"The poorest man may in his cottage bid defiance to all the force of the Crown. It may be frail—its roof may shake—the wind may blow through it—the storm may enter, the rain may enter—but the King of England cannot enter—all his force dares not cross the threshold of the ruined tenement!"

William Pitt, March 1763

Introduction

William Pitt, arguing before the British Parliament against excise officers entering private homes to levy the Cyder Tax, eloquently articulated this long-held and cherished notion of the sanctity of private property. However, a person's right to privacy is not absolute. There has always been a tension between the rights of property owners to do whatever they desire with their property and the ability of the government to regulate uses to protect the safety, health, and welfare of the community. Few, however, would argue with the right and duty of a city government to prohibit the operation of a munitions factory or a chemical plant in the middle of a crowded residential neighborhood.

History

The first known housing laws are in the Code of Laws of Hammurabi [1], who was the King of Babylonia, circa 1792–1750 BC. These laws addressed the responsibility of the home builder to construct a quality home and outlined the implications to the builder if injury or harm came to the owner as a result of the failure to do so. During the Puritan period (about 1620–1690), housing laws essentially governed the behavior of the members of the society. For example, no one was allowed to live alone, so bachelors, widows, and widowers were placed with other families as servants or boarders. In 1652, Boston prohibited building privies within 12 feet of the street. Around the turn of the 18th century, some New England communities implemented local ordinances that specified the size of houses. During the 17th century, additional public policies on housing were established. Because the English tradition of using wooden chimneys and thatched roofs led to fires in many dwellings, several colonies passed regulations prohibiting them.

After the early 17th century came an era of very rapid metropolitan growth along the East Coast. This growth was due largely to immigration from Europe and was spurred by the Industrial Revolution. The most serious housing problems began in New York about 1840 when the first tenements were built. In 1867, a report by the New York Metropolitan Board of Health on living conditions in tenements convinced the New York State legislature to pass the Tenement Housing Act of 1867 [2]. The principal requirements of the act included the following:

- Every room occupied for sleeping, if it does not communicate directly with the external air, must have a ventilating or transom window of at least 3 square feet to the neighboring room or hall.
- A proper fire escape is necessary on every tenement or lodging house.
- The roof is to be kept in repair and the stairs are to have banisters.
- At least one toilet is required for every 20 occupants for all such houses, and those toilets must be connected to approved disposal systems.
- Cleansing of every lodging house is to be to the satisfaction of the Board of Health, which is to have access at any time.
- All cases of infectious disease are to be reported to the Board by the owner or his agent; buildings are to be inspected and, if necessary, disinfected or vacated if found to be out of repair.

There were also regulations governing distances between buildings, heights of rooms, and dimensions of windows. Although this act had some beneficial influences on overcrowding, sewage disposal, lighting, and ventilation, perhaps its greatest contribution was in laying a foundation for more stringent future legislation.

Jacob A. Riis, a Danish immigrant and a police reporter on New York's Lower East Side, published a book titled *How the Other Half Lives—Studies Among the Tenements of New York* [3], which swayed public opinion in the direction of housing reform and resulted in the Tenement House Act of 1901. The basic principles established in the Tenement House Act of 1901 still underlie much of the housing efforts in New York City today [4]. Since 1909, with the establishment of the Philadelphia Housing Association, that city has had almost continual inspection and improvement. Chicago enacted housing legislation as early as 1889 and health legislation as early as 1881. Regulations on ventilation, light, drainage, and plumbing were put into effect in 1896.

Before 1892, all government involvement in housing was at a local level. In 1892, however, the federal government passed a resolution authorizing investigation of slum conditions in cities with 200,000 or more inhabitants. Congress appropriated only $20,000 (roughly equal to $390,000 in 2003) to cover the expenses of this project, which limited the number of investigations.

No significant housing legislation was passed in the 20th century until 1929 [5], when the New York State legislature passed its Multiple Dwelling Law. Other cities and states followed New York's example and permitted less strict requirements in their codes. This decreased what little emphasis there was on enforcement. Conditions declined until, by the 1930s, President Franklin D. Roosevelt's shocking report to the people was "that one-third of the nation is ill-fed, ill-housed, and ill-clothed." In response to the overwhelming loss of homes during the Great Depression, Congress passed the United States Housing Act of 1937, which created the United States Housing Authority (USHA). This act subsidized construction of new public housing units and required the elimination of at least an equivalent number of units from the local housing supply that were determined to be inferior. In 1942, the USHA was renamed the Federal Public Housing Administration and, in 1947, was renamed the Public Housing Administration.

The federal government not only encouraged the construction of public housing, but took on the role of financing private housing. In 1938, the Federal National Mortgage Association was created. (Fannie Mae became a private organization in 1968 [6].) Its purpose was to provide a secondary market for the FHA, created in 1934, and Veterans Administration (VA) mortgage loans. The Servicemen's Readjustment Act of 1944, also known as the GI Bill of Rights, created a VA loan program guaranteeing home mortgage loans for veterans. This legislation, in conjunction with the FHA loan program, was the impetus for initiating the huge program of home construction and subsequent suburban growth following World War II. In 1946, the Farmers Home Administration, housed in the United States Department of Agriculture (USDA), was created to make loans and grants for constructing and repairing farm homes and assisting rural self-help housing groups.

The Housing Act of 1949 allowed "primarily residential" and "blighted" urban areas to be condemned, cleared of buildings, and sold for private development. In addition to assisting in slum clearance, this act also provided for additional public housing and authorized the USDA to provide farmers with loans to construct, improve, repair or replace dwellings to provide decent, safe, and sanitary living conditions for themselves, their tenants, lessees, sharecroppers, and laborers.

Because the many housing responsibilities administered by various agencies within the federal government proved unwieldy, the Housing and Urban Development Act was passed in 1965. The U.S. Department of Housing and Urban Development (HUD) was created to centralize the responsibilities of the Housing and Home Finance Agency and incorporated the FHA, the Federal National Mortgage Association, the Public Housing Administration, Urban Development Administration, and the Community Facilities Administration.

Zoning, Housing Codes, and Building Codes

Housing is inextricably linked to the land on which it is located. Changes in the patterns of land use in the United States, shifting demographics, an awareness of the need for environmental stewardship, and competing uses for increasingly scarce (desirable) land have all placed added stress on the traditional relationship between the property owner and the community. This is certainly not a new development.

In the early settlement of this country, following the precedent set by their forefathers from Great Britain, gunpowder mills and storehouses were prohibited from the heavily populated portions of towns, owing to the frequent fires and explosions. Later, zoning took the form of fire districts and, under implied legislative powers, wooden buildings were prohibited from certain sections of a municipality. Massachusetts passed one of the first zoning laws in 1692. This law authorized Boston, Salem, Charlestown, and certain other market towns in the province to restrict the establishment of slaughterhouses and stillhouses for currying leather to certain locations in each town.

Few people objected to such restrictions. Still, the tension remained between the right to use one's land and the community's right to protect its citizens. In 1926, the United States Supreme Court took up the issue in Village of Euclid, Ohio, v. Ambler Realty [7]. In this decision, the Court noted,

> *"Until recent years, urban life was comparatively simple; but with great increase and concentration of population, problems have developed which require additional restrictions in respect of the use and occupation of private lands in urban communities."*

In explaining its reasoning, the Court said,

> *"the law of nuisances may be consulted not for the purpose of controlling, but for the helpful aid of its analogies in the process of ascertaining the scope of the police power. Thus the question of whether the power exists to forbid the erection of a building of a particular kind or a particular use is to be determined, not by an abstract consideration of the building or other thing considered apart, but by considering it in connection with the circumstances and the locality… A nuisance may be merely the right thing in the wrong place—like a pig in the parlor instead of the barnyard."*

Zoning, housing, and building codes were adopted to improve the health and safety of people living in communities. And, to some extent, they have performed this function. Certainly, housing and building codes, when enforced, have resulted in better constructed and maintained buildings. Zoning codes have been effective in segregating noxious and dangerous enterprises from residential areas. However, as the U.S. population has grown and changed from a rural to an urban then to a suburban society, land use and building regulations developed for the 19th and early 20th centuries are creating new health and safety problems not envisioned in earlier times.

Zoning and Zoning Ordinances

Zoning is essentially a means of ensuring that a community's land uses are compatible with the health, safety, and general welfare of the community. Experience has shown that some types of controls are needed to provide orderly growth in relation to the community plan for development. Just as a capital improvement program governs public improvements such as streets, parks and other recreational facilities, schools, and public buildings, so zoning governs the planning program with respect to the use of public and private property.

It is very important that housing inspectors know the general nature of zoning regulations because properties in violation of both the housing code and the zoning ordinance must be brought into full compliance with the zoning ordinance before the housing code can be enforced. In many cases, the housing inspector may be able to eliminate violations or properties in violation of housing codes through enforcement of the zoning ordinance.

Zoning Objectives

As stated earlier, the purpose of a zoning ordinance is to ensure that the land uses within a community are regulated not only for the health, safety, and welfare of the community, but also are in keeping with the comprehensive plan for community development. The provisions in a zoning ordinance that help to achieve development that provides for health, safety, and welfare are designed to do the following:

- Regulate height, bulk, and area of structure. To provide established standards for healthful housing within the community, regulations dealing with building heights, lot coverage, and floor areas must be established. These regulations then ensure that adequate natural lighting, ventilation, privacy, and recreational areas for children will be realized. These are all fundamental physiologic needs necessary for a healthful environment. Safety from fires is enhanced by separating buildings to meet yard and open-space requirements. Through requiring a minimum lot area per dwelling unit, population density controls are established.
- Avoid undue levels of noise, vibration, glare, air pollution, and odor. By providing land-use category districts, these environmental stresses upon the individual can be reduced.
- Lessen street congestion by requiring off-street parking and off-street loading.
- Facilitate adequate provision of water, sewerage, schools, parks, and playgrounds.
- Provide safety from flooding.
- Conserve property values. Through careful enforcement of the zoning ordinance provisions, property values can be stabilized and conserved.

To understand more fully the difference between zoning and subdivision regulations, building codes, and housing ordinances, the housing inspector must know what cannot be accomplished by a zoning ordinance. Items that cannot be accomplished by a zoning ordinance include the following:

- Overcrowding or substandard housing. Zoning is not retroactive and cannot correct existing conditions. These are corrected through enforcement of a minimum standards housing code.
- Materials and methods of construction. Materials and methods of construction are enforced through building codes rather than through zoning.

- Cost of construction. Quality of construction, and hence construction costs, are often regulated through deed restrictions or covenants. Zoning does, however, stabilize property values in an area by prohibiting incompatible development, such as heavy industry in the midst of a well-established subdivision.
- Subdivision design and layout. Design and layout of subdivisions, as well as provisions for parks and streets, are controlled through subdivision regulations.

Content of the Zoning Ordinance

Zoning ordinances establish districts of whatever size, shape, and number the municipality deems best for carrying out the purposes of the zoning ordinance. Most cities use three major districts: residential (R), commercial (C), and industrial (I). These three may then be subdivided into many subdistricts, depending on local conditions; e.g., R-1 (single-unit dwellings), R-2 (duplexes), R-3 (low-rise apartment buildings), and so on. These districts specify the principal and accessory uses, exceptions, and prohibitions [8].

In general, permitted land uses are based on the intensity of land use—a less intense land use being permitted in a more intense district, but not vice versa. For example, a single-unit residence is a less intense land use than a multiunit dwelling (defined by HUD as more than four living units) and hence would be permitted in a residential district zoned for more intense land use (e.g., R-3). A multiunit dwelling would not, however, be permitted in an R-1 district. While intended to promote the health, safety, and general welfare of the community, housing trends in the last half of the 20th century have led a number of public health and planning officials to question the blind enforcement of zoning districts. These individuals, citing such problems as urban sprawl, have stated that municipalities need to adopt a more flexible approach to land use regulation—one that encourages creating mixed-use spaces, increasing population densities, and reducing reliance on the automobile.

These initiatives are often called smart growth programs. It is imperative, if this approach is taken, that both governmental officials and citizens be involved in the planning stage. Without this involvement, the community may end up with major problems, such as overloaded infrastructure, structures of inappropriate construction crowded together, and fire and security issues for residents. Increased density could strain the existing water, sewer and waste collection systems, as well as fire and police services, unless proper planning is implemented.

In recent years, some ordinances have been partially based on performance standards rather than solely on land-use intensity. For example, some types of industrial developments may be permitted in a less intense use district provided that the proposed land use creates no noise, glare, smoke, dust, vibration, or other environmental stress exceeding acceptable standards and provided further that adequate off-street parking, screening, landscaping, and similar measures are taken.

Bulk and Height Requirements. Most early zoning ordinances stated that, within a particular district, the height and bulk of any structure could not exceed certain dimensions and specified dimensions for front, side, and rear yards. Another approach was to use floor-area ratios for regulation. A floor-area ratio is the relation between the floor space of the structure and the size of the lot on which it is located. For example, a floor-area ratio of 1 would permit either a two-story building covering 50% of the lot, or a one-story building covering 100% of the lot, as demonstrated in Figure 3.1. Other zoning ordinances specify the maximum amount of the lot that can be covered or merely require that a certain amount of open space must be provided for each structure, and leave the builder the flexibility to determine the location of the structure. Still other ordinances, rather than specify a particular height for the structure, specify the angle of light obstruction that will assure adequate air and light to the surrounding structures, as demonstrated in Figure 3.2.

Yard Requirements. Zoning ordinances also contain minimum requirements for front, rear, and side yards. These requirements, in addition to stating the lot dimensions, usually designate the amount of setback required. Most ordinances permit the erection of auxiliary buildings in rear yards provided that they are located at stated distances from all lot lines and provided sufficient open space is maintained. If the property is a corner lot, additional requirements are established to allow visibility for motorists.

Off-street Parking. Space for off-street parking and off-street loading, especially for commercial buildings, is also contained in zoning ordinances. These requirements are based on the relationship of floor space or seating capacity to land use. For example, a furniture store would require fewer off-street parking spaces in relation to the floor area than would a movie theater.

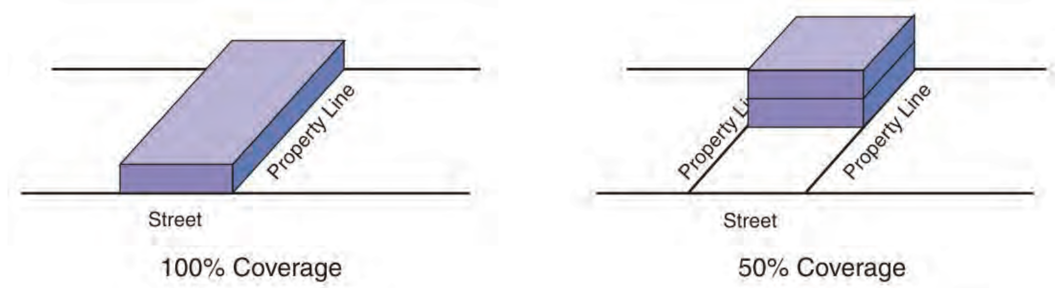

Figure 3.1. Example of a Floor Area

Exceptions to the Zoning Code

Nonconforming Uses

Because zoning is not retroactive, all zoning ordinances contain a provision for nonconforming uses. If a use has already been established within a particular district before the adoption of the ordinance, it must be permitted to continue, unless it can be shown to be a public nuisance.

Provisions are, however, put into the ordinance to aid in eliminating nonconforming uses over time. These provisions generally prohibit a) an enlargement or expansion of the nonconforming use, b) reconstruction of the nonconforming use if more than a certain portion of the building should be destroyed, c) resumption of the use after it has been abandoned for a period of specified time, and d) changing the use to a higher classification or to another nonconforming use. Some zoning ordinances further provide a period of amortization during which nonconforming land use must be phased out.

Variances

Zoning ordinances contain provisions for permitting variances and providing a method for granting these variances, subject to certain specified provisions. A variance may be granted when, owing to the specific conditions or use of a particular lot, an undue hardship would be imposed on the owner if the exact content of the ordinance is enforced. A variance may be granted due to the shape, topography, or other characteristic of the lot. For example, suppose an irregularly shaped lot is located in a district having a side yard requirement of 20 feet on a side and a total lot size requirement of 10,000 square feet. Further suppose that this lot contains 10,200 square feet (and thus meets the total size requirement); however, due to the irregular shape of the lot, there would be sufficient space for only a 15-foot side yard. Because a hardship would be imposed on the owner if the exact letter of the law is applied, the owner of the property could apply to the zoning adjustment board for a variance. Because the total area of the lot is sufficient and a lessening of the ordinance requirements would not be detrimental to the surrounding property, nor would it interfere with neighboring properties, a variance would probably be granted. Note that a variance is granted to the owner under specific conditions. Should use of the property change, the variance would be voided.

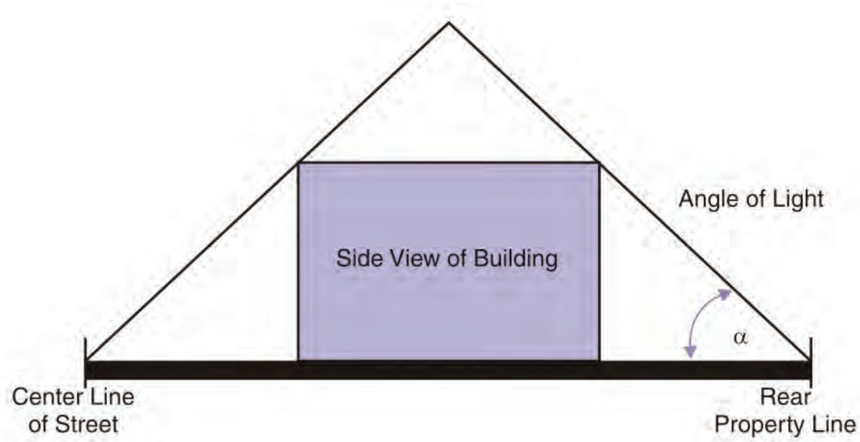

Figure 3.2. Example of an Angle of Light Obstruction

Exceptions

An exception is often confused with a variance. In every city there are some necessary uses that do not correspond to the permitted land uses within the district. The zoning code recognizes, however, that if proper safeguards are provided, these uses would not have a detrimental effect on the district. An example would be a fire station that could be permitted in a residential area, provided the station house is designed and the property is properly landscaped to resemble or fit in with the characteristics of the neighborhood in which it is located.

Administration

Zoning inspectors are essential to the zoning process because they have firsthand knowledge of a case. Often, the zoning inspector may also be the building inspector or housing inspector. Because the building inspector or housing inspector is already in the field making inspections, it is relatively easy for that individual to check compliance with the zoning ordinances. Compliance is determined by comparing the actual land use with that allowed for the area and shown on the zoning map.

Each zoning ordinance has a map detailing the permitted usage for each block. Using a copy of this map, the inspector can make a preliminary check of the land use in the field. If the use does not conform, the inspector must then contact the Zoning Board to see whether the property in question was a nonconforming use at the time of the passage of the ordinance and whether an exception or variance has been granted. In cities where up-to-date records are maintained, the inspector can check the use in the field.

When a violation is observed, and the property owners are duly notified of the violation, they have the right to request a hearing before the Zoning Board of Adjustment (also called the Zoning Board of Appeals in some cities). The board may uphold the zoning enforcement officer or may rule in favor of the property owner. If the action of the zoning officer is upheld, the property owner may, if desired, seek relief by appealing the decision to the courts; otherwise, the violation must be corrected to conform to the zoning code.

It is critical for the housing or building inspector and the zoning inspector to work closely in municipalities where these positions and responsibilities are separate. Experience has shown that illegally converted properties are often among the most substandard encountered in the municipality and often contain especially dangerous housing code violations.

In communities where the zoning code is enforced effectively, the resulting zoning compliance helps to advance, as well as sustain, many of the minimum standards of the housing code such as occupancy, ventilation, light, and unimpeded egress. By the same token, building or housing inspectors can often aid the zoning inspector by helping eliminate some nonconforming uses through code enforcement.

Housing Codes

A housing code, regardless of who promulgates it, is basically an environmental health protection code. Housing codes are distinguished from building codes in that they cover houses, not buildings in general. For example, the housing code requires that walls support the weight of the roof, any floors above, and the furnishings, occupants, etc., within a building.

Early housing codes primarily protected only physical health; hence, they were enforced only in slum areas. In the 1970s, it was realized that, if urban blight and its associated human suffering were to be controlled, housing codes must consider both physical and mental health and must be administered uniformly throughout the community.

In preparing or revising housing codes, local officials must maintain a level of standards that will not merely be minimal. Standards should maintain a living environment that contributes positively to healthful individual and family living. The fact that a small portion of housing fails to meet a desirable standard is not a legitimate reason for retrogressive modification or abolition of a standard. The adoption of a housing ordinance that establishes low standards for existing housing serves only to legalize and perpetuate an unhealthy living environment. Wherever local conditions are such that immediate enforcement of some standards within the code would cause undue hardship for some individuals, it is better to allow some time for compliance than to eliminate an otherwise satisfactory standard. When immediate health or safety hazards are not involved, it is often wise to attempt to create a reasonable timetable for accomplishing necessary code modifications.

History

To assist municipalities with developing legislation necessary to regulate the quality of housing, the American Public Health Association (APHA) Committee on the Hygiene of Housing prepared and published in 1952 a proposed housing ordinance. This provided a prototype on which such legislation might be based and has served as the basis for countless housing codes enacted in the United States since that time. Some municipalities enacted it without change. Others made revisions by omitting some portions, modifying others, and sometimes adding new provisions [9].

The APHA ordinance was revised in 1969 and 1971. In 1975, APHA and the CDC jointly undertook the job of rewriting and updating this model ordinance. The new ordinance was entitled the *APHA-CDC Recommended Housing Maintenance and Occupancy Ordinance* [10]. The most recent model ordinance was published by APHA in 1986 as *Housing and Health: APHA-CDC Recommended Minimum Housing Standards* [11]. This new ordinance is one of several model ordinances available to communities when they are interested in adopting a housing code.

A community should read and consider each element within the model code to determine its applicability to their community. A housing code is merely a means to an end. The end is the eventual elimination of all substandard conditions within the home and the neighborhood. This end cannot be achieved if the community adopts an inadequate housing code.

Objectives

The Housing Act of 1949 [12] gave new impetus to existing local, state, and federal housing programs directed toward eliminating poor housing. In passing this legislation, Congress defined a new national objective by declaring that "the general welfare and security of the nation and the health and living standards of its people... require a decent home and a suitable living environment for every American family." This mandate generated an awareness that the quality of housing and residential environment has an enormous influence upon the physical and mental health and the social well-being of each individual and, in turn, on the economic, political, and social conditions in every community. Consequently, public agencies, units of government, professional organizations and others sought ways to ensure that the quality of housing and the residential environment did not deteriorate.

It soon became apparent that ordinances regulating the supplied utilities and the maintenance and occupancy of dwellings were needed. Commonly called housing codes, these ordinances establish minimum standards to make dwellings safe, sanitary, and fit for human habitation by governing their condition and maintenance, their supplied utilities and facilities, and their occupancy. The 2003 International Code Council (ICC) [13,14] International Residential Code-One- and Two-Family Dwellings (R101.3) states

> *"the purpose of this code is to provide minimum requirements to safeguard the public safety, health and general welfare, through affordability, structural strength, means of egress, facilities, stability, sanitation, light and ventilation, energy conservation, safety to fire and property from fire and other hazards attributed to the built environment."*

Critical Requirements of an Effective Housing Program

A housing code is limited in its effectiveness by several factors. First, if the housing code does not contain standards that adequately protect the health and well-being of the individuals, it cannot be effective. The best-trained housing inspector, if not armed with an adequate housing code, can accomplish little good in the battle against urban blight.

A second issue in establishing an effective housing code is the need to establish a baseline of current housing conditions. A systems approach requires that you establish where you are, where you are going, and how you plan to achieve your goals. In using a systems approach, it is essential to know where the program started so that the success or failure of various initiatives can be established. Without this information, success cannot be replicated, because you cannot identify the obstacles navigated nor the elements of success. Many initiatives fail because program administrators are without the necessary proof of success when facing funding shortfalls and budget cuts.

A third factor affecting the quality of housing codes is budget. Without adequate funds and personnel, the community can expect to lose the battle against urban blight. It is only through a systematic enforcement effort by an adequately sized staff of properly trained inspectors that the battle can be won.

A fourth factor is the attitude of the political bodies within the area. A properly administered housing program will require upgrading substandard housing throughout the community. Frequently, this results in political pressures being exerted to prevent the enforcement of the code in certain areas of the city. If the housing effort is backed properly by all political elements, blight can be controlled and eventually eliminated within the community. If, however, the housing program is not permitted to choke out the spreading influence of substandard conditions, urban blight will spread like a cancer, engulfing greater and greater portions of the city. Similarly, an effort directed at only the most seriously blighted blocks in the city will upgrade merely those blocks, while the blight spreads elsewhere. If urban blight is to be controlled, it must be cut out in its entirety.

A fifth element that limits housing programs is whether they are supported fully by the other departments within the city. Regardless of which city agency administers the housing program, other city agencies must support the activities of the housing program. In addition, great effort should be expended to obtain the support and cooperation of the community. This can be accomplished through public awareness and public information programs, which can result in considerable support or considerable resistance to the efforts of the program.

A sixth limitation is an inadequately or improperly trained inspection staff. Inspectors should be capable of evaluating whether a serious or a minor problem exists in matters ranging from the structural stability of a building to the health and sanitary aspects of the structure. If they do not have the authority or expertise, they should develop that expertise or establish effective and efficient agreements with overlapping agencies to ensure timely and appropriate response.

A seventh item that frequently restricts the effectiveness of a housing program is the fact that many housing groups fail to do a complete job of evaluating housing problems. The deterioration of an area may be due to factors such as housing affordability, tax rates, or issues related to investment cost and return. In many cases, the inspection effort is restricted to merely evaluating the conditions that exist, with little or no thought given to why these conditions exist. If a housing effort is to be successful, as part of a systems approach, the question of why the homes deteriorated must be considered. Was it because of environmental stresses within the neighborhood that need to be eliminated or was it because of apathy on the part of the occupants? In either case, if the causative agent is not removed, then the inspector faces an annual problem of maintaining the quality of that residence. It is only by eliminating the causes of deterioration that the quality of the neighborhood can be maintained. Often the regulatory authority does not have adequate authority within the enabling legislation of the code needed to resolve the problem or there are gaps in jurisdiction.

Content of a Housing Code

Although all comprehensive housing codes or ordinances contain a number of common elements, the provisions of communities will usually vary. These variations stem from differences in local policies, preferences, and, to a lesser extent, needs. They are also influenced by the standards set by the related provisions of the diverse building, electrical, and plumbing codes in use in the municipality.

Within any housing code there are generally five features:

1. Definitions of terms used in the code.
2. Administrative provisions showing who is authorized to administer the code and the basic methods and procedures that must be followed in implementing and enforcing the sections of the code. Administrative provisions deal with items such as reasonable hours of inspections, whether serving violation notices is required, how to notify absentee owners or resident-owners or tenants, how to process and conduct hearings, what rules to follow in processing dwellings alleged to be unfit for human habitation, and how to occupy or use dwellings finally declared fit.
3. Substantive provisions specifying the various types of health, building, electrical, heating, plumbing, maintenance, occupancy, and use conditions that constitute violations of the housing code. These provisions can be and often are grouped into three categories: minimum facilities and equipment for dwelling units; adequate maintenance of dwellings and dwelling units, as well as their facilities and equipment; and occupancy conditions of dwellings and dwelling units.
4. Court and penalty sections outlining the basis for court action and thepenalty or penalties to which the alleged violator will be subjected if proved guilty of violating one or more provisions of the code.
5. Enabling, conflict, and unconstitutionality clauses providing the date a new or amended code will take effect, prevalence of more stringent provision when there is a conflict of two codes, severability of any part of the ordinance that might be found unconstitutional, and retention of all other parts in full course and effect. In any city following the format of the *APHA-CDC Recommended Housing Maintenance and Occupancy Ordinance* [10] the housing officer or other supervisor in charge of housing inspections will also adopt appropriate housing rules and regulations from time to time to clarify or further refine the provisions of the ordinance. When rules and regulations are used, care should be taken that the department is not overburdened with a number of minor rules and regulations. Similarly, a housing ordinance that encompasses all rules and regulations might have difficulty because any amendments to it will require action by the political element of the community. Some

housing groups, in attempting to obtain amendments to an ordinance, have had the entire ordinance thrown out by the political bodies.

Administrative Provisions of a Housing Code

The administrative procedures and powers of the housing inspection agency, its supervisors, and its staff are similar to other provisions in that all are based on the police power of the state to legislate for public health and safety. In addition, the administrative provisions, and to a lesser extent, the court and penalty provisions, outline how the police power is to be exercised in administering and enforcing the code.

Generally, the administrative elements deal with procedures for ensuring that the constitutional doctrines of reasonableness, equal protection under the law and due process of law are observed. They also must guard against violation of prohibitions against unlawful search and seizure, impairment of obligations of contract, and unlawful delegation of authority. These factors encompass items of great importance to housing inspection supervisors such as the inspector's right of entry, reasonable hours of inspection, proper service, and the validity of the provisions of the housing codes they administer.

Owner of Record. It is essential to file legal actions against the true owners of properties in violation of housing codes. With the advent of the computer, this is often much easier than in the past. Databases that provide this information are readily available from many offices of local government such as the tax assessment office. The method of obtaining the name and address of the legal owner of a property in violation varies from place to place. Ordinarily, a check of the city tax records will suffice unless there is reason to believe these are not up to date. In this case, a further check of county or parish records will turn up the legal owner if state law requires deed registration there. If it does not, the advice of the municipal law department should be sought about the next steps to follow.

Due Process Requirements. Every notice, complaint, summons, or other type of legal paper concerning alleged housing code violations in a given dwelling or dwelling unit must be legally served on the proper party to be valid and to prevent harassment of innocent parties. This might be the owner, agent, or tenant, as required by the code. It is customary to require that the notice to correct existing violations and any subsequent notices or letters be served by certified or registered mail with return receipt requested. The receipt serves as proof of service if the case has to be taken to court.

Due process requirements also call for clarity and specificity with respect to the alleged violations, both in the violation notices and the court complaint-summons. For this reason, special care must be taken to be complete and accurate in listing the violations and charges. To illustrate, rather than direct the violator to repair all windows where needed, the violator should be told exactly which windows and what repairs are involved.

The chief limitation on the due process requirement, with respect to service of notices, lies in cases involving immediate threats to health and safety. In these instances, the inspection agency or its representative may, without notice or hearing, issue an order citing the existence of the emergency and requiring that action deemed necessary to meet the emergency be taken.

In some areas housing courts on the municipal level have advocates that assist both plaintiffs and defendants prepare for the court process or to resolve the issue to avoid court.

Hearings and Condemnation Power. The purpose of a hearing is to give the alleged violator an opportunity to be heard before further action is taken by the housing inspection agency. These hearings may be very informal, involving meetings between a representative of the agency and the person ordered to take corrective action. They also may be formal hearings at which the agency head presides and at which the city and the defendant both are entitled to be represented by counsel and expert witnesses.

Informal Hearings. A violator may have questions about a violation notice or the notice may be served at a time when personal hardship or other factors prevent a violator from meeting the terms of the notice. Therefore, many housing codes provide the opportunity for a hearing at which the violator may discuss questions or problems and seek additional time or some modification of the order. Administered in a firm but understanding manner, these hearings can serve as invaluable aids in relieving needless fears of those involved, in showing how the inspection program is designed to help them and in winning their voluntary compliance.

Formal Hearings. Formal hearings are often quasijudicial hearings (even though the prevailing court rules of evidence do not always apply) from which an appeal may be taken to court. All witnesses must therefore be sworn in, and a record of the proceedings must be made. The formal hearing is used chiefly as the basis for determining whether a dwelling is fit for human habitation, occupancy, or use. In the event it is proved unfit, the building is condemned and the owner is given a designated amount of time either to rehabilitate it completely or to demolish it. Where local funds are available, a municipality may demolish the building and place a lien against the property to cover demolition costs if the owner fails to obey the order within the time specified. This type of condemnation hearing is a very effective means of stimulating prompt and appropriate corrective action when it is administered fairly and firmly.

Procedures for Coping With Common Problems. Several states and local communities have developed innovative ways to resolve code violation issues.

Limitation of Occupancy Notification. This technique was pioneered in Wilmington, Delaware. It makes it mandatory for property owners in the community to obtain a legal notice from the housing inspection agency specifying the maximum number of persons that may occupy each of their properties. It also requires these owners to have a residence, place of business, or an agent for their properties within the community. The agent should be empowered to take remedial action on any of the properties found in violation. In addition, if the property is sold, the new owner must obtain a new Limitation of Occupancy Notification.

Request for Inspections. Several states permit their municipalities to offer a request for inspection service. For a fee, the housing inspector will inspect a property for violations of the housing code before its sale so that the buyer can learn its condition in advance. Many states and localities now require owners to notify prospective purchasers of any outstanding notice of health risk or violations they have against their property before the sale. If they fail to do so, some codes will hold the owner liable to the purchaser and the inspection agency for violations.

Tickets for Minor Offenses. Denver, Colorado, has used minimal financial fines to prod minor violators and first offenders into correcting violations without the city resorting to court action. There are mixed views about this technique because it is akin to formal police action. Nevertheless, the action may stimulate compliance and reduce the amount of court action needed to achieve it.

Forms and Form Letters. A fairly typical set of forms and form letters are described below. It should be stressed that inspection forms to be used for legal notices must satisfy legal standards of the code, be meaningful to the owner and sufficiently explicit about the extent and location of particular defects, be adaptable to statistical compilation for the governing body reports, and be written in a manner that will facilitate clerical and other administrative usage.

The Daily Report Form. This form gives the inspection agency an accurate basis for reporting, evaluating, and, if necessary, improving the productivity and performance of its inspectors.

Complaint Form. This form helps obtain full information from the complainant and thus makes the relative seriousness of the problem clear and reduces the number of crank complaints.

No-entry Notice. This notice advises occupants or owners that an inspector was there and that they must return a call to the inspector.

Inspection Report Form. This is the most important form in an agency. It comes in countless varieties, but if designed properly, it will ensure more productivity and more thoroughness by the inspectors, reduce the time spent in writing reports, locate all violations correctly, and reduce the time required for typing violation notices. Forms may vary widely in sophistication from a very simple form to one whose components are identified by number for use in processing the case by automation. Some forms are a combined inspection report and notice form in triplicate so that the first page can be used as the notice of violation, the second as the office record, and the third as the guide for reinspection. A covering form letter notifies the violator of the time allowed to correct the conditions listed in the report form.

Violation Notice. This is the legal notice that housing code violations exist and must be corrected within the indicated amount of time. The notice may be in the form of a letter that includes the alleged violations or has a copy of these attached. It may be a standard notice form, or it may be a combined report-notice. Regardless of the type of notice used, it should make the location and nature of all violations clear and specify the exact section of the code that covers each one. The notice must advise violators of their right to a hearing. It should also indicate that the violator has a right to be represented by counsel and that failure to obtain counsel will not be accepted as grounds for postponing a hearing or court case.

Hearing Forms. These should include a form letter notifying the violator of the date and time set for the hearing, a standard summary sheet on which the supervisor can record the facts presented at an informal hearing, and a hearing-decision letter for notifying all concerned of the hearing results. The latter should include the names of the violator, inspector, law department, and any other city official or agency that may be involved in the case.

Reinspection Form Letters or Notices. These have the same characteristics as violation notices except that they cover the follow-up orders given to the violator who has failed to comply with the original notice within the time specified. Some agencies may use two or three types of these form letters to accommodate different degrees of response by the violator. Whether one or several are used, standardization of these letters or notices will expedite the processing of cases.

Court Complaint and Summons Forms. These forms advise alleged violators of the charges against them and summon them to appear in court at the specified time and place. It is essential that the housing inspection agency work closely with the municipal law department in preparing these forms so that each is done in exact accord with the rules of court procedure in the relevant state and community.

Court Action Record Form. This form provides an accurate running record of the inspection agency's court actions and their results.

Substantive Provisions of a Housing Code

A housing code is the primary tool of the housing inspector. The code spells out what the inspector may or may not do. An effort to improve housing conditions can be no better than the code allows. The substantive provisions of the code specify the minimal housing conditions acceptable to the community that developed them.

Dwelling units should have provisions for preparing at least one regularly cooked meal per day. Minimum equipment should include a kitchen sink in good working condition and properly connected to the water supply system approved by the appropriate authority. It should provide, at all times, an adequate amount of heated and unheated running water under pressure and should be connected to a sewer system approved by the appropriate authority. Cabinets or shelves, or both, for storing eating, drinking, and cooking utensils and food should be provided. These surfaces should be of sound construction and made of material that is easy to clean and that will not have a toxic or deleterious effect on food.

In addition, a stove and refrigerator should be provided. Within every dwelling there should be a room that affords privacy and is equipped with a flush toilet in good working condition.

Within the vicinity of the flush toilet, a sink should be provided. In no case should a kitchen sink substitute as a lavatory sink. In addition, within each dwelling unit there should be, within a room that affords privacy, either a bathtub or shower or both, in good working condition. Both the lavatory sink and the bathtub or shower or both should be equipped with an adequate amount of heated and unheated water under pressure. Each should be connected to an approved sewer system.

Within each dwelling unit two or more means of egress should be provided to safe and open space at ground level. Provisions should be incorporated within the housing code to meet the safety requirements of the state and community involved. The housing code should spell out minimum standards for lighting and ventilation within each room in the structure. In addition, minimum thermal standards should be provided. Although most codes merely provide the requirement of a given temperature at a given height above floor level, the community should give consideration to the use of effective temperatures. The effective temperature is a means of incorporating not only absolute temperature in degrees, but also humidity and air movement, giving a better indication of the comfort index of a room.

The code should provide that no person shall occupy or let for occupancy any dwelling or dwelling units that do not comply with stated requirements. Generally, these requirements specify that the foundation, roof, exterior walls, doors, window space and windows of the structure be sound and in good repair; that it be moisture-free, watertight and reasonably weather tight and that all structural surfaces be sound and in good repair.

HUD defines a multifamily dwelling unit as one that contains four or more dwelling units in a single structure. A dwelling unit is further defined as a single unit of residence for a family of one or more persons in which sleeping accommodations are provided but toileting or cooking facilities are shared by the occupants.

Building Codes

Building codes define what materials and methods are tobe used in the construction of various buildings. Model building codes have been published by various trade organizations such as the Southern Building Code Congress International (SBCCI), Building Officials and Code Administrators (BOCA), and the International Conference of Building Officials (ICBO). Each of these groups published a model building code that was widely used or adapted regionally in the United States. BOCA national codes were used mostly in eastern and Great Lakes states, ICBO uniform codes in western and Midwest states, and SBCCI standard codes in southern states. As a result, the construction industry often faced the challenge, and cost, of building to different codes in different areas of the country.

In 1994, BOCA, ICBO, and SBCCI created the International Code Council (ICC) to develop a single set of comprehensive, coordinated model construction codes that could be used throughout the United States and around the world. The first I-Code published was the International Plumbing Code in 1995. By 2000, a complete family of I-Codes was available, including the International Building Code. The ICC Performance Code for Buildings and Facilities joined the I-Code family in 2001.

On February 1, 2003, the three organizations (BOCA, SBCCI, and ICBO) were consolidated into the ICC [13,14]. According to ICC Board president, Paul E. Myers,

> *"The ICC International Codes (I Codes) combine the strengths of the regional codes without regional limitations. The ICC is a nonprofit organization dedicated to developing a single set of comprehensive and coordinated national codes to make compliance easier and more cost-effective. I Codes respond to the needs of the construction industry and public safety. A single set of codes has strong support from government, code enforcement officials, fire officials, architects, engineers, builders, developers, and building owners and managers."*

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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.

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.

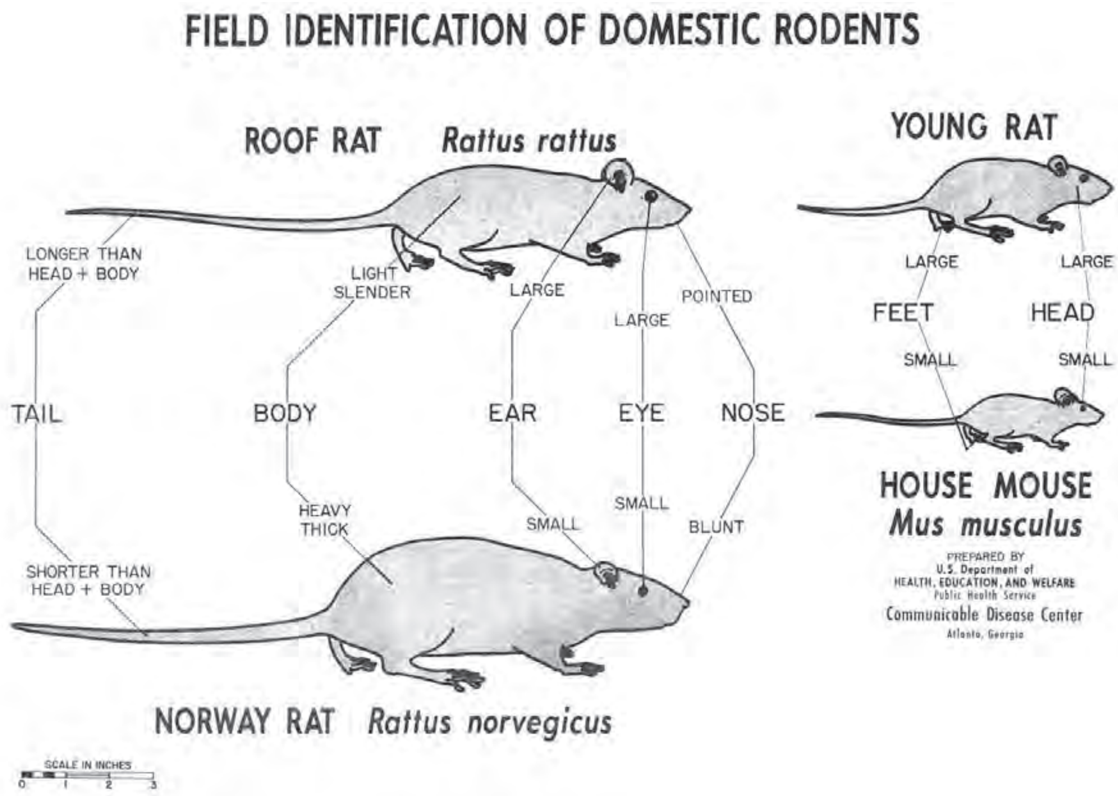

Figure 4.1. Field Identification of Domestic Rodents [2]

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."

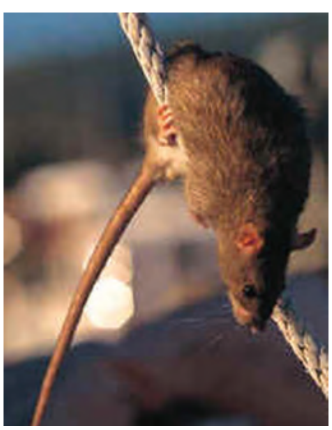

Figure 4.2. Norway Rat [3]

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.

Figure 4.3. Roof Rat [4]

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

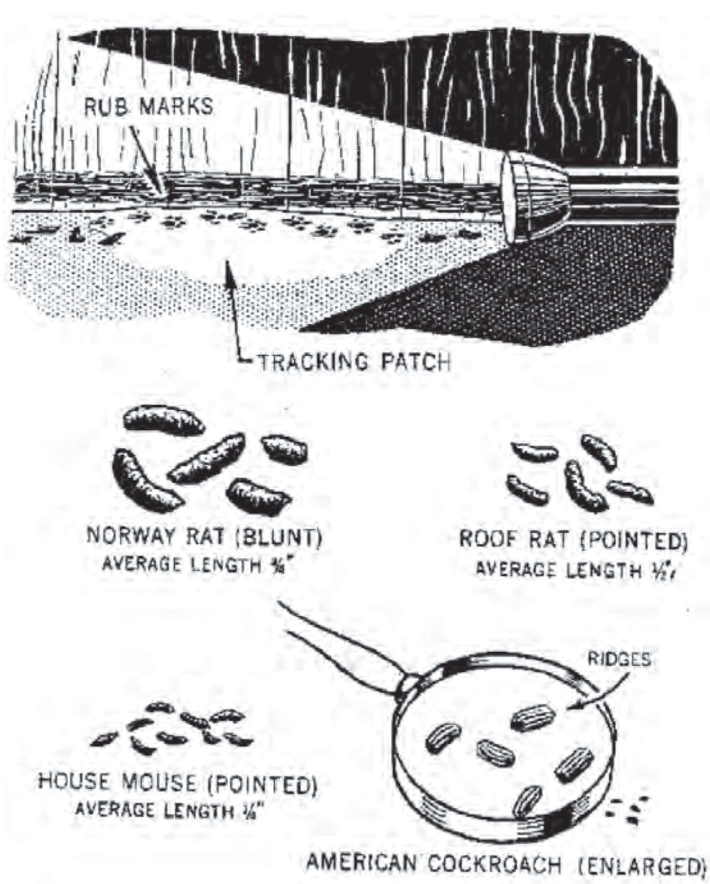

Figure 4.4. Signs of Rodent Infestation [2]

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 are 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.

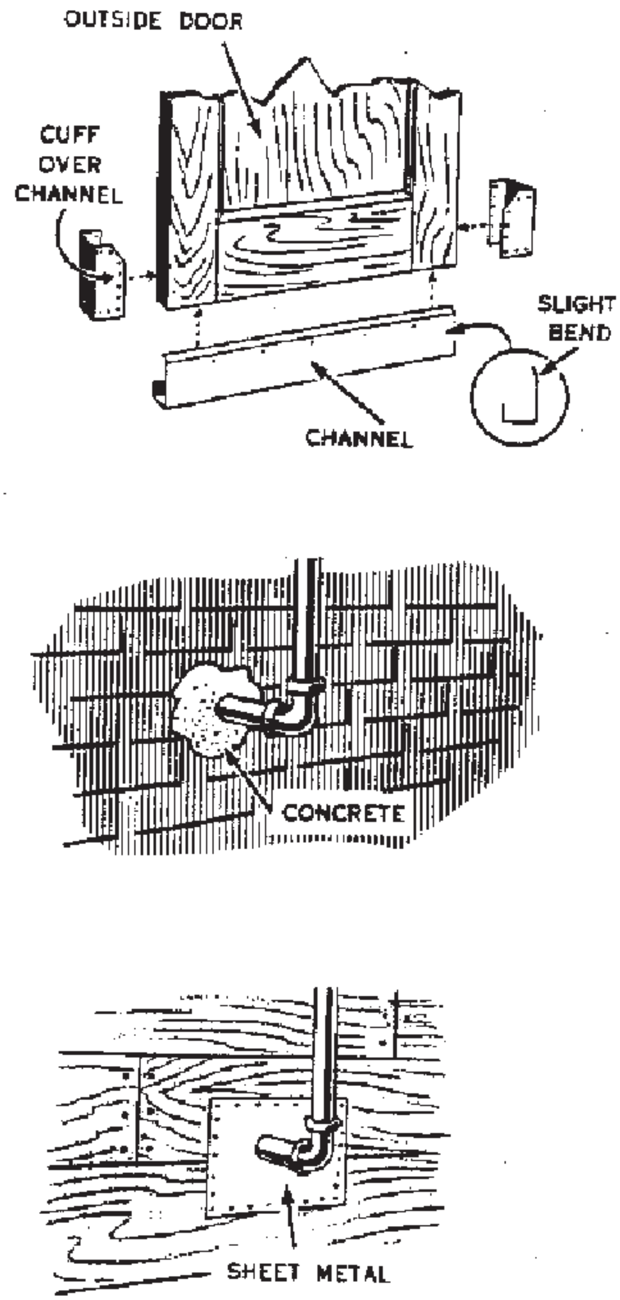

Figure 4.5. Rodent Prevention [2]

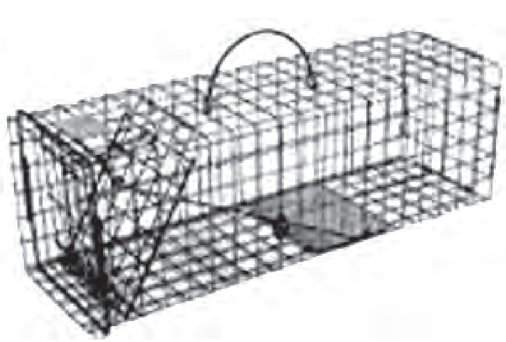

Figure 4.6. Live Traps for Rats [5]

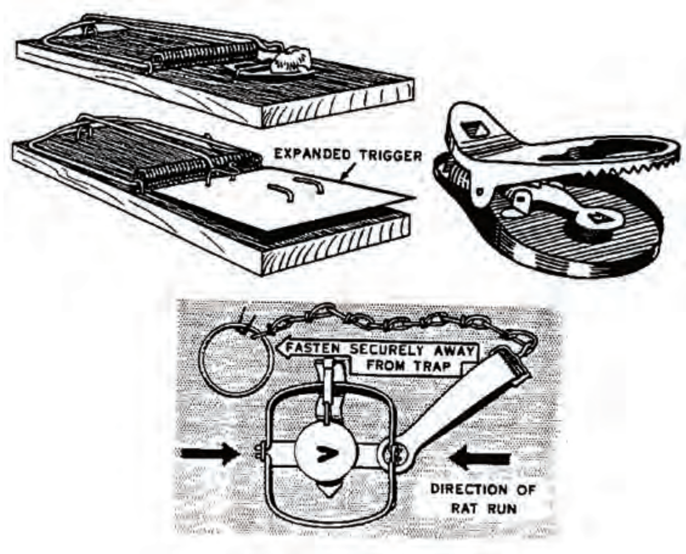

Figure 4.7. Kill Traps for Rats [2]

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 bee 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 4.8–4.13) 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

Figure 4.10. Oriental Cockroaches, Various Stages and Ages [7]

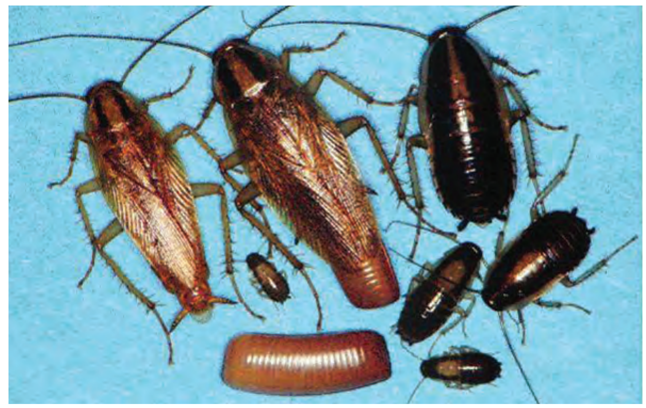

Figure 4.11. German Cockroaches, Various Stages and Ages [7]

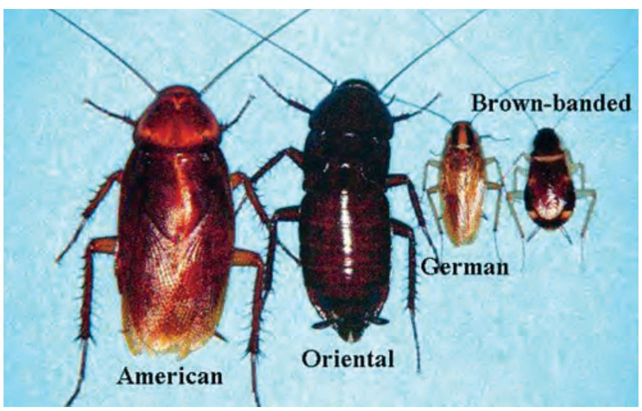

Figure 4.8. American, Oriental, German, and Brown-banded Cockroaches [7]

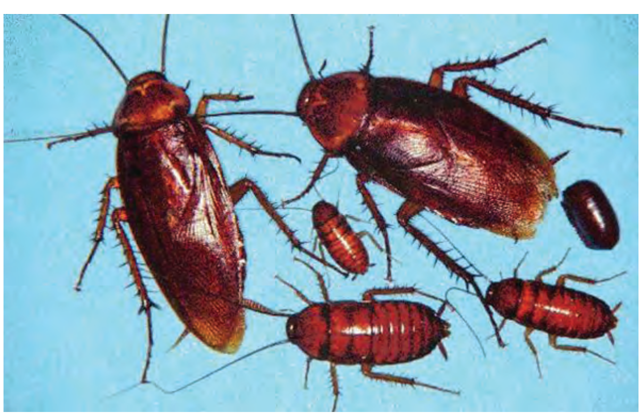

Figure 4.9. American Cockroaches, Various Stages and Ages [7]

Figure 4.12. Brown-banded Cockroaches, Various Stages and Ages [7]

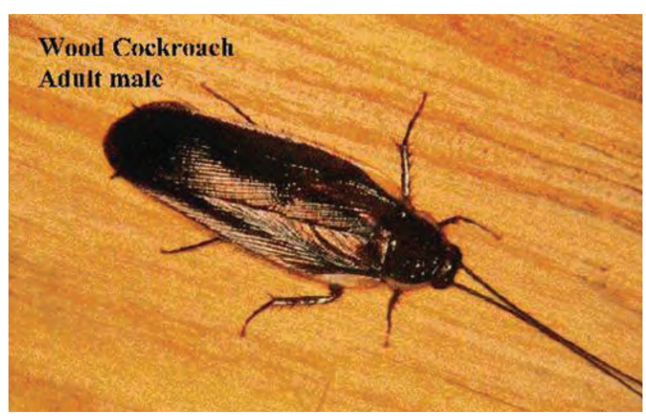

Figure 4.13. Wood Cockroach, Adult Male [7]

leaking plumbing, drains, sink traps, and 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 (mm) long, averaging 2 to 4 mm, 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.

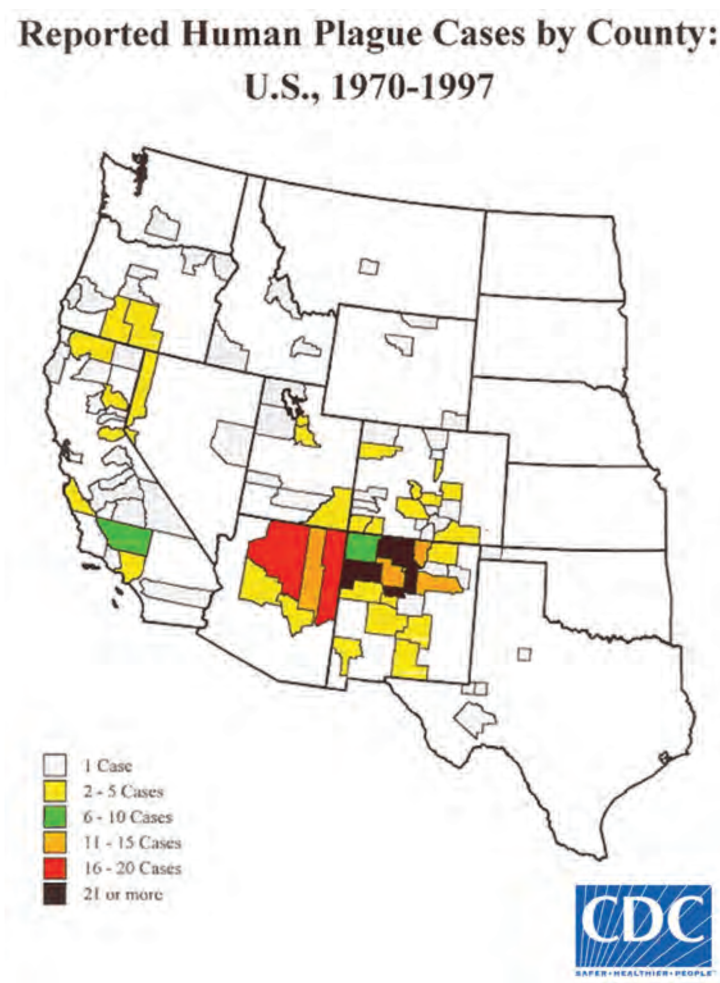

Figure 4.14. Reported Human Plague Cases (1970–1997) [8]

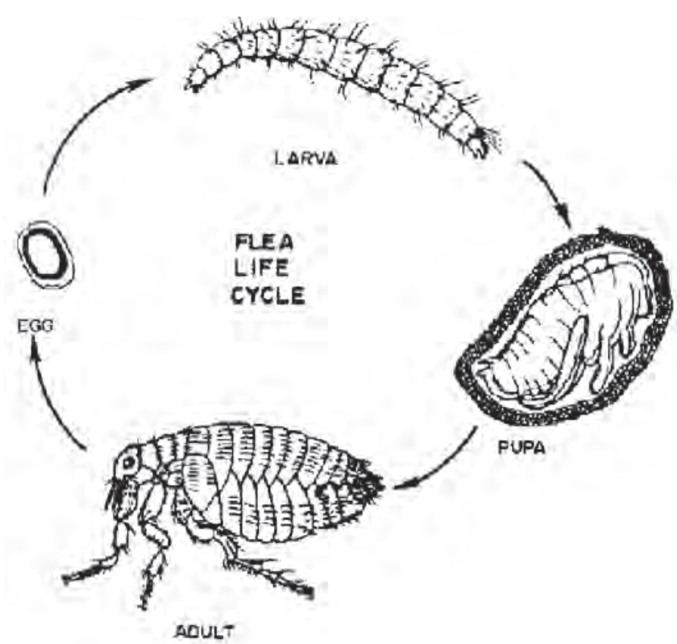

Figure 4.15. Flea Life Cycle [2]

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 mm), 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 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.

Figure 4.16. Housefly [***Musca domestica***][9]

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.

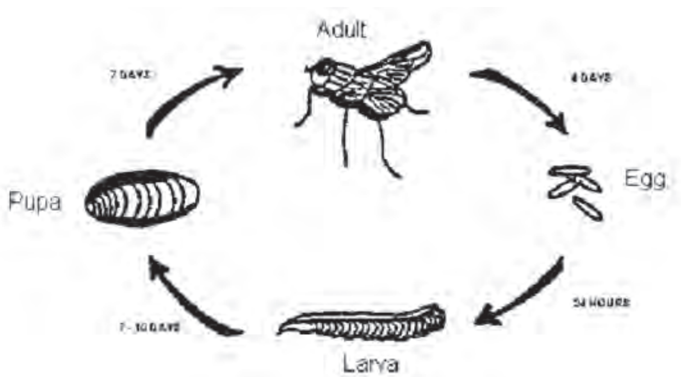

Figure 4.17. Life Cycle of the Fly [10]

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 4.20a and b demonstrates the differences between the ant and termite. 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.

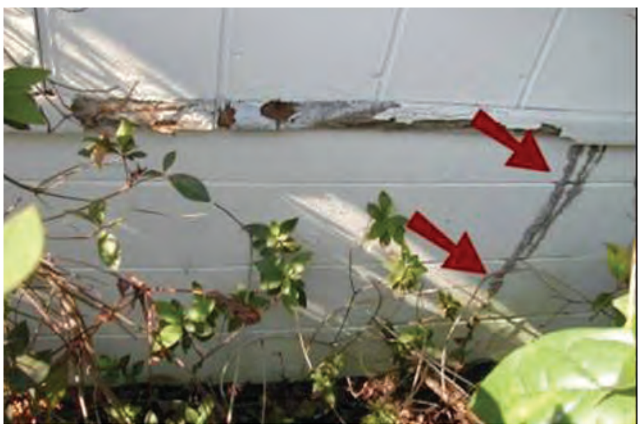

Figure 4.18. Termite Tube Extending from Ground to Wall [Red Arrows] [13]

Figure 4.19. Termite Mud Shelter Tube Constructed Over a Brick Foundation [14]

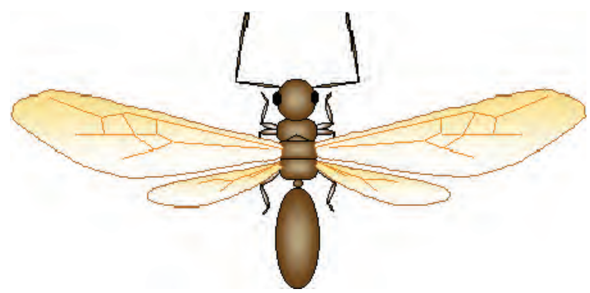

Figure 4.20a. Ant (Elbowed Antennae: Fore Wings Larger Than Hind; Constricted Waist) [16]

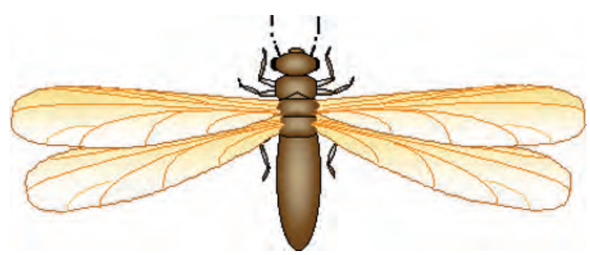

Figure 4.20b. Termite (Beaded Antennae; All Wings Equal) [16]

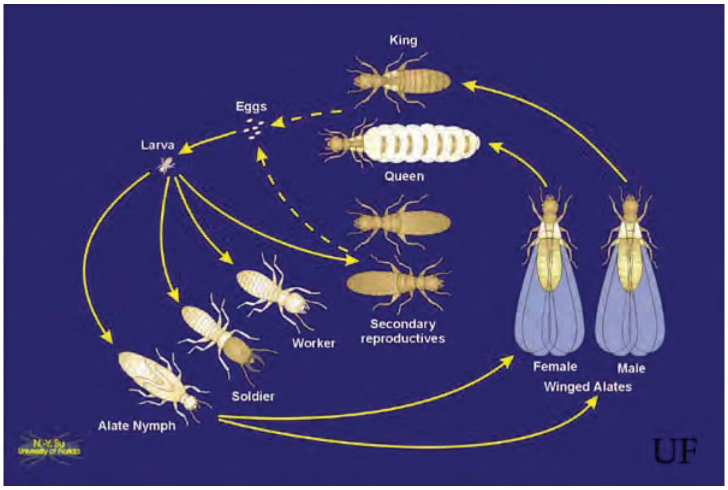

Figure 4.21. Life Cycle of the Subterranean Termite [17]

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 one 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.

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.

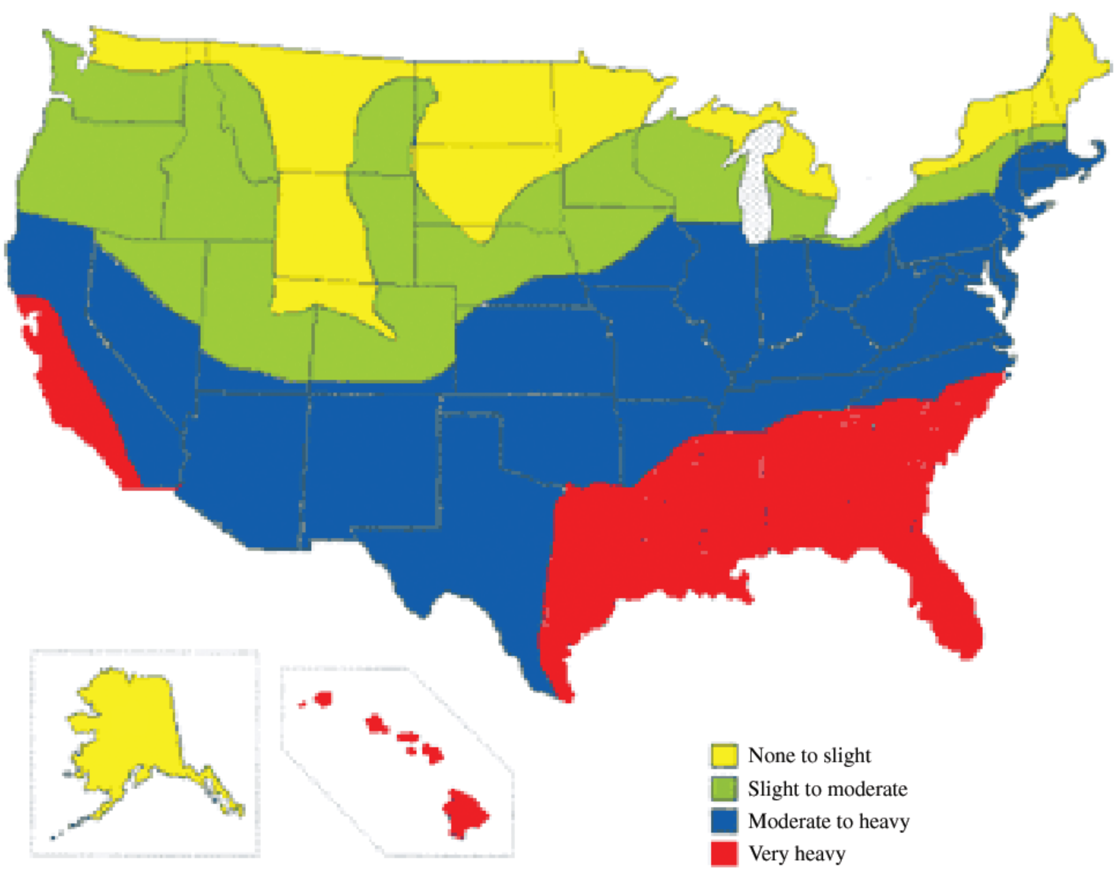

Figure 4.22. Subterranean Termite Risk in the United States [18]

- **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 [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.

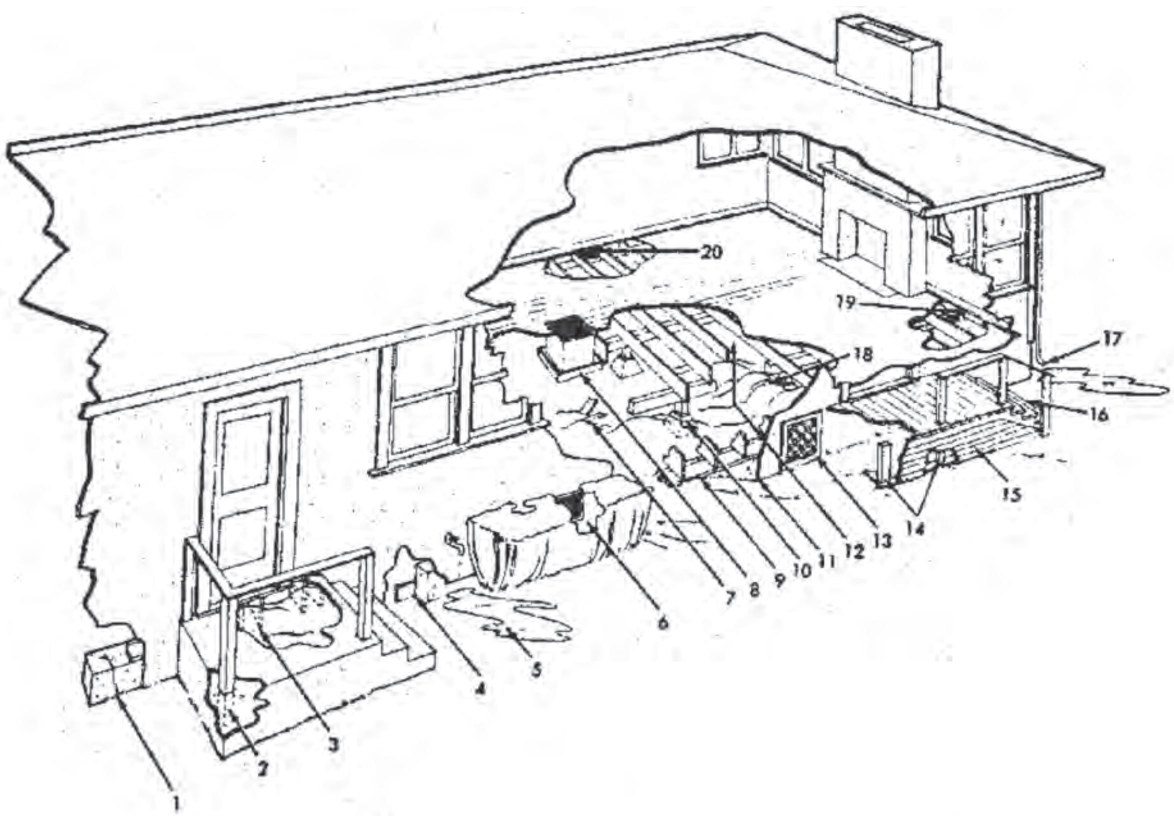

Figure 4.23. Typical Points of Attack by Termites in the Home [2]

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).

Key to Figure 4.23

1. Cracks in foundation permit hidden points of entry from soil to sill.
2. Posts through concrete in contact with substructural soil. Watch door frames and intermediate supporting posts.
3. Wood-framing members in contact with earthfill under concrete slab.
4. Form boards left in place contribute to termite food supply.
5. Leaking pipes and dripping faucets sustain soil moisture. Excess irrigation has same effect.
6. Shrubbery blocking air flow through vents.
7. Debris supports termite colony until large population attacks superstructure.
8. Heating unit accelerates termite development by maintaining warmth of colony on a year-round basis.
9. Foundation wall too low permits wood to contact soil. Adding topsoil often builds exterior grade up to sill level.
10. Footing too low or soil thrown against it causes wood-soil contact. There should be 8 inches of clean concrete between soil and pier block.
11. Stucco carried down over concrete foundation permits hidden entrance between stucco and foundation if bond fails.
12. Insufficient clearance for inspection also permits easy construction of termite shelter tubes from soil to wood.
13. Wood framing of crawl hole forming wood-soil contact.
14. Mud sill and/or posts in contact with soil.
15. Wood siding and skirting form soil contact. There should be a minimum of 3 inches clearance between skirting and soil.
16. Porch steps in contact with soil. Also watch for ladders and other wooden materials.
17. Downspouts should carry water away from the building.
18. Improper maintenance of soil piled against pier footing. Also makes careful inspection impossible.
19. Wall girder entering recess and foundation wall. Should have a 1-inch free air space on both sides and end and be protected with a moisture-impervious seal.
20. Vents placed between joists tunnel air through space without providing good substructural aeration. Vents placed in foundation wall give better air circulation.

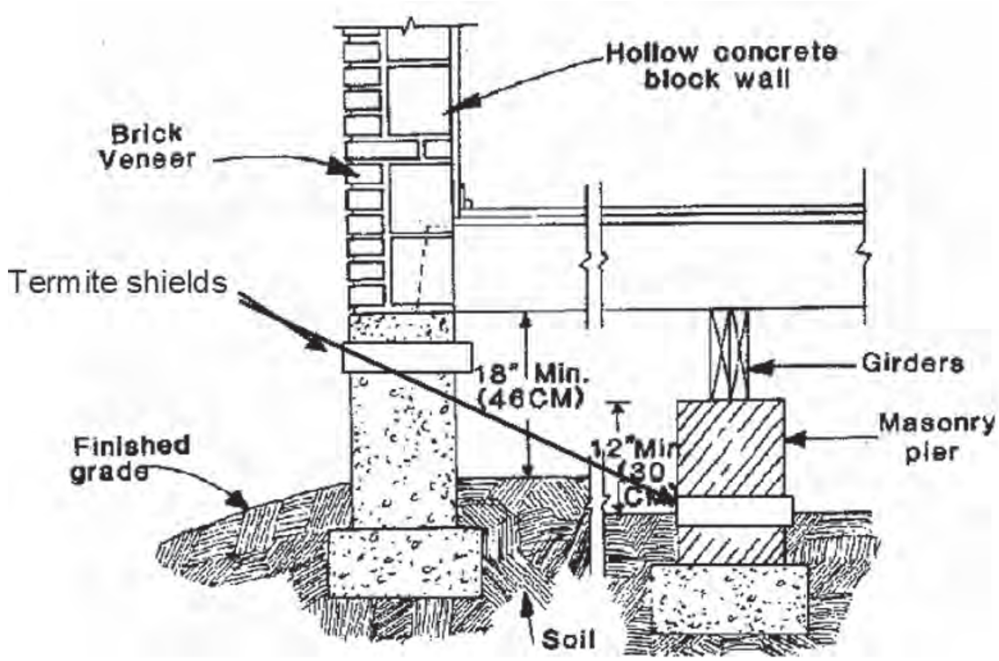

Figure 4.24. Construction Techniques That Discourage Termite Attacks: Thin Metal Termite Shield Should Extend 2 Inches Beyond Foundation and 2 Inches Down [2]

Figure 4.25. Fire Ants [22]

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

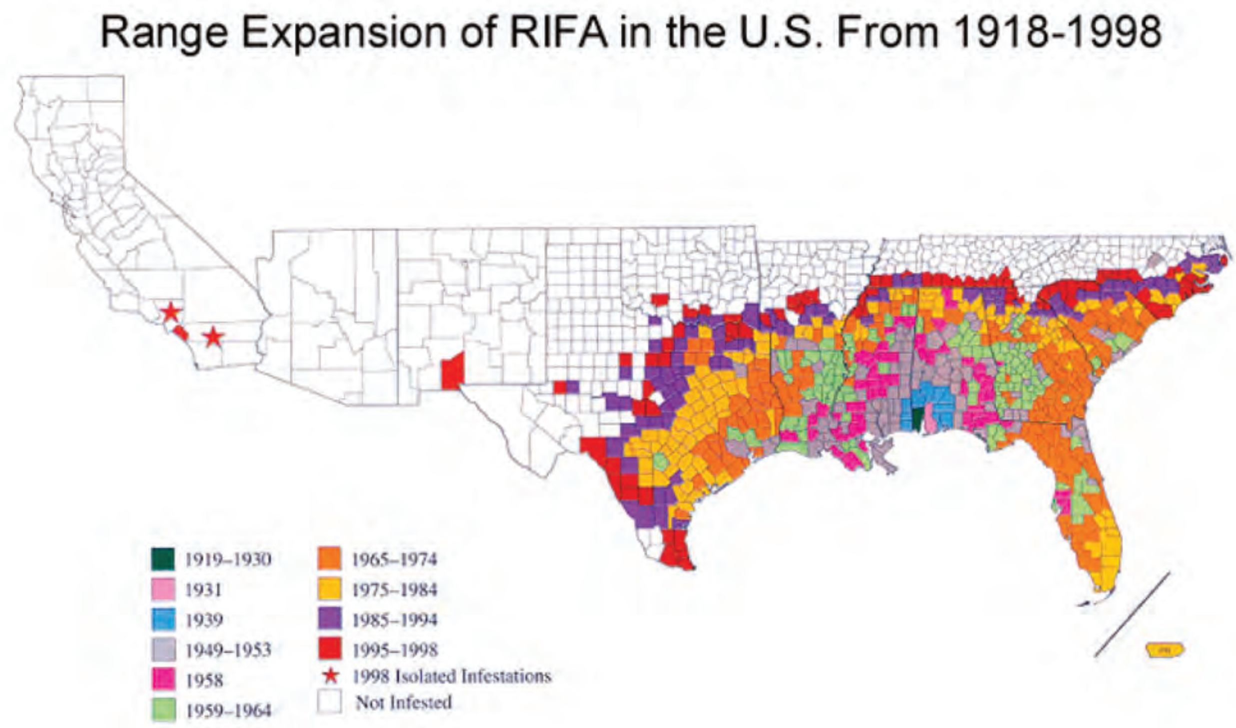

Figure 4.26. Range Expansion of Red Imported Fire Ants [RIFAs] in the United States, 1918–1998 [23]

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

Figure 4.27. Fire Ant Mound
Source: CAPT Craig Shepherd, U.S. PHS; used with permission.

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. Newer 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 drips 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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"Walking into a modern building can sometimes be compared to placing your head inside a plastic bag that is filled with toxic fumes."

John Bower
Founder, *Healthy House Institute*

Introduction

We all face a variety of risks to our health as we go about our day-to-day lives. Driving in cars, flying in airplanes, engaging in recreational activities, and being exposed to environmental pollutants all pose varying degrees of risk. Some risks are simply unavoidable. Some we choose to accept because to do otherwise would restrict our ability to lead our lives the way we want. Some are risks we might decide to avoid if we had the opportunity to make informed choices. Indoor air pollution and exposure to hazardous substances in the home are risks we can do something about.

In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. Other research indicates that people spend approximately 90% of their time indoors. Thus, for many people, the risks to health from exposure to indoor air pollution may be greater than risks from outdoor pollution.

In addition, people exposed to indoor air pollutants for the longest periods are often those most susceptible to their effects. Such groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease [1].

Indoor Air Pollution

Numerous forms of indoor air pollution are possible in the modern home. Air pollutant levels in the home increase if not enough outdoor air is brought in to dilute emissions from indoor sources and to carry indoor air pollutants out of the home. In addition, high temperature and humidity levels can increase the concentration of some pollutants. Indoor pollutants can be placed into two groups, biologic and chemical.

Biologic Pollutants

Biologic pollutants include bacteria, molds, viruses, animal dander, cat saliva, dust mites, cockroaches, and pollen. These biologic pollutants can be related to some serious health effects. Some biologic pollutants, such as measles, chickenpox, and influenza are transmitted through the air. However, the first two are now preventable with vaccines. Influenza virus transmission, although vaccines have been developed, still remains of concern in crowded indoor conditions and can be affected by ventilation levels in the home.

Common pollutants, such as pollen, originate from plants and can elicit symptoms such as sneezing, watery eyes, coughing, shortness of breath, dizziness, lethargy, fever, and digestive problems. Allergic reactions are the result of repeated exposure and immunologic sensitization to particular biologic allergens.

Although pollen allergies can be bothersome, asthmatic responses to pollutants can be life threatening. Asthma is a chronic disease of the airways that causes recurrent and distressing episodes of wheezing, breathlessness, chest tightness, and coughing [2]. Asthma can be broken down into two groups based on the causes of an attack: extrinsic (allergic) and intrinsic (nonallergic). Most people with asthma do not fall neatly into either type, but somewhere in between, displaying characteristics of both classifications. Extrinsic asthma has a known cause, such as allergies to dust mites, various pollens, grass or weeds, or pet danders. Individuals with extrinsic asthma produce an excess amount of antibodies when exposed to triggers. Intrinsic asthma has a known cause, but the connection between the cause and the symptoms is not clearly understood. There is no antibody hypersensitivity in intrinsic asthma. Intrinsic asthma usually starts in adulthood without a strong family history of asthma. Some of the known triggers of intrinsic asthma are infections, such as cold and flu viruses, exercise and cold air, industrial and occupational pollutants, food additives and preservatives, drugs such as aspirin, and emotional stress. Asthma is more common in children than in adults, with nearly 1 of every 13 school-age children having asthma [3]. Low-income African-Americans and certain Hispanic populations suffer disproportionately, with urban inner cities having particularly severe problems. The impact on neighborhoods, school systems, and health care facilities from asthma is severe because one-third of all pediatric emergency room visits are due to asthma, and it is the fourth most prominent cause of physician office visits. Additionally, it is the leading cause of school absenteeism—14 million school days lost each year—from chronic illness [4]. The U.S. population, on the average, spends as much as 90% of its time indoors. Consquently, allergens and irritants from the indoor environment may play a significant role in triggering asthma episodes. A number of indoor environmental asthma triggers are biologic pollutants. These can include rodents (discussed in Chapter 4), cockroaches, mites, and mold.

Cockroaches

The droppings, body parts, and saliva of cockroaches can be asthma triggers. Cockroaches are commonly found in crowded cities and in the southern United States. Allergens contained in the feces and saliva of cockroaches can cause allergic reactions or trigger asthma symptoms. A national study by Crain et al. [5] of 994 inner-city allergic children from seven U.S. cities revealed that cockroaches were reported in 58% of the homes. The Community Environmental Health Resource Center reports that cockroach debris, such as body parts and old shells, trigger asthma attacks in individuals who are sensitized to cockroach allergen [6]. Special attention to cleaning must be a priority after eliminating the presence of cockroaches to get rid of the presence of any allergens left that can be asthma triggers.

House Dust Mites

Another group of arthropods linked to asthma is house dust mites. In 1921, a link was suggested between asthmatic symptoms and house dust, but it was not until 1964 that investigators suggested that a mite could be responsible. Further investigation linked a number of mite species to the allergen response and revealed that humid homes have more mites and, subsequently, more allergens. In addition, researchers established that fecal pellets deposited by the mites accumulated in home fabrics and could become airborne via domestic activities such as vacuuming and dusting, resulting in inhalation by the inhabitants of the home. House dust mites are distributed worldwide, with a minimum of 13 species identified from house dust. The two most common in the United States are the North American house dust mite (*Dermatophagoides farinae*) and the European house dust mite (*D. pteronyssinus*). According to Lyon [7], house dust mites thrive in homes that provide a source of food and shelter and adequate humidity. Mites prefer relative humidity levels of 70% to 80% and temperatures of 75°F to 80°F (24°C to 27°C). Most mites are found in bedrooms in bedding, where they spend up to a third of their lives. A typical used mattress may have from 100,000 to 10 million mites in it. In addition, carpeted floors, especially long, loose pile carpet, provide a microhabitat for the accumulation of food and moisture for the mite, and also provide protection from removal by vacuuming. The house dust mite's favorite food is human dander (skin flakes), which are shed at a rate of approximately 0.20 ounces per week.

A good microscope and a trained observer are imperative in detecting mites. House dust mites also can be detected using diagnostic tests that measure the presence and infestation level of mites by combining dust samples collected from various places inside the home with indicator reagents [7]. Assuming the presence of mites, the precautions listed below should be taken if people with asthma are present in the home:

- Use synthetic rather than feather and down pillows.
- Use an approved allergen barrier cover to enclose the top and sides of mattresses and pillows and the base of the bed.
- Use a damp cloth to dust the plastic mattress cover daily.
- Change bedding and vacuum the bed base and mattress weekly.
- Use nylon or cotton cellulose blankets rather than wool blankets.
- Use hot (120°F–130°F [49°C–54°C]) water to wash all bedding, as well as room curtains.
- Eliminate or reduce fabric wall hangings, curtains, and drapes.
- Use wood, tile, linoleum, or vinyl floor covering rather than carpet. If carpet is present, vacuum regularly with a high-efficiency particulate air (HEPA) vacuum or a household vacuum with a microfiltration bag.
- Purchase stuffed toys that are machine washable.
- Use fitted sheets to help reduce the accumulation of human skin on the mattress surface.

HEPA vacuums are now widely available and have also been shown to be effective [8]. A conventional vacuum tends to be inefficient as a control measure and results in a significant increase in airborne dust concentrations, but can be used with multilayer microfiltration collection bags. Another approach to mite control is reducing indoor humidity to below 50% and installing central air conditioning.

Two products are available to treat house dust mites and their allergens. These products contain the active ingredients benzyl benzoate and tannic acid.

Pets

According to the U.S. Environmental Protection Agency (EPA) [9], pets can be significant asthma triggers because of dead skin flakes, urine, feces, saliva, and hair. Proteins in the dander, urine, or saliva of warm-blooded animals can sensitize individuals and lead to allergic reactions or trigger asthmatic episodes. Warm-blooded animals include dogs, cats, birds, and rodents (hamsters, guinea pigs, gerbils, rats, and mice). Numerous strategies, such as the following, can diminish or eliminate animal allergens in the home:

- Eliminate animals from the home.
- Thoroughly clean the home (including floors and walls) after animal removal.
- If pets must remain in the home, reduce pet exposure in sleeping areas. Keep pets away from upholstered furniture, carpeted areas, and stuffed toys, and keep the pets outdoors as much as possible.

However, there is some evidence that pets introduced early into the home may prevent asthma. Several studies have shown that exposure to dogs and cats in the first year of life decreases a child's chances of developing allergies [10] and that exposure to cats significantly decreases sensitivity to cats in adulthood [11]. Many other studies have shown a decrease in allergies and asthma among children who grew up on a farm and were around many animals [12].

Mold

People are routinely exposed to more than 200 species of fungi indoors and outdoors [13]. These include moldlike fungi, as well as other fungi such as yeasts and mushrooms. The terms "mold" and "mildew" are nontechnical names commonly used to refer to any fungus that is growing in the indoor environment. Mold colonies may appear cottony, velvety, granular, or leathery, and may be white, gray, black, brown, yellow, greenish, or other colors. Many reproduce via the production and dispersion of spores. They usually feed on dead organic matter and, provided with sufficient moisture, can live off of many materials found in homes, such as wood, cellulose in the paper backing on drywall, insulation, wallpaper, glues used to bond carpet to its backing, and everyday dust and dirt.

Certain molds can cause a variety of adverse human health effects, including allergic reactions and immune responses (e.g., asthma), infectious disease (e.g., histoplasmosis), and toxic effects (e.g., aflatoxin-induced liver cancer from exposure to this mold-produced toxin in food) [14]. A recent Institute of Medicine (IOM) review of the scientific literature found sufficient evidence for an association between exposure to mold or other agents in damp indoor environments and the following conditions: upper respiratory tract symptoms, cough, wheeze, hypersensitivity pneumonitis in susceptible persons, and asthma symptoms in sensitized persons [15]. A previous scientific review was more specific in concluding that sufficient evidence exists to support associations between fungal allergen exposure and asthma exacerbation and upper respiratory disease [13]. Finally, mold toxins can cause direct lung damage leading to pulmonary diseases other than asthma [13].

The topic of residential mold has received increasing public and media attention over the past decade. Many news stories have focused on problems associated with "toxic mold" or "black mold," which is often a reference to the toxin-producing mold, *Stachybotrys chartarum*. This might give the impression that mold problems in homes are more frequent now than in past years; however, no good evidence supports this. Reasons for the increasing attention to this issue include high-visibility lawsuits brought by property owners against builders and developers, scientific controversies regarding the degree to which specific illness outbreaks are mold-induced, and an increase in the cost of homeowner insurance policies due to the increasing number of mold-related claims. Modern construction might be more vulnerable to mold problems because tighter construction makes it more difficult for internally generated water vapor to escape, as well as the widespread use of paper-backed drywall in construction (paper is an excellent medium for mold growth when wet), and the widespread use of carpeting.

Allergic Health Effects. Many molds produce numerous protein or glycoprotein allergens capable of causing allergic reactions in people. These allergens have been measured in spores as well as in other fungal fragments. An estimated 6%–10% of the general population and 15%–50% of those who are genetically susceptible are sensitized to mold allergens [13]. Fifty percent of the 937 children tested in a large multicity asthma study sponsored by the National Institutes of Health showed sensitivity to mold, indicating the importance of mold as an asthma trigger among these children [16]. Molds are thought to play a role in asthma in several ways. Molds produce many potentially allergenic compounds, and molds may play a role in asthma via release of irritants that increase potential for sensitization or release of toxins (mycotoxins) that affect immune response [13].

Toxics and Irritants. Many molds also produce mycotoxins that can be a health hazard on ingestion, dermal contact, or inhalation [14]. Although common outdoor molds present in ambient air, such as *Cladosporium cladosporioides* and *Alternaria alternata*, do not usually produce toxins, many other different mold species do [17]. Genera-producing fungi associated with wet buildings, such as *Aspergillus versicolor, Fusarium verticillioides, Penicillium aiurantiorisen,* and *S. chartarum*, can produce potent toxins [17]. A single mold species may produce several different toxins, and a given mycotoxin may be produced by more than one species of fungi. Furthermore, toxin-producing fungi do not necessarily produce mycotoxins under all growth conditions, with production being dependent on the substrate it is metabolizing, temperature, water content, and humidity [17]. Because species of toxin-producing molds generally have a higher water requirement than do common household molds, they tend to thrive only under conditions of chronic and severe water damage [18]. For example, *Stachybotrys* typically only grows under continuously wet conditions [19]. It has been suggested that very young children may be especially vulnerable to certain mycotoxins [19,20]. For example, associations have been reported for pulmonary hemorrhage (bleeding lung) deaths in infants and the presence of *S. chartarum* [21–24].

Causes of Mold. Mold growth can be caused by any condition resulting in excess moisture. Common moisture sources include rain leaks (e.g., on roofs and wall joints); surface and groundwater leaks (e.g., poorly designed or clogged rain gutters and footing drains, basement leaks); plumbing leaks; and stagnant water in appliances (e.g., dehumidifiers, dishwashers, refrigerator drip pans, and condensing coils and drip pans in HVAC systems). Moisture problems can also be due to water vapor migration and condensation problems, including uneven indoor temperatures, poor air circulation, soil air entry into basements, contact of humid unconditioned air with cooled interior surfaces, and poor insulation on indoor chilled surfaces (e.g., chilled water lines). Problems can also be caused by the production of excess moisture within homes from humidifiers, unvented clothes dryers, overcrowding, etc. Finished basements are particularly susceptible to mold problems caused by the combination of poorly controlled moisture and mold-supporting materials (e.g., carpet, paper-backed sheetrock) [15]. There is also some evidence that mold spores from damp or wet crawl spaces can be transported through air currents into the upper living quarters. Older, substandard housing low income families can be particularly prone to mold problems because of inadequate maintenance (e.g., inoperable gutters, basement and roof leaks), overcrowding, inadequate insulation, lack of air conditioning, and poor heating. Low interior temperatures (e.g., when one or two rooms are left unheated) result in an increase in the relative humidity, increasing the potential for water to condense on cold surfaces.

Mold Assessment Methods. Mold growth or the potential for mold growth can be detected by visual inspection for active or past microbial growth, detection of musty odors, and inspection for water staining or damage. If it is not possible or practical to inspect a residence, this information can be obtained using occupant questionnaires. Visual observation of mold growth, however, is limited by the fact that fungal elements such as spores are microscopic, and that their presence is often not apparent until growth is extensive and the fact that growth can occur in hidden spaces (e.g., wall cavities, air ducts).

Portable, hand-held moisture meters, for the direct measurement of moisture levels in materials, may also be useful in qualitative home assessments to aid in pinpointing areas of potential biologic growth that may not otherwise be obvious during a visual inspection [14].

For routine assessments in which the goal is to identify possible mold contamination problems before remediation, it is usually unnecessary to collect and analyze air or settled dust samples for mold analysis because decisions about appropriate intervention strategies can typically be made on the basis of a visual inspection [25]. Also, sampling and analysis costs can be relatively high and the interpretation of results is not straightforward. Air and dust monitoring may, however, be necessary in certain situations, including 1) if an individual has been diagnosed with a disease associated with fungal exposure through inhalation, 2) if it is suspected that the ventilation systems are contaminated, or 3) if the presence of mold is suspected but cannot be identified by a visual inspection or bulk sampling [26]. Generally, indoor environments contain large reservoirs of mold spores in settled dust and contaminated building materials, of which only a relatively small amount is airborne at a given time.

Common methods for sampling for mold growth include bulk sampling techniques, air sampling, and collection of settled dust samples. In bulk sampling, portions of materials with visual or suspected mold growth (e.g., sections of wallboard, pieces of duct lining, carpet segments, or return air filters) are collected and directly examined to determine if mold is growing and to identify the mold species or groups that are present. Surface sampling in mold contamination investigations may also be used when a less destructive technique than bulk sampling is desired. For example, nondestructive samples of mold may be collected using a simple swab or adhesive tape [14].

Air can also be sampled for mold using pumps that pull air across a filter medium, which traps airborne mold spores and fragments. It is generally recommended that outdoor air samples are collected concurrent with indoor samples for comparison purposes for measurement of baseline ambient air conditions. Indoor contamination can be indicated by indoor mold distributions (both species and concentrations) that differ significantly from the distributions in outdoor samples [14]. Captured mold spores can be examined under a microscope to identify the mold species/groups and determine concentrations or they can be cultured on growth media and the resulting colonies counted and identified. Both techniques require considerable expertise.

Dust sampling involves the collection of settled dust samples (e.g., floor dust) using a vacuum method in which the dust is collected onto a porous filter medium or into a container. The dust is then processed in the laboratory and the mold identified by culturing viable spores.

Mold Standards. No standard numeric guidelines exist for assessing whether mold contamination exists in an area. In the United States, no EPA regulations or standards exist for airborne mold contaminants [26]. Various governmental and private organizations have, however, proposed guidance on the interpretation of fungal measures of environmental media in indoor environments (quantitative limits for fungal concentrations).

Given evidence that young children may be especially vulnerable to certain mycotoxins [18] and in view of the potential severity or diseases associated with mycotoxin exposure, some organizations support a precautionary approach to limiting mold exposure [19]. For example, the American Academy of Pediatrics recommends that infants under 1 year of age are not exposed at all to chronically moldy, water-damaged environments [18].

Mold Mitigation. Common intervention methods for addressing mold problems include the following:

- maintaining heating, ventilating, and air conditioning (HVAC) systems;
- changing HVAC filters frequently, as recommended by manufacturer;
- keeping gutters and downspouts in working order and ensuring that they drain water away from the foundation;
- routinely checking, cleaning, and drying drip pans in air conditioners, refrigerators, and dehumidifiers;
- increasing ventilation (e.g., using exhaust fans or open windows to remove humidity when cooking, showering, or using the dishwasher);
- venting clothes dryers to the outside; and
- maintaining an ideal relative humidity level in the home of 40% to 60%.
- locating and removing sources of moisture (controlling dampness and humidity and repairing water leakage problems);
- cleaning or removing mold-contaminated materials;
- removing materials with severe mold growth; and
- using high-efficiency air filters.

Moisture Control. Because one of the most important factors affecting mold growth in homes is moisture level, controlling this factor is crucial in mold abatement strategies. Many simple measures can significantly control moisture, for example maintaining indoor relative humidity at no greater than 40%–60% through the use of dehumidifiers, fixing water leakage problems, increasing ventilation in kitchens and bathrooms by using exhaust fans, venting clothes dryers to the outside, reducing the number of indoor plants, using air conditioning at times of high outdoor humidity, heating all rooms in the winter and adding heating to outside wall closets, sloping surrounding soil away from building foundations, fixing gutters and downspouts, and using a sump pump in basements prone to flooding [27]. Vapor barriers, sump pumps, and aboveground vents can also be installed in crawlspaces to prevent moisture problems [28].

Removal and Cleaning of Mold-contaminated Materials. Nonporous (e.g., metals, glass, and hard plastics) and semiporous (e.g., wood and concrete) materials contaminated with mold and that are still structurally sound can often be cleaned with bleach-and-water solutions. However, in some cases, the material may not be easily cleaned or may be so severely contaminated that it may have to be removed. It is recommended that porous materials (e.g., ceiling tiles, wallboards, and fabrics) that cannot be cleaned be removed and discarded [29]. In severe cases, clean-up and repair of mold-contaminated buildings may be conducted using methods similar to those used for abatement of other hazardous substances such as asbestos [30]. For example, in situations of extensive colonization (large surface areas greater than 100 square feet or where the material is severely degraded), extreme precautions may be required, including full containment (complete isolation of work area) with critical barriers (airlock and decontamination room) and negative pressurization, personnel trained to handle hazardous wastes, and the use of full-face respirators with HEPA filters, eye protection, and disposable full-body covering [26].

Worker Protection When Conducting Mold Assessment and Mitigation Projects. Activities such as cleaning or removal of mold-contaminated materials in homes, as well as investigations of mold contamination extent, have the potential to disturb areas of mold growth and release fungal spores and fragments into the air. Recommended measures to protect workers during mold remediation efforts depend on the severity and nature of the mold contamination being addressed, but include the use of well fitted particulate masks or respirators that retain particles as small as 1 micrometer or less, disposable gloves and coveralls, and protective eyewear [31].

Following are examples of guidance documents for remediation of mold contamination:

- New York City Department of Health and Mental Hygiene. Guidelines on Assessment and Remediation of Fungi in Indoor Environments (available from URL: http://www.nyc.gov/html/doh/html/epi/moldrpt1.shtml).
- American Conference of Governmental Industrial Hygienists (ACGIH) 1999 document, Biosaerosols: Assessment and Control (can be ordered at URL http://www.acgih.org/home.htm).
- American Industrial Hygiene Association (AIHA) 2004 document, Assessment, Remediation, and Post-Remediation Verification of Mold in Buildings (can be ordered at URL http://www.aiha.org)
- Environmental Protection Agency guidance, Mold Remediation in Schools and Commercial Buildings (includes many general principles also applicable to residential mold mitigation efforts; available at URL: http://www.epa.gov/iaq/molds/mold_remediation.html)
- Environmental Protection Agency guidance, A Brief Guide to Mold, Moisture, and Your Home (for homeowners and renters on how to clean up residential mold problems and how to prevent mold growth; available at URL: http://www.epa.gov/iaq/molds/images/moldguide.pdf)
- Canada Mortgage and Housing Corporation, Clean-up Procedures for Mold in Houses, (provides qualitative guidance for mold mitigation; can be ordered at URL: https://www.cmhc-schl.gc.ca:50104/b2c/b2c/init.do?language=en).

Figure 5.1 shows mold growth in the home.

Figure 5.1. Mold Growth in the Home

Chemical Pollutants

Carbon Monoxide

Carbon monoxide (CO) is a significant combustion pollutant in the United States. CO is a leading cause of poisoning deaths [32]. According to the National Fire Protection Association (NFPA), CO-related nonfire deaths are often attributed to heating and cooking equipment. The leading specific types of equipment blamed for CO-related deaths include gas-fueled space heaters, gas-fueled furnaces, charcoal grills, gas-fueled ranges, portable kerosene heaters, and wood stoves.

As with fire deaths, the risk for unintentional CO death is highest for the very young (ages 4 years and younger) and the very old (ages 75 years and older). CO is an odorless, colorless gas that can cause sudden illness and death. It is a result of the incomplete combustion of carbon. Headache, dizziness, weakness, nausea, vomiting, chest pain, and confusion are the most frequent symptoms of CO poisoning. According to the American Lung Association (ALA) [33], breathing low levels of CO can cause fatigue and increase chest pain in people with chronic heart disease. Higher levels of CO can cause flulike symptoms in healthy people. In addition, extremely high levels of CO cause loss of consciousness and death. In the home, any fuel-burning appliance that is not adequately vented and maintained can be a potential source of CO. The following steps should be followed to reduce CO (as well as sulfur dioxide and oxides of nitrogen) levels:

- Never use gas-powered equipment, charcoal grills, hibachis, lanterns, or portable camping stoves in enclosed areas or indoors.

- Install a CO monitor (Figure 5.2) in appropriate areas of the home. These monitors are designed to provide a warning before potentially life-threatening levels of CO are reached.
- Choose vented appliances when possible and keep gas appliances properly adjusted to decrease the combustion to CO. (Note: Vented appliances are always preferable for several reasons: oxygen levels, carbon dioxide buildup, and humidity management).
- Only buy certified and tested combustion appliances that meet current safety standards, as certified by Underwriter's Laboratories (UL), American Gas Association (AGA) Laboratories, or equivalent.
- Assure that all gas heaters possess safety devices that shut off an improperly vented gas heater. Heaters made after 1982 use a pilot light safety system known as an oxygen depletion sensor. When inadequate fresh air exists, this system shuts off the heater before large amounts of CO can be produced.
- Use appliances that have electronic ignitions instead of pilot lights. These appliances are typically more energy efficient and eliminate the continuous low-level pollutants from pilot lights.
- Use the proper fuel in kerosene appliances.
- Install and use an exhaust fan vented to the outdoors over gas stoves.
- Have a trained professional annually inspect, clean, and tune up central heating systems (furnaces, flues, and chimneys) and repair them as needed.
- Do not idle a car inside a garage.

The U.S. Consumer Product Safety Commission (CPSC) recommends installing at least one CO alarm per household near the sleeping area. For an extra measure of safety, another alarm should be placed near the home's heating source. ALA recommends weighing the benefits of using models powered by electrical outlets versus models powered by batteries that run out of power and need replacing. Battery-powered CO detectors provide continuous protection and do not require recalibration in the event of a power outage. Electric-powered systems do not provide protection during a loss of power and can take up to 2 days to recalibrate. A device that can be easily self-tested and reset to ensure proper functioning should be chosen. The product should meet Underwriters Laboratories Standard UL 2034.

Ozone

Inhaling ozone can damage the lungs. Inhaling small amounts of ozone can result in chest pain, coughing, shortness of breath, and throat irritation. Ozone can also exacerbate chronic respiratory diseases such as asthma. Susceptibility to the effects of ozone varies from person to person, but even healthy people can experience respiratory difficulties from exposure.

Figure 5.2. Home Carbon Monoxide Monitor
Source: U.S. Navy

According to the North Carolina Department of Health and Human Services [34], the major source of indoor ozone is outdoor ozone. Indoor levels can vary from 10% of the outdoor air to levels as high as 80% of the outdoor air. The Food and Drug Administration has set a limit of 0.05 ppm of ozone in indoor air. In recent years, there have been numerous advertisements for ion generators that destroy harmful indoor air pollutants. These devices create ozone or elemental oxygen that reacts with pollutants. EPA has reviewed the evidence on ozone generators and states: "available scientific evidence shows that at concentrations that do not exceed public health standards, ozone has little potential to remove indoor air contaminants," and "there is evidence to show that at concentrations that do not exceed public health standards, ozone is not effective at removing many odor causing chemicals" [35].

Ozone is also created by the exposure of polluted air to sunlight or ultraviolet light emitters. This ozone produced outside of the home can infiltrate the house and react with indoor surfaces, creating additional pollutants.

Environmental Tobacco Smoke or Secondhand Smoke

Like CO, environmental tobacco smoke (ETS; also known as secondhand smoke), is a product of combustion. The National Cancer Institute (NCI) [36], states that ETS is the combination of two forms of smoke from burning tobacco products:

- Sidestream smoke, or smoke that is emitted between the puffs of a burning cigarette, pipe, or cigar; and
- Mainstream smoke, or the smoke that is exhaled by the smoker.

The physiologic effects of ETS are numerous. ETS can trigger asthma; irritate the eyes, nose, and throat; and cause ear infections in children, respiratory illnesses, and lung cancer. ETS is believed to cause asthma by irritating chronically inflamed bronchial passages. According to the EPA [37], ETS is a Group A carcinogen; thus, it is a known cause of cancer in humans. Laboratory analysis has revealed that ETS contains in excess of 4,000 substances, more than 60 of which cause cancer in humans or animals. The EPA also estimates that approximately 3,000 lung cancer deaths occur each year in nonsmokers due to ETS. Additionally, passive smoking can lead to coughing, excess phlegm, and chest discomfort. NCI also notes that spontaneous abortion (miscarriage), cervical cancer, sudden infant death syndrome, low birth weight, nasal sinus cancer, decreased lung function, exacerbation of cystic fibrosis, and negative cognitive and behavioral effects in children have been linked to ETS [36].

The EPA [37] states that, because of their relative body size and respiratory rates, children are affected by ETS more than adults are. It is estimated that an additional 7,500 to 15,000 hospitalizations resulting from increased respiratory infections occur in children younger than 18 months of age due to ETS exposure. Figure 5.3 shows the ETS exposure levels in homes with children under age 7 years. The following actions are recommended in the home to protect children from ETS:

- if individuals insist on smoking, increase ventilation in the smoking area by opening windows or using exhaust fans; and
- refrain from smoking in the presence of children and do not allow babysitters or others who work in the home to smoke in the home or near children.

Volatile Organic Compounds

In the modern home, many organic chemicals are used as ingredients in household products. Organic chemicals that vaporize and become gases at normal room temperature are collectively known as VOCs.

Examples of common items that can release VOCs include paints, varnishes, and wax, as well as in many cleaning, disinfecting, cosmetic, degreasing, and hobby products. Levels of approximately a dozen common VOCs can be two to five times higher inside the home, as opposed to outside, whether in highly industrialized areas or rural areas. VOCs that frequently pollute indoor air include toluene, styrene, xylenes, and trichloroethylene. Some of these chemicals may be emitted from aerosol products, dry-cleaned clothing, paints, varnishes, glues, art supplies, cleaners, spot removers, floor waxes, polishes, and air fresheners. The health effects of these chemicals are varied. Trichlorethylene has been linked to childhood leukemia. Exposure to toluene can put pregnant women at risk for having babies with neurologic problems, retarded growth, and developmental problems. Xylenes have been linked to birth defects. Styrene is a suspected endocrine disruptor, a chemical that can block or mimic hormones in humans or animals. EPA data reveal that methylene chloride, a common component of some paint strippers, adhesive removers, and specialized aerosol spray paints, causes cancer in animals [38]. Methylene chloride is also converted to CO in the body and can cause symptoms associated with CO exposure. Benzene, a known human carcinogen, is contained in tobacco smoke, stored fuels, and paint supplies. Perchloroethylene, a product uncommonly found in homes, but common to dry cleaners, can be a pollution source by off-gassing from newly cleaned clothing. Environmental Media Services [39] also notes that xylene, ketones, and aldehydes are used in aerosol products and air fresheners.

To lower levels of VOCs in the home, follow these steps:

- use all household products according to directions;
- provide good ventilation when using these products;
- properly dispose of partially full containers of old or unneeded chemicals;
- purchase limited quantities of products; and
- minimize exposure to emissions from products containing methylene chloride, benzene, and perchlorethylene.

A prominent VOC found in household products and construction products is formaldehyde. According to CPSC [40], these products include the glue or adhesive used in pressed wood products; preservatives in paints, coating, and cosmetics; coatings used for permanent-press quality in fabrics and draperies; and the finish on paper products and certain insulation materials. Formaldehyde

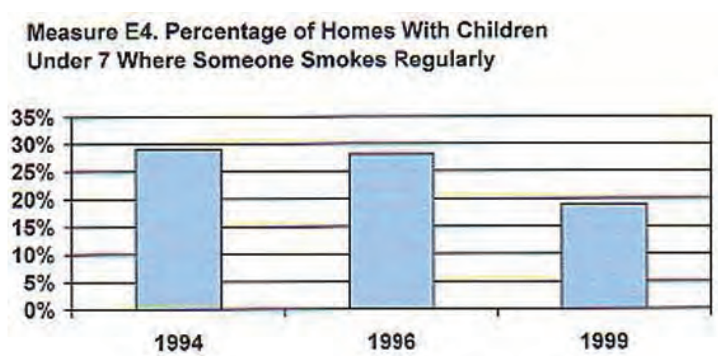

Figure 5.3. Environmental Tobacco Smoke and Children's Exposure [37]

is contained in urea-formaldehyde (UF) foam insulation installed in the wall cavities of homes as an energy conservation measure. Levels of formaldehyde increase soon after installation of this product, but these levels decline with time. In 1982, CPSC voted to ban UF foam insulation. The courts overturned the ban; however, the publicity has decreased the use of this product.

More recently, the most significant source of formaldehyde in homes has been pressed wood products made using adhesives that contain UF resins [41]. The most significant of these is medium-density fiberboard, which contains a higher resin-to-wood ratio than any other UF pressed wood product. This product is generally recognized as being the highest formaldehyde-emitting pressed wood product. Additional pressed wood products are produced using phenol-formaldehyde resin. The latter type of resin generally emits formaldehyde at a considerably slower rate than those containing UF resin. The emission rate for both resins will change over time and will be influenced by high indoor temperatures and humidity. Since 1985, U.S. Department of Housing and Urban Development (HUD) regulations (24 CFR 3280.308, 3280.309, and 3280.406) have permitted only the use of plywood and particleboard that conform to specified formaldehyde emission limits in the construction of prefabricated and manufactured homes [42]. This limit was to ensure that indoor formaldehyde levels are below 0.4 ppm.

CPSC [40] notes that formaldehyde is a colorless, strong-smelling gas. At an air level above 0.1 ppm, it can cause watery eyes; burning sensations in the eyes, nose, and throat; nausea; coughing; chest tightness; wheezing; skin rashes; and allergic reactions. Laboratory animal studies have revealed that formaldehyde can cause cancer in animals and may cause cancer in humans. Formaldehyde is usually present at levels less than 0.03 ppm indoors and outdoors, with rural areas generally experiencing lower concentrations than urban areas. Indoor areas that contain products that release formaldehyde can have levels greater than 0.03 ppm. CPSC also recommends the following actions to avoid high levels of exposure to formaldehyde:

- Purchase pressed wood products that are labeled or stamped to be in conformance with American National Standards Institute criteria ANSI A208.1-1993. Use particleboard flooring marked with ANSI grades PBU, D2, or D3. Medium-density fiberboard should be in conformance with ANSI A208.2-1994 and hardwood plywood with ANSI/HPVA HP-1-1994 (Figure 5.4).

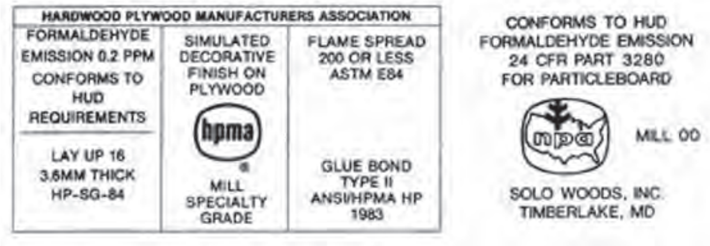

Figure 5.4. Wood Products Label [42]

- Purchase furniture or cabinets that contain a high percentage of panel surface and edges that are laminated or coated. Unlaminated or uncoated (raw) panels of pressed wood panel products will generally emit more formaldehyde than those that are laminated or coated.
- Use alternative products, such as wood panel products not made with UF glues, lumber, or metal.
- Avoid the use of foamed-in-place insulation containing formaldehyde, especially UF foam insulation.
- Wash durable-press fabrics before use.

CPSC also recommends the following actions to reduce existing levels of indoor formaldehyde:

- Ventilate the home well by opening doors and windows and installing an exhaust fan(s).
- Seal the surfaces of formaldehyde-containing products that are not laminated or coated with paint, varnish, or a layer of vinyl or polyurethane-like materials.
- Remove products that release formaldehyde in the indoor air from the home.

Radon

According to the EPA [43], radon is a colorless, odorless gas that occurs naturally in soil and rock and is a decay product of uranium. The U.S. Geological Survey (USGS) [44] notes that the typical uranium content of rock and the surrounding soil is between 1 and 3 ppm. Higher levels of uranium are often contained in rock such as light-colored volcanic rock, granite, dark shale, and sedimentary rock containing phosphate. Uranium levels as high as 100 ppm may be present in various areas of the United States because of these rocks. The main source of high-level radon pollution in buildings is surrounding uranium-containing soil. Thus, the greater the level of uranium nearby, the greater the chances are that buildings in the area will have high levels of indoor radon. Figure 5.5 demonstrates the geographic variation in radon levels in the United States. Maps of the individual states and areas that have proven high for radon are available at

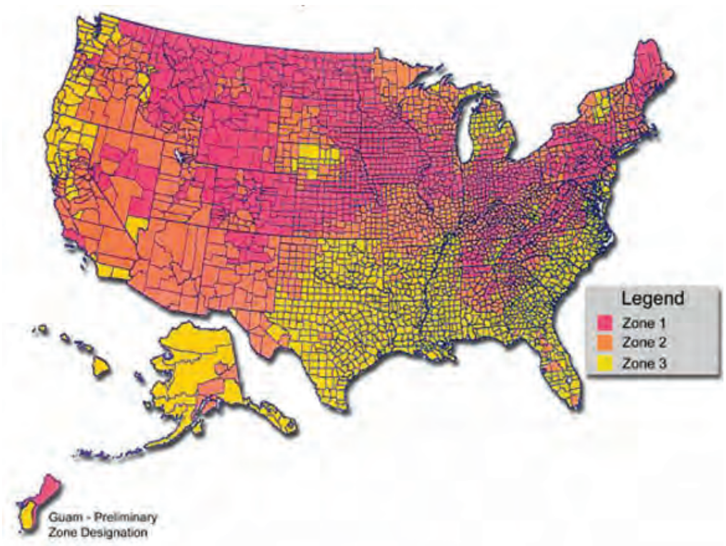

Figure 5.5. EPA Map of Radon Zones [43]
Zone 1: predicted average indoor radon screening level greater than 4 pCi/L [picocuries per liter]
Zone 2: predicted average indoor radon screening level between 2 and 4 pCi/L
Zone 3: predicted average indoor radon screening level less than 2 pCi/L
Important: Consult the EPA Map of Radon Zones document [EPA-402-R-93-071] before using this map. This document contains information on radon potential variations within counties.
EPA also recommends that this map be supplemented with any available local data to further understand and predict the radon potential of a specific area.

http://www.epa.gov/iaq/radon/ zonemap.html. A free video is available from the U.S. EPA: call 1-800-438-4318 and ask for EPA 402-V-02-003 (TRT 13.10).

Radon, according to the California Geological Survey [45], is one of the intermediate radioactive elements formed during the radioactive decay of uranium-238, uranium-235, or thorium-232. Radon-222 is the radon isotope of most concern to public health because of its longer half-life (3.8 days). The mobility of radon gas is much greater than are uranium and radium, which are solids at room temperature. Thus, radon can leave rocks and soil, move through fractures and pore spaces, and ultimately enter a building to collect in high concentrations. When in water, radon moves less than 1 inch before it decays, compared to 6 feet or more in dry rocks or soil. USGS [44] notes that radon near the surface of soil typically escapes into the atmosphere. However, where a house is present, soil air often flows toward the house foundation because of

- differences in air pressure between the soil and the house, with soil pressure often being higher;
- presence of openings in the house's foundation; and
- increases in permeability around the basement (if present).

Houses are often constructed with loose fill under a basement slab and between the walls and exterior ground. This fill is more permeable than the original ground. Houses typically draw less than 1% of their indoor air from the soil. However, houses with low indoor air pressures, poorly sealed foundations, and several entry points for soil air may draw up to 20% of their indoor air from the soil.

USGS [44] states that radon may also enter the home through the water systems. Surface water sources typically contain little radon because it escapes into the air. In larger cities, radon is released to the air by municipal processing systems that aerate the water. However, in areas where groundwater is the main water supply for communities, small public systems and private wells are typically closed systems that do not allow radon to escape. Radon then enters the indoor air from showers, clothes washing, dishwashing, and other uses of water. Figure 5.6 shows typical entry points of radon.

Health risks of radon stem from its breakdown into "radon daughters," which emit high-energy alpha particles. These progeny enter the lungs, attach themselves, and may eventually lead to lung cancer. This exposure to radon is believed to contribute to between 15,000 and 21,000 excess lung cancer deaths in the United States each year. The EPA has identified levels greater than 4 picocuries per liter as levels at which remedial action should be taken. Approximately 1 in 15 homes nationwide have radon above this level, according to the U.S. Surgeon General's recent advisory [46]. Smokers are at significantly higher risk for radon-related lung cancer.

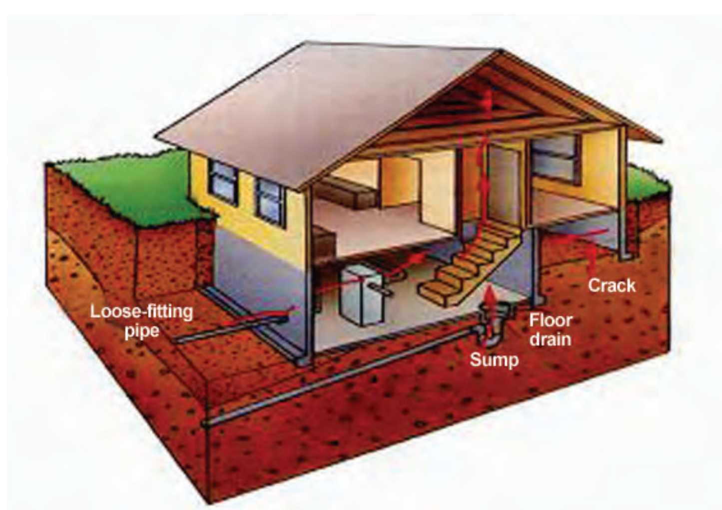

Figure 5.6. Radon Entry [30]

Radon in the home can be measured either by the occupant or by a professional. Because radon has no odor or color, special devices are used to measure its presence. Radon levels vary from day to day and season to season. Short-term tests (2 to 90 days) are best if quick results are needed, but long-term tests (more than 3 months) yield better information on average year-round exposure. Measurement devices are routinely placed in the lowest occupied level of the home. The devices either measure the radon gas directly or the daughter products. The simplest devices are passive, require no electricity, and include a charcoal canister, charcoal liquid scintillation device, alpha tract detector, and electret ion detectors [47].

All of these devices, with the exception of the ion detector, can be purchased in hardware stores or by mail. The ion detector generally is only available through laboratories. These devices are inexpensive, primarily used for short-term testing, and require little to no training. Active devices, however, need electrical power and include continuous monitoring devices. They are customarily more expensive and require professionally trained testers for their operation. Figure 5.7 shows examples of the charcoal tester (a; left) and the alpha tract detector (b; right).

After testing and evaluation by a professional, it may be necessary to lower the radon levels in the structure. The Pennsylvania Department of Environmental Protection [48] states that in most cases, a system with pipes and a fan is used to reduce radon. This system, known as a subslab depressurization system, requires no major changes to the home. The cost typically ranges from $500 to $2,500 and averages approximately $1,000, varying with geographic region. The typical mitigation system usually has only one pipe penetrating through the basement floor; the pipe also may be installed outside the house. The Connecticut Department of Public Health [49] notes that it is more cost effective to include radon-resistant techniques while constructing a building than to install a reduction system in an existing home. Inclusion of radon-resistant techniques in initial construction costs approximately $350 to $500 [50]. Figure 5.8 shows examples of radon-resistant construction techniques.

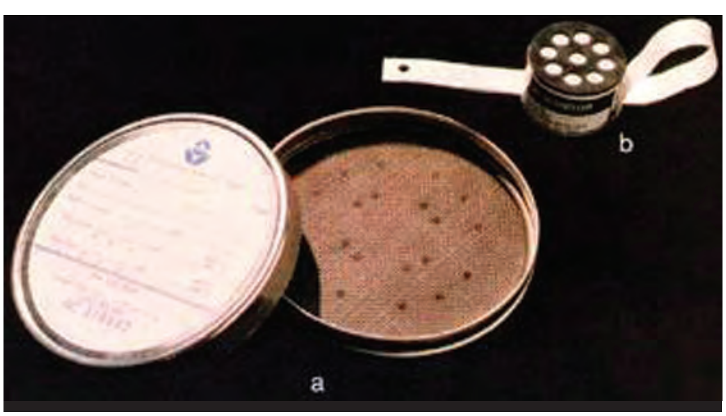

Figure 5.7. Home Radon Detectors [31]

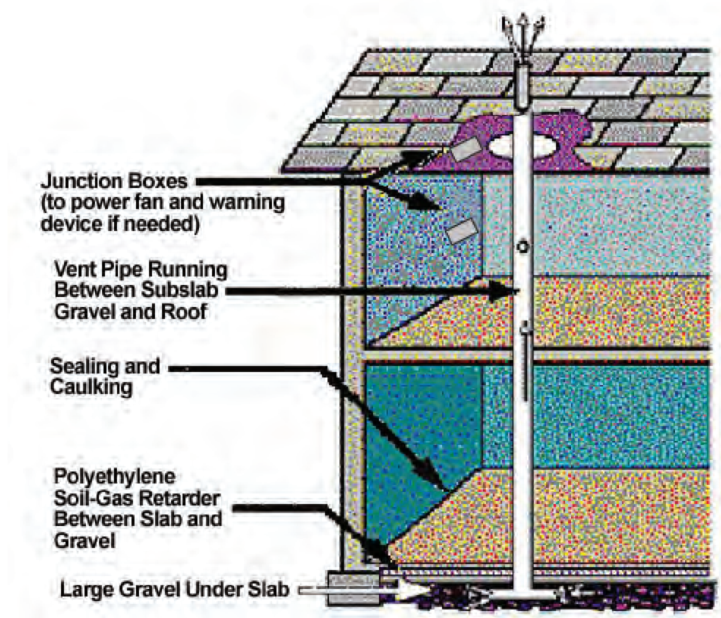

Figure 5.8. Radon-resistant Construction [50]

A passive radon-resistant system has five major parts:

1. A layer of gas-permeable material under the foundation.
2. The foundation (usually 4 inches of gravel).
3. Plastic sheeting over the foundation, with all openings in the concrete foundation floor sealed and caulked.
4. A gas-tight, 3- or 4-inch vent pipe running from under the foundation through the house to the roof.
5. A roughed-in electrical junction box for the future installation of a fan, if needed.

These features create a physical barrier to radon entry. The vent pipe redirects the flow of air under the foundation, preventing radon from seeping into the house.

Pesticides

Much pesticide use could be reduced if integrated pest management (IPM) practices were used in the home. IPM is a coordinated approach to managing roaches, rodents, mosquitoes, and other pests that integrates inspection, monitoring, treatment, and evaluation, with special emphasis on the decreased use of toxic agents. However, all pest management options, including natural, biologic, cultural, and chemical methods, should be considered. Those that have the least impact on health and the environment should be selected. Most household pests can be controlled by eliminating the habitat for the pest both inside and outside, building or screening them out, eliminating food and harborage areas, and safely using appropriate pesticides if necessary.

EPA [51] states that 75% of U.S. households used at least one pesticide indoors during the past year and that 80% of most people's exposure to pesticides occurs indoors. Measurable levels of up to a dozen pesticides have been found in the air inside homes. Pesticides used in and around the home include products to control insects (insecticides), termites (termiticides), rodents (rodenticides), fungi (fungicides), and microbes (disinfectants). These products are found in sprays, sticks, powders, crystals, balls, and foggers.

Delaplane [52] notes that the ancient Romans killed insect pests by burning sulfur and controlled weeds with salt. In the 1600s, ants were controlled with mixtures of honey and arsenic. U.S. farmers in the late 19th century used copper actoarsenite (Paris green), calcium arsenate, nicotine sulfate, and sulfur to control insect pests in field crops. By World War II and afterward, numerous pesticides had been introduced, including DDT, BHC, aldrin, dieldrin, endrin, and 2,4-D. A significant factor with regard to these pesticides used in and around the home is their impact on children. According to a 2003 EPA survey, 47% of all households with children under the age of 5 years had at least one pesticide stored in an unlocked cabinet less than 4 feet off the ground. This is within easy reach of children. Similarly, 74% of households without children under the age of 5 also stored pesticides in an unlocked cabinet less than 4 feet off the ground. This issue is significant because 13% of all pesticide poisoning incidents occur in homes other than the child's home. The EPA [53] notes a report by the American Association of Poison Control Centers indicating that approximately 79,000 children were involved in common household pesticide poisonings or exposures.

The health effects of pesticides vary with the product. However, local effects from most of the products will be on eyes, noses, and throats; more severe consequences, such as on the central nervous system and kidneys and on cancer risks, are possible. The active and inert ingredients of pesticides can be organic compounds, which can contribute to the level of organic compounds in indoor air. More significantly, products containing cyclodiene pesticides have been commonly associated with misapplication. Individuals inadvertently exposed during this misapplication had numerous symptoms, including headaches, dizziness, muscle twitching, weakness, tingling sensations, and nausea. In addition, there is concern that these pesticides may cause long-term damage to the liver and the central nervous system, as well as an increased cancer risk. Cyclodiene pesticides were developed for use as insecticides in the 1940s and 1950s. The four main cyclodiene pesticides—aldrin, dieldrin, chlordane, and heptachlor—were used to guard soil and seed against insect infestation and to control insect pests in crops. Outside of agriculture they were used for ant control; farm, industrial, and domestic control of fleas, flies, lice, and mites; locust control; termite control in buildings, fences, and power poles; and pest control in home gardens. No other commercial use is permitted for cyclodiene or related products. The only exception is the use of heptachlor by utility companies to control fire ants in underground cable boxes.

An EPA survey [53] revealed that bathrooms and kitchens are areas in the home most likely to have improperly stored pesticides. In the United States, EPA regulates pesticides under the pesticide law known as the Federal Insecticide, Fungicide, and Rodenticide Act. Since 1981, this law has required most residential-use pesticides to bear a signal word such as "danger" or "warning" and to be contained in child-resistant packaging. This type of packaging is designed to prevent or delay access by most children under the age of 5 years. EPA offers the following recommendations for preventing accidental poisoning:

- store pesticides away from the reach of children in a locked cabinet, garden shed, or similar location;
- read the product label and follow all directions exactly, especially precautions and restrictions;
- remove children, pets, and toys from areas before applying pesticides;
- if interrupted while applying a pesticide, properly close the package and assure that the container is not within reach of children;
- do not transfer pesticides to other containers that children may associate with food or drink;
- do not place rodent or insect baits where small children have access to them;
- use child-resistant packaging properly by closing the container tightly after use;
- assure that other caregivers for children are aware of the potential hazards of pesticides;

- teach children that pesticides are poisons and should not be handled; and
- keep the local Poison Control Center telephone number available.

Toxic Materials

Asbestos

Asbestos, from the Greek word meaning "inextinguishable," refers to a group of six naturally occurring mineral fibers. Asbestos is a mineral fiber of which there are several types: amosite, crocidiolite, tremolite, actinolite, anthrophyllite, and chrysotile. Chrysotile asbestos, also known as white asbestos, is the predominant commercial form of asbestos. Asbestos is strong, flexible, resistant to heat and chemical corrosion, and insulates well. These features led to the use of asbestos in up to 3,000 consumer products before government agencies began to phase it out in the 1970s because of its health hazards. Asbestos has been used in insulation, roofing, siding, vinyl floor tiles, fireproofing materials, texturized paint and soundproofing materials, heating appliances (such as clothes dryers and ovens), fireproof gloves, and ironing boards. Asbestos continues to be used in some products, such as brake pads. Other mineral products, such as talc and vermiculite, can be contaminated with asbestos.

The health effects of asbestos exposure are numerous and varied. Industrial studies of workers exposed to asbestos in factories and shipyards have revealed three primary health risk concerns from breathing high levels of asbestos fibers: lung cancer, mesothelioma (a cancer of the lining of the chest and the abdominal cavity), and asbestosis (a condition in which the lungs become scarred with fibrous tissue). The verification code for this document is 447229.

The risk for all of these conditions is amplified as the number of fibers inhaled increases. Smoking also enhances the risk for lung cancer from inhaling asbestos fibers by acting synergistically. The incubation period (from time of exposure to appearance of symptoms) of these diseases is usually about 20 to 30 years. Individuals who develop asbestosis have typically been exposed to high levels of asbestos for a long time. Exposure levels to asbestos are measured in fibers per cubic centimeter of air. Most individuals are exposed to small amounts of asbestos in daily living activities; however, a preponderance of them do not develop health problems. According to the Agency for Toxic Substances and Disease Registry (ATSDR), if an individual is exposed, several factors determine whether the individual will be harmed [54]. These factors include the dose (how much), the duration (how long), and the fiber type (mineral form and distribution). ATSDR also states that children may be more adversely affected than adults [54]. Children breathe differently and have different lung structures than adults; however, it has not been determined whether these differences cause a greater amount of asbestos fibers to stay in the lungs of a child than in the lungs of an adult. In addition, children drink more fluids per kilogram of body weight than do adults and they can be exposed through asbestos-contaminated drinking water. Eating asbestos-contaminated soil and dust is another source of exposure for children. Certain children intentionally eat soil and children's hand-to-mouth activities mean that all young children eat more soil than do adults. Family members also have been exposed to asbestos that was carried home on the clothing of other family members who worked in asbestos mines or mills. Breathing asbestos fibers may result in difficulty in breathing. Diseases usually appear many years after the first exposure to asbestos and are therefore not likely to be seen in children. But people who have been exposed to asbestos at a young age may be more likely to contract diseases than those who are first exposed later in life. In the small number of studies that have specifically looked at asbestos exposure in children, there is no indication that younger people might develop asbestos-related diseases more quickly than older people. Developing fetuses and infants are not likely to be exposed to asbestos through the placenta or breast milk of the mother. Results of animal studies do not indicate that exposure to asbestos is likely to result in birth defects.

A joint document issued by CPSC, EPA, and ALA, notes that most products in today's homes do not contain asbestos. However, asbestos can still be found in products and areas of the home. These products contain asbestos that could be inhaled and are required to be labeled as such. Until the 1970s, many types of building products and insulation materials used in homes routinely contained asbestos. A potential asbestos problem both inside and outside the home is that of vermiculite. According to the USGS [55], vermiculite is a claylike material that expands when heated to form wormlike particles. It is used in concrete aggregate, fertilizer carriers, insulation, potting soil, and soil conditioners. This product ceased being mined in 1992, but old stocks may still be available. Common products that contained asbestos in the past and conditions that may release fibers include the following:

- Steam pipes, boilers, and furnace ducts insulated with an asbestos blanket or asbestos paper tape. These materials may release asbestos fibers if damaged, repaired, or removed improperly.

- Resilient floor tiles (vinyl asbestos, asphalt, and rubber), the backing on vinyl sheet flooring, and adhesives used for installing floor tile. Sanding tiles can release fibers, as may scraping or sanding the backing of sheet flooring during removal.
- Cement sheet, millboard, and paper used as insulation around furnaces and wood-burning stoves. Repairing or removing appliances may release asbestos fibers, as may cutting, tearing, sanding, drilling, or sawing insulation.
- Door gaskets in furnaces, wood stoves, and coal stoves. Worn seals can release asbestos fibers during use.
- Soundproofing or decorative material sprayed on walls and ceilings. Loose, crumbly, or water-damaged material may release fibers, as will sanding, drilling, or scraping the material.
- Patching and joint compounds for walls, ceilings, and textured paints. Sanding, scraping, or drilling these surfaces may release asbestos.
- Asbestos cement roofing, shingles, and siding. These products are not likely to release asbestos fibers unless sawed, drilled, or cut.
- Artificial ashes and embers sold for use in gas-fired fireplaces in addition to other older household products such as fireproof gloves, stove-top pads, ironing board covers, and certain hair dryers.
- Automobile brake pads and linings, clutch facings, and gaskets.

Homeowners who believe material in their home may be asbestos should not disturb the material. Generally, material in good condition will not release asbestos fibers, and there is little danger unless the fibers are released and inhaled into the lungs. However, if disturbed, asbestos material may release asbestos fibers, which can be inhaled into the lungs. The fibers can remain in the lungs for a long time, increasing the risk for disease. Suspected asbestos-containing material should be checked regularly for damage from abrasions, tears, or water. If possible, access to the area should be limited. Asbestos-containing products such as asbestos gloves, stove-top pads, and ironing board covers should be discarded if damaged or worn. Permission and proper disposal methods should be obtainable from local health, environmental, or other appropriate officials. If asbestos material is more than slightly damaged, or if planned changes in the home might disturb it, repair or removal by a professional is needed. Before remodeling, determine whether asbestos materials are present.

Only a trained professional can confirm suspected asbestos materials that are part of a home's construction. This individual will take samples for analysis and submit them to an EPA-approved laboratory.

If the asbestos material is in good shape and will not be disturbed, the best approach is to take no action and continue to monitor the material. If the material needs action to address potential exposure problems, there are two approaches to correcting the problem: repair and removal.

Repair involves sealing or covering the asbestos material. Sealing or encapsulation involves treating the material with a sealant that either binds the asbestos fibers together or coats the material so fibers are not released. This is an approach often used for pipe, furnace, and boiler insulation; however, this work should be done only by a professional who is trained to handle asbestos safely. Covering (enclosing) involves placing something over or around the material that contains asbestos to prevent release of fibers. Exposed insulated piping may be covered with a protective wrap or jacket. In the repair process, the approach is for the material to remain in position undisturbed. Repair is a less expensive process than is removal.

With any type of repair, the asbestos remains in place. Repair may make later removal of asbestos, if necessary, more difficult and costly. Repairs can be major or minor. Both major and minor repairs must be done only by a professional trained in methods for safely handling asbestos.

Removal is usually the most expensive and, unless required by state or local regulations, should be the last option considered in most situations. This is because removal poses the greatest risk for fiber release. However, removal may be required when remodeling or making major changes to the home that will disturb asbestos material. In addition, removal may be called for if asbestos material is damaged extensively and cannot be otherwise repaired. Removal is complex and must be done only by a contractor with special training. Improper removal of asbestos material may create more of a problem than simply leaving it alone.

Lead

Many individuals recognize lead in the form often seen in tire weights and fishing equipment, but few recognize its various forms in and around the home. The Merriam-Webster Dictionary [56] defines lead as "a heavy soft malleable ductile plastic but inelastic bluish white metallic element found mostly in combination and used especially in pipes, cable sheaths, batteries, solder, and shields against radioactivity." Lead is a metal with many uses. It melts easily and quickly. It can be molded or shaped into thin sheets and can be drawn out into wire or threads. Lead also is very resistant to weather conditions. Lead and lead compounds are toxic and can present a severe hazard to those who are overexposed to them. Whether ingested or inhaled, lead is readily absorbed and distributed throughout the body.

Until 1978, lead compounds were an important component of many paints. Lead was added to paint to promote adhesion, corrosion control, drying, and covering. White lead (lead carbonate), linseed oil, and inorganic pigments were the basic components for paint in the 18th and 19th centuries, and continued until the middle of the 20th century. Lead was banned by CPSC in 1978. Lead-based paint was used extensively on exteriors and interior trim-work, window sills, sashes, window frames, baseboards, wainscoting, doors, frames, and high-gloss wall surfaces, such as those found in kitchens and bathrooms. The only way to determine which building components are coated with lead paint is through an inspection for lead-based paint. Almost all painted metals were primed with red lead or painted with lead-based paints. Even milk (casein) and water-based paints (distemper and calcimines) could contain some lead, usually in the form of hiding agents or pigments. Varnishes sometimes contained lead. Lead compounds also were used as driers in paint and window-glazing putty.

Lead is widespread in the environment. People absorb lead from a variety of sources every day. Although lead has been used in numerous consumer products, the most important sources of lead exposure to children and others today are the following:

- contaminated house dust that has settled on horizontal surfaces,
- deteriorated lead-based paint,
- contaminated bare soil,
- food (which can be contaminated by lead in the air or in food containers, particularly lead-soldered food containers),
- drinking water (from corrosion of plumbing systems), and
- occupational exposure or hobbies.

Federal controls on lead in gasoline, new paint, food canning, and drinking water, as well as lead from industrial air emissions, have significantly reduced total human exposure to lead. The number of children with blood lead levels above 10 micrograms per deciliter (µg/dL), a level designated as showing no physiologic toxicity, has declined from 1.7 million in the late 1980s to 310,000 in 1999–2002. This demonstrates that the controls have been effective, but that many children are still at risk. CDC data show that deteriorated lead-based paint and the contaminated dust and soil it generates are the most common sources of exposure to children today. HUD data show that the number of houses with lead paint declined from 64 million in 1990 to 38 million in 2000 [57].

Children are more vulnerable to lead poisoning than are adults. Infants can be exposed to lead in the womb if their mothers have lead in their bodies. Infants and children can swallow and breathe lead in dirt, dust, or sand through normal hand-to-mouth contact while they play on the floor or ground. These activities make it easier for children to be exposed to lead. Other sources of exposure have included imported vinyl miniblinds, crayons, children's jewelry, and candy. In 2004, increases in lead in water service pipes were observed in Washington, D.C., accompanied by increases in blood lead levels in children under the age of 6 years who were served by the water system [58].

In some cases, children swallow nonfood items such as paint chips. These may contain very large amounts of lead, particularly in and around older houses that were painted with lead-based paint. Many studies have verified the effect of lead exposure on IQ scores in the United States. The effects of lead exposure have been reviewed by the National Academy of Sciences [59].

Generally, the tests for blood lead levels are from drawn blood, not from a finger-stick test, which can be unreliable if performed improperly. Units are measured in micrograms per deciliter and reflect the 1991 guidance from the Centers of Disease Control [60]:

- Children: 10 µg/dL (level of concern)—find source of lead;
- Children: 15 µg/dL and above—environmental intervention, counseling, medical monitoring;
- Children: 20 µg/dL and above—medical treatment;
- Adults: 25 µg/dL (level of concern)—find source of lead; and
- Adults: 50 µg/dL—Occupational Safety and Health Administration (OSHA) standard for medical removal from the worksite.

Adults are usually exposed to lead from occupational sources (e.g., battery construction, paint removal) or at home (e.g., paint removal, home renovations).

In 1978, CPSC banned the use of lead-based paint in residential housing. Because houses are periodically repainted, the most recent layer of paint will most likely not contain lead, but the older layers underneath probably will. Therefore, the only way to accurately determine the amount of lead present in older paint is to have it analyzed.

It is important that owners of homes built before 1978 be aware that layers of older paint can contain a great deal of lead. Guidelines on identifying and controlling lead-based paint hazards in housing have been published by HUD [61].

Controlling Lead Hazards

The purpose of a home risk assessment is to determine, through testing and evaluation, where hazards from lead warrant remedial action. A certified inspector or risk assessor can test paint, soil, or lead dust either on-site or in a laboratory using methods such as x-ray fluorescence (XRF) analyzers, chemicals, dust wipe tests, and atomic absorption spectroscopy. Lists of service providers are available by calling 1-800-424-LEAD. Do-it-yourself test kits are commercially available; however, these kits do not tell you how much lead is present, and their reliability at detecting low levels of lead has not been determined. Professional testing for lead in paint is recommended. The recommended sampling method for dust is the surface wet wipe. Dust samples are collected from different surfaces, such as bare floors, window sills, and window wells. Each sample is collected from a measured surface area using a wet wipe, which is sent to a laboratory for testing. Risk assessments can be fairly low-cost investigations of the location, condition, and severity of lead hazards found in house dust, soil, water, and deteriorating paint. Risk assessments also will address other sources of lead from hobbies, crockery, water, and work environments. These services are critical when owners are seeking to implement measures to reduce suspected lead hazards in housing and day-care centers or when extensive rehabilitation is planned.

HUD has published detailed protocols for risk assessments and inspections [61].

It is important from a health standpoint that future tenants, painters, and construction workers know that lead-based paint is present, even under treated surfaces, so they can take precautions when working in areas that will generate lead dust. Whenever mitigation work is completed, it is important to have a clearance test using the dust wipe method to ensure that lead-laden dust generated during the work does not remain at levels above those established by the EPA and HUD. Such testing is required for owners of most housing that is receiving federal financial assistance, such as Section 8 rental housing. A building or housing file should be maintained and updated whenever any additional lead hazard control work is completed. Owners are required by law to disclose information about lead-based paint or lead-based paint hazards to buyers or tenants before completing a sales or lease contract [62].

All hazards should be controlled as identified in a risk assessment.

Whenever extensive amounts of lead must be removed

Action Levels for Lead

Lead in paint. Differing methods report results in differing units. Lead is considered a potential hazard if above the following levels, but can be a hazard at lower levels if improperly handled. Below are the current action levels identified by HUD [62] and EPA (40 CFR Part 745):

Lab analysis of samples:
5,000 milligram per kilogram (mg/kg) or 5,000 parts per million (ppm) 0.5% lead by weight.

X-ray fluorescence:
1 milligram per square centimeter (mg/cm^2)

Lead in dust:
Floors, 40 micrograms per square foot (µg/ft^2)

Window sills, 250 µg/ft^2 Window troughs, 400 µg/ft^2 (clearance only)

Lead in soil:
High-contact bare play areas: 400 ppm

Other yard areas: 1,200 ppm

from a property, or when methods of removing toxic substances will affect the environment, it is extremely important that the owner be aware of the issues surrounding worker safety, environmental controls, and proper disposal. Appropriate architectural, engineering, and environmental professionals should be consulted when lead hazard projects are complex.

Following are brief explanations of the two approaches for controlling lead hazard risks. These controls are recommended by HUD in HUD *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing* [61], and are summarized here to focus on special considerations for historic housing:

Interim Controls. Short-term solutions include thorough dust removal and thorough washdown and cleanup, paint film stabilization and repainting, covering of lead-contaminated soil, and informing tenants about lead hazards. Interim controls require ongoing maintenance and evaluation.

Hazard Abatement. Long-term solutions are defined as having an expected life of 20 years or more and involve permanent removal of hazardous paint through chemicals, heat guns, or controlled sanding or abrasive methods; permanent removal of deteriorated painted features through replacement; removal or permanent covering of contaminated soil; and the use of enclosures (such as drywall) to isolate painted surfaces. The use of specialized encapsulant products can be considered as permanent abatement of lead.

Reducing and controlling lead hazards can be successfully accomplished without destroying the character-defining features and finishes of historic buildings. Federal and state laws generally support the reasonable control of lead-based paint hazards through a variety of treatments, ranging from modified maintenance to selective substrate removal. The key to protecting children, workers, and the environment is to be informed about the hazards of lead, to control exposure to lead dust and lead in soil and lead paint chips, and to follow existing regulations.

The following summarizes several important regulations that affect lead-hazard reduction projects. Owners should be aware that regulations change, and they have a responsibility to check state and local ordinances as well. Care must be taken to ensure that any procedures used to release lead from the home protect both the residents and workers from lead dust exposure.

Residential Lead-Based Paint Hazard Reduction Act of 1992, Title X [62]. Part of the Housing and Community Development Act of 1992 (Public Law 102-550) [63]. It established that HUD issue *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing* [61] to outline risk assessments, interim controls, and abatement of lead-based paint hazards in housing. Title X calls for the reduction of lead in federally supported housing. It outlines the federal responsibility toward its own residential units and the need for disclosure of lead in residences, even private residences, before a sale. Title X also required HUD to establish regulations for federally assisted housing (24 CFR Part 35) and EPA to establish

Definitions Related to Lead

Deteriorated lead-based paint: Paint known to contain lead above the regulated level that shows signs of peeling, chipping, chalking, blistering, alligatoring, or otherwise separating from its substrate.

Dust removal: The process of removing dust to avoid creating a greater problem of spreading lead particles; usually through wet or damp collection and use of HEPA vacuums.

Hazard abatement: Long-term measures to remove the hazards of lead-based paint through replacement of building components, enclosure, encapsulation, or paint removal.

Interim control: Short-term methods to remove lead dust, stabilize deteriorating painted surfaces, treat friction and impact surfaces that generate lead dust, and repaint surfaces. Maintenance can ensure that housing remains lead-safe.

Lead-based paint: Any existing paint, varnish, shellac, or other coating that is equal to or greater than 1.0 milligrams per square centimeter (mg/cm^2) or greater than 0.5% by weight (5,000 ppm, 5,000 micrograms per gram [µg/g], or 5,000 milligrams per kilogram [mg/kg]). For new paint, CPSC has established 0.06% as the maximum amount of lead allowed in new paint. Lead in paint can be measured by x-ray fluorescence analyzers or laboratory analysis by certified personnel and approved laboratories.

Risk assessment: An on-site investigation to determine the presence and condition of lead-based paint, including limited test samples and an evaluation of the age, condition, housekeeping practices, and uses of a residence.

standards for lead in paint, dust, and soil, as well as standards for laboratory accreditation (40 CFR Part 745). EPA's residential lead hazard standards are available at http://www.epa.gov/lead/leadhaz.htm.

Interim Final Rule on Lead in Construction (29 Code of Federal Regulations [CFR] 1926.62) [64]. Issued by OSHA, these regulations address worker safety, training, and protective measures. The regulations are based in part on personal-air sampling to determine the amount of lead dust exposure to workers.

State Laws. States generally have the authority to regulate the removal and transportation of lead-based paint and the generated waste through the appropriate state environmental and public health agencies. Most requirements are for mitigation in the case of a lead-poisoned child, for protection of children, or for oversight to ensure the safe handling and disposal of lead waste. When undertaking a lead-based paint reduction program, it is important to determine which laws are in place that may affect the project.

Local Ordinances. Check with local health departments, poison control centers, and offices of housing and community development to determine whether any laws require compliance by building owners. Determine whether projects are considered abatements and will require special contractors and permits.

Owner's Responsibility. Owners are ultimately responsible for ensuring that hazardous waste is properly disposed of when it is generated on their own sites. Owners should check with their state government to determine whether an abatement project requires a certified contractor. Owners should establish that the contractor is responsible for the safety of the crew, to ensure that all applicable laws are followed, and that transporters and disposers of hazardous waste have liability insurance as a protection for the owner. The owner should notify the contractor that lead-based paint may be present and that it is the contractor's responsibility to follow appropriate work practices to protect workers and to complete a thorough cleanup to ensure that lead-laden dust is not present after the work is completed. Renovation contractors are required by EPA to distribute an informative educational pamphlet (Protect Your Family from Lead in Your Home) to occupants before starting work that could disturb lead-based paint (http://www.epa.gov/lead/ leadinfo.htm#remodeling).

Arsenic

Lead arsenate was used legally up to 1988 in most of the orchards in the United States. Often 50 applications or more of this pesticide were applied each year. This toxic heavy metal compound has accumulated in the soil around houses and under the numerous orchards in the country, contaminating both wells and land. These orchards are often turned into subdivisions as cities expand and sprawl occurs. Residues from the pesticide lead arsenate, once used heavily on apple, pear, and other orchards, contaminate an estimated 70,000 to 120,000 acres in the state of Washington alone, some of it in areas where agriculture has been replaced with housing, according to state ecology department officials and others.

Lead arsenate, which was not banned for use on food crops until 1988, nevertheless was mostly replaced by the pesticide dichlorodiphenyltrichloroethane (DDT) and its derivatives in the late 1940s. DDT was banned in the United States in 1972, but is used elsewhere in the world.

For more than 20 years, the wood industry has infused green wood with heavy doses of arsenic to kill bugs and prevent rot. Numerous studies show that arsenic sticks to children's hands when they play on treated wood, and it is absorbed through the skin and ingested when they put their hands in their mouths. Although most uses of arsenic wood treatments were phased out by 2004, an estimated 90% of existing outdoor structures are made of arsenic-treated wood [65].

In a study conducted by the University of North Carolina Environmental Quality Institute in Asheville, wood samples were analyzed and showed that

- Older decks and play sets (7 to 15 years old) that were preserved with chromated copper arsenic expose people to just as much arsenic on the wood surface as do newer structures (less than 1 year old). The amount of arsenic that testers wiped off a small area of wood about the size of a 4-year-old's handprint typically far exceeds what EPA allows in a glass of water under the Safe Drinking Water Act standard. Figure 5.9 shows a safety warning label placed on wood products.
- Arsenic in the soil from two of every five backyards or parks tested exceeded EPA's Superfund cleanup level of 20 ppm.

Arsenic is not just poisonous in the short term, it causes cancer in the long term. Arsenic is on EPA's short list of chemicals known to cause cancer in humans. According to the National Academy of Sciences, exposure to arsenic

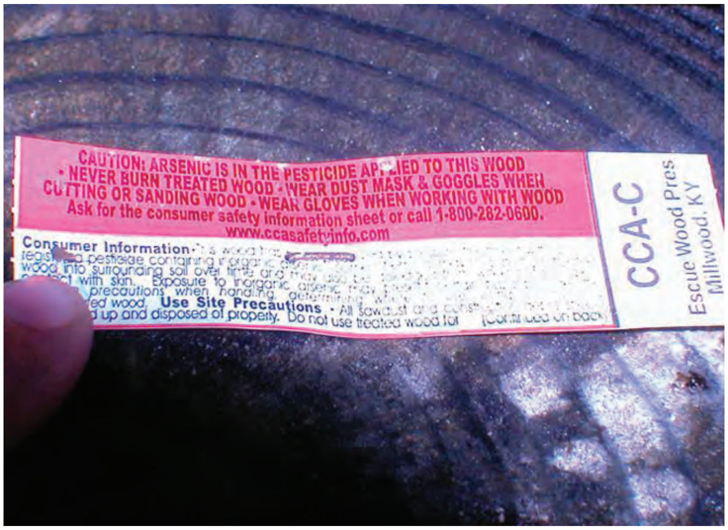

Figure 5.9. Arsenic Label

causes lung, bladder, and skin cancer in humans, and is suspected as a cause of kidney, prostate, and nasal passage cancer.

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