama. There are two native species of fire ants: the tropical or native fire ant, *S. geminata*, ranging from South Carolina to Florida and west to

Texas; and the Southern fire ant, *S. xyloni*, which occurs from North Carolina south to northern Florida, along the Gulf Coast, and west to California. The most important extension of the RIFA range is thought to have occurred during the 1950s housing boom as a result of the transportation of sod and nursery plants **(Figure 4.26)**.

RIFAs prefer open and sun-exposed areas. They are found in cultivated fields, cemeteries, parks, and yards, and even inside cars, trucks, and recreational vehicles. RIFAs are attracted to electrical currents and are known to nest in and around heat pumps, junction boxes, and similar areas. They are omnivorous; thus they will attack most things, living or dead. Their economic effects are felt by their destruction of the seeds, fruit, shoots, and seedlings of numerous native plant species. Fire ants are known to "tend" pests, such as scale insects, mealy bugs, and aphids, for feeding on their sweet waste excretion (honeydew). RIFAs transport these insects to new feeding sites and protect them from predators. The positive side of RIFA infestation is that the fire ant is a predator of ticks and controls the ground stage of horn flies.

The urban dweller with a RIFA infestation may find significant damage to landscape plants, with reductions in the number of wild birds and mammals. RIFAs can discourage outdoor activities and be a threat to young animals or small confined pets. RIFA nests typically are not found indoors, but around homes, roadways, and structures, as well as under sidewalks. Shifting of soil after RIFAs abandon sites has resulted in collapsing structures. **Figure 4.27** shows a fire ant mound with fire ants and a measure of their relative size.

The medical complications of fire ant stings have been noted in the literature since 1957. People with disabilities, reduced feeling in their feet and legs, young children, and those with mobility issues are at risk for sustaining numerous stings before escaping or receiving assistance. Fatalities have resulted from attacks on the elderly and on infants.

Control of the fire ant is primarily focused on the mound by using attractant bait consisting of soybean oil, corn grits, or chemical agents. The bait is picked up by the worker ants and taken deep into the mound to the queen. These products typically require weeks to work.

Individual mound treatment is usually most effective in the spring. The key is to locate and treat all mounds in the area to be protected. If young mounds are missed, the area can become reinfested in less than a year.

Mosquitoes

All mosquitoes have four stages of development—egg, larva, pupa, and adult—and spend their larval and pupal stages in water. The females of some mosquito species deposit eggs on moist surfaces, such as mud or fallen leaves, that may be near water but dry. Later, rain or high tides reflood these surfaces and stimulate the eggs to hatch into larvae. The females of other species deposit their eggs directly on the surface of still water in such places as ditches, street catch basins, tire tracks, streams that are drying up, and fields or excavations that hold water for some time. This water is often stagnant and close to the home in discarded tires, ornamental pools, unused wading and swimming pools, tin cans, bird baths, plant saucers, and even gutters and flat roofs. The eggs soon hatch into larvae. In the hot summer months, larvae grow rapidly, become pupae, and emerge 1 week later as flying adult mosquitoes. A few important spring species have only one generation per year. However, most species have many generations per year, and their rapid increase in numbers becomes a problem.

When adult mosquitoes emerge from the aquatic stages, they mate, and the female seeks a blood meal to obtain the protein necessary for the development of her eggs. The females of a few species may produce a first batch of eggs without this first blood meal. After a blood meal is digested and the eggs are laid, the female mosquito again seeks a blood meal to produce a second batch of eggs. Depending on her stamina and the weather, she may repeat this process many times without mating again. The male mosquito does not take a blood meal, but may feed on plant nectar. He lives for only a short time after mating. Most mosquito species survive the winter, or overwinter, in the egg stage, awaiting the spring thaw, when waters warm and the eggs hatch. A few important species spend the winter as adult, mated females, resting in protected, cool locations, such as cellars, sewers, crawl spaces, and well pits. With warm spring days, these females seek a blood meal and begin the cycle again. Only a few species can overwinter as larvae.

Mosquitoborne diseases, such as malaria and yellow fever, have plagued civilization for thousands of years. New threats include Lyme disease and West Nile Virus. Organized mosquito control in the United States has greatly reduced the incidence of these diseases. However, mosquitoes can still transmit a few diseases, including eastern equine encephalitis and St. Louis encephalitis. The frequency and extent of these diseases depend on a complex series of factors. Mosquito control agencies and health departments cooperate in being aware of these factors and reducing the chance for disease. It is important to recognize that young adult female mosquitoes taking their first blood meal do not transmit diseases. It is instead the older females, who, if they have picked up a disease organism in their first blood meals, can then transmit the disease during the second blood meal.

The proper method to manage the mosquito problem in a community is through an organized integrated pest management system that includes all approaches that safely manage the problem. The spraying of toxic agents is but one of many approaches.

When mosquitoes are numerous and interfere with living, recreation, and work, you can use the various measures described in the following paragraphs to reduce their annoyance, depending on location and conditions.

How to Reduce the Mosquito Population

The most efficient method of controlling mosquitoes is by reducing the availability of water suitable for larval and pupal growth. Large lakes, ponds, and streams that have waves, contain mosquito-eating fish, and lack aquatic vegetation around their edges do not contain mosquitoes; mosquitoes thrive in smaller bodies of water in protected places. Examine your home and neighborhood and take the following precautions recommended by the New Jersey Agricultural Experiment Station **[24]**:

- dispose of unwanted tin cans and tires;
- clean clogged roof gutters and drain flat roofs;
- turn over unused wading pools and other containers that tend to collect rainwater;
- change water in birdbaths, fountains, and troughs twice a week;
- clean and chlorinate swimming pools;
- cover containers tightly with window screen or plastic when storing rainwater for garden use during drought periods;
- flush sump-pump pits weekly; and
- stock ornamental pools with fish.

If mosquito breeding is extensive in areas such as woodland pools or roadside ditches, the problem may be too great for individual residents. In such cases, call the organized mosquito control agency in your area. These agencies have highly trained personnel who can deal with the problem effectively.

Several commercially available insecticides can be effective in controlling larval and adult mosquitoes. These chemicals are considered sufficiently safe for use by the public. Select a product whose label states that the material is effective against mosquito larvae or adults. For safe and effective use, read the label and follow the instructions for applying the material. The label lists those insects that the EPA agrees are effectively controlled by the product.

For use against adult mosquitoes, some liquid insecticides can be mixed according to direction and sprayed lightly on building foundations, hedges, low shrubbery, ground covers, and grasses. Do not overapply liquid insecticides—excess spray dips from the sprayed surfaces to the ground, where it is ineffective. The purpose of such sprays is to leave a fine deposit of insecticide on surfaces where mosquitoes rest. Such sprays are not effective for more than 1 or 2 days.

Some insecticides are available as premixed products or aerosol cans. These devices spray the insecticide as very small aerosol droplets that remain floating in the air and hit the flying mosquitoes. Apply the sprays upwind, so the droplets drift through the area where mosquito control is desired. Rather than applying too much of these aerosols initially, it is more practical to apply them briefly but periodically, thereby eliminating those mosquitoes that recently flew into the area.

Various commercially available repellents can be purchased as a cream or lotion or in pressurized cans, then applied to the skin and clothing. Some manufacturers also offer clothing impregnated with repellents; coarse, repellent-bearing particles to be scattered on the ground; and candles whose wicks can be lit to release a repellent chemical. The effectiveness of all repellents varies from location to location, from person to person, and from mosquito to mosquito. Repellents can be especially effective in recreation areas, where mosquito control may not be conducted. All repellents should be used according to the manufacturers' instructions. Mosquitoes are attracted by perspiration, warmth, body odor, carbon dioxide, and light. Mosquito control agencies use some of these attractants to help determine the relative number of adult mosquitoes in an area. Several devices are sold that are supposed to attract, trap, and destroy mosquitoes and other flying insects. However, if these devices are attractive to mosquitoes, they probably attract more mosquitoes into the area and may, therefore, increase rather than decrease mosquito annoyance.

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