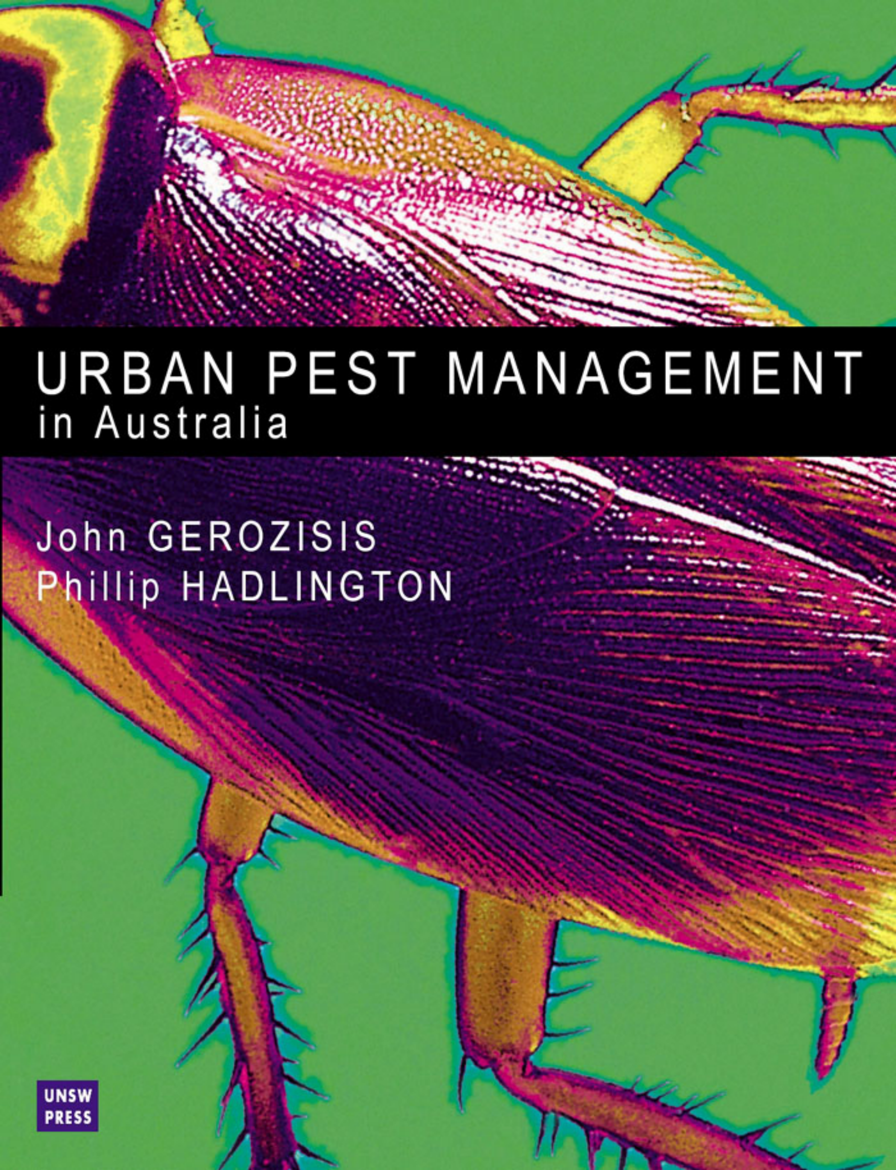
URBAN PEST MANAGEMENT
in Australia

John GEROZISIS
Phillip HADLINGTON



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John Gerozisis has worked for many years in the pest control industry as an entomologist, pest control operator and consultant. He is a Science graduate from the University of New South Wales (with majors in Entomology and Zoology) and spent some ten years as a teacher of pest control with NSW TAFE and a further ten years undertaking timber inspection and consultative work for a leading Sydney building consultancy.

Phillip Hadlington OAM is a consultant in pest control and tree care and is principal of the Australian Environmental Pest Managers' correspondence courses in New South Wales and Victoria.

Until his retirement in 1983, Phillip worked with State Forests of NSW as a forest entomologist and between 1955 and 1978 he worked on a part-time basis with NSW TAFE as the first teacher of pest control in Australia. Phillip is also the senior co-author of *Australian Trees: Their Care and Repair*; *Australian Termites and Other Common Timber Pests*; *An Introduction to Australian Insects*; *Termites and Borers: A Homeowner's Guide to Detection and Control* and *Common Household Pests: A Homeowners Guide to Detection and Control*, all published by UNSW Press.

Phillip is a keen photographer and is responsible for most of the photos in this book.

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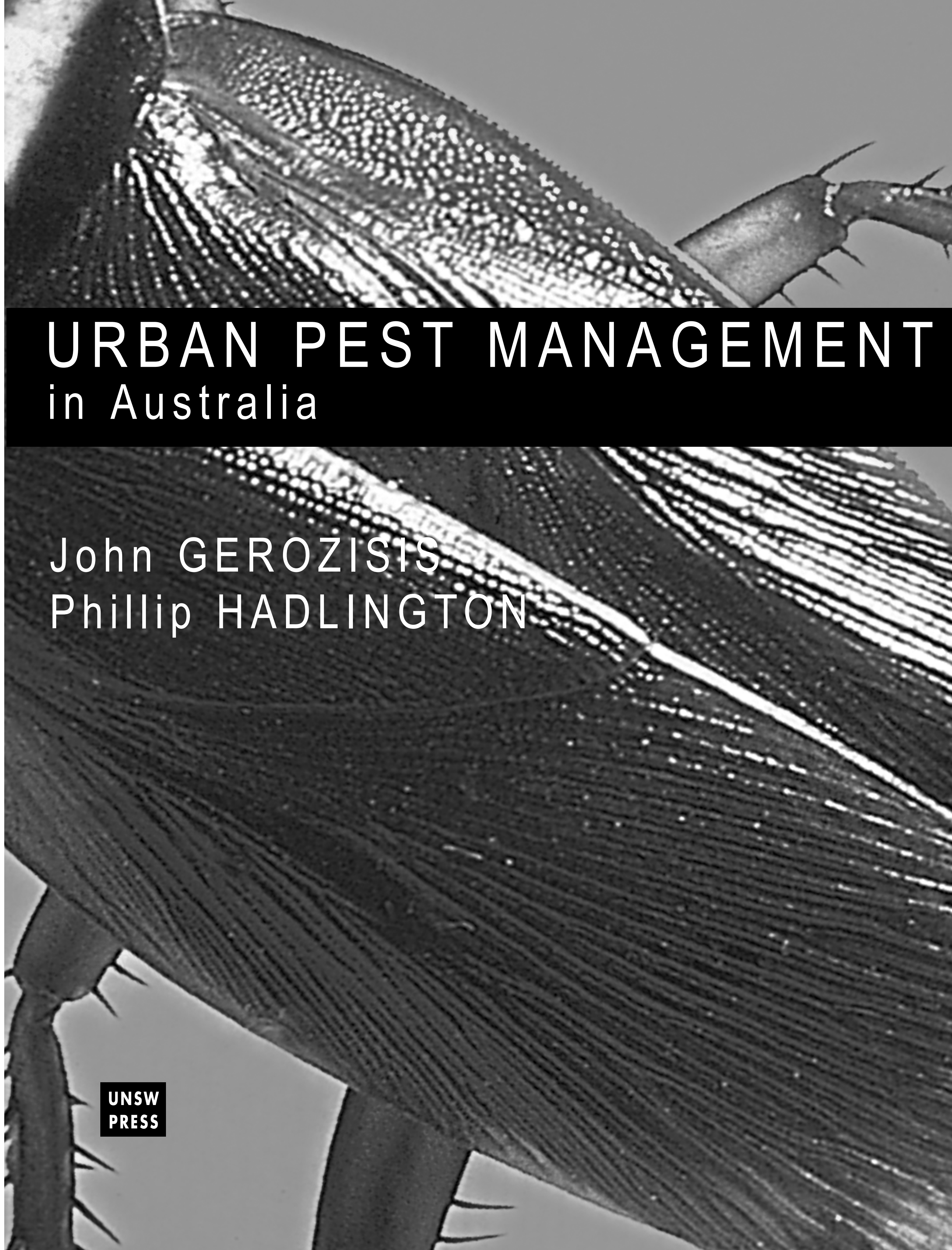

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A UNSW Press book

Published by
University of New South Wales Press Ltd
University of New South Wales
UNSW Sydney NSW 2052 Australia
www.unswpress.com.au

First published in 1985 as *Urban Pest Control in Australia*
2nd revised edition 1988
3rd revised edition 1995
4th revised edition 2001

National Library of Australia
Cataloguing-in-Publication entry:

Gerozisis, J. (John), 1954– .
Urban pest management in Australia.

Includes index.
ISBN 0 86840 532 9.

1. Urban pests — Control. I. Hadlington, Phillip W., 1923– .
II. Title.

628.9/6

Printer BPA

CONTENTS

ACKNOWLEDGMENTS

Thanks are due to many people for their assistance in the preparation of this fourth revised edition of *Urban Pest Management in Australia* (formerly *Urban Pest Control in Australia*).

In particular, the authors gratefully acknowledge the assistance of: Peter Lamond of Rentokil Pest Control; Bryce Peters and Peter Miller of the University of Technology, Sydney; Greg Hooper of the National Registration Authority; Karla Juranek and Sheree Glasson of the Australian Quarantine and Inspection Service; Jerry Tyrrell of Tyrrells Property Inspections; Glen Kervan of Chemical Enterprises Pty Ltd; Peter McCarthy of Globe Australia Pty Ltd; John Thornton of John Thornton & Associates; John Read; Martin Horwood; and Doug Howick of the Australian Environmental Pest Managers Association.

Additionally, we would like to thank the many people who helped us in the preparation of previous editions of the book.

CHAPTER 1

INTRODUCTION TO URBAN PEST MANAGEMENT

Urban pest management is concerned with the management of undesirable animals that intrude on a built environment. Proper management requires an understanding of the problem. A broad view of the activities of plant and animal life forms in their environments can serve as an introduction to considering the exploitation of urban environments by live organisms. Given the multitudes of organisms that can be found in urban environments, one might well ask: 'What is a pest?' An understanding of how a pest interacts with its environment (pest ecology) can be, essentially, a consideration of the types of control measures available. Control measures are often broadly broken up into non-chemical and chemical methods. Presently, many urban pest-control procedures rely heavily on chemical control methods. Approaching a pest problem requires an understanding of both the pest and appropriate control procedures.

LIFE FORMS

Water is an essential prerequisite for life, which began in some kind of watery, chemical 'soup' and has continued to depend on water as the 'solvent' in which most cell reactions occur. To survive, all living organisms must maintain the right balance of water.

Plant and animal life exists in almost every kind of environment found on this planet. Even harsh climatic regions such as deserts support live organisms, which have adapted to the shortage of water either structurally (eg have thick skins), physiologically (eg produce very concentrated urine) or behaviourally (eg are active only at night) .

In stark contrast to deserts, tropical rainforest regions receive abundant rainfall. With plenty of water and a warm climate, plants and animals abound in a great variety of life forms, having developed a very complex community of living organisms that interact with each other and their environment. In these ideal conditions plant life flourishes, but there is keen competition for the sunlight that is their essential source of energy. This search for sunlight forces foliage to stretch upward and creates a canopy of very tall trees with their attendant creepers and climbers, which filter light to the forest floor.

Competition between life forms is obvious in rainforests. Wood, the very substance that humans have exploited widely, testifies to keen competition among live plants for resources. The development of woodiness in some plants gave them the structural means of obtaining more height and hence more sunlight than that available at ground level to shorter, less woody plants. In turn, the early, primitive wingless insects, perhaps feeding on these woody plants, found themselves higher and higher above ground level. First they probably learned to glide down. Then they developed wings and conquered the air, which they had to themselves for millions of years. The abundance, diversity and success of insects is probably, at least in part, attributable to the ability to fly. In terms of numbers of species alone, insects outnumber collectively all other animals.

Life forms untiringly exploit environments that will support their existence. They are constantly expanding into the space around them and surviving, often in great abundance, in environments that provide their basic needs for growth and reproduction.

As people evolved, other animals, mainly insects, found the means for survival on their bodies and within their dwellings: these animals found nutriment in clothing, human blood, timber and food scraps. When humans first began to grow foods and store them for future use, other organisms no doubt claimed a share of this new, exploitable resource. And things have not changed much. Many animals, perhaps mostly insects, still find the means for their survival within and around the dwellings of human beings.

URBAN EXPLOITATION

When houses or other buildings are constructed and then inhabited by humans, a variety of micro-environments are created. The provision of food, moisture and shelter in various forms within a building may well lead to its exploitation by a variety of organisms.

One of the most successful invaders of buildings is the rather small German cockroach, which probably originated, not in Germany, but in north-eastern Africa. Although it is a very hardy species, its tropical origins are disclosed by its preference for conditions that provide warmth, moisture and food. Domestic kitchens and commercial food-processing establishments often support enormous populations of this highly successful scavenger. It can be found thriving in just about every part of the world that people have taken it to, even heated buildings in Alaska.

Rats and mice often use accessible cavities and spaces in buildings that afford them shelter and warmth with food and water within a reasonably safe distance. Often these rodents live indoors only during the colder winter months; but if the conditions offered are generous (eg as may be the case around grain-handling facilities), rodents may take up year-round residence.

Cockroaches and rats are notorious for their disease transmitting capabilities. Although it is seldom possible to categorically implicate a cockroach as the cause of food poisoning symptoms, the potential of cockroaches for disease transmission cannot be disputed.

Other invaders of buildings may directly threaten the structure of the building itself. As bushland is cleared for house construction, mature colonies of subterranean termites may be suddenly isolated from their previous food source. A new house, built over a tree stump supporting a mature colony of termites can suffer significant damage within a few months provided that the timbers are palatable and accessible. The appearance of small round holes in furniture or flooring timber betrays the activity of wood-boring beetles which can, after years of many individuals feeding, cause the total collapse of timbers.

Houses often acquire a build-up of spider webs around windows and doors and under eaves. Spiders maintain their livelihood by capturing and devouring prey, mainly flying insects. Buildings offer a variety of locations suitable for spider habitats, protected, with a crack for retreat and areas to span with webbing. At times, the proliferation of spiders around houses hints at the spiders' exploitation of the attraction of many flying insects to lights at night time. The reactions of occupants to invasions of this kind vary enormously. While some appreciate the feeling of proximity to nature (in which spiders act as 'automatic' insect traps around windows and doors), others react with abhorrence. So intimidated can the latter be, presumably by the very appearance of spiders and their perceived threat to well-being, that pest control operators are regularly employed to keep the spiders at bay.

WHAT IS A PEST?

Many of the urban pest control operator's activities relate directly to protection from disease transmission by animals such as cockroaches and rodents. As well, much work involves the protection of material possessions, ranging from food and fabrics to house timbers.

Although the activities of certain animals are widely recognised as threatening to either health or material possessions, it is hardly possible to outline an all-embracing definition for a 'pest'. This difficulty arises because the concept of 'pest' is a human construction about which people have their own individual opinions and attitudes. One individual may control spider webbing around the house while another prefers to leave it be. One individual may not tolerate the sight of a cockroach in the laundry, while another tolerates an infestation in the kitchen. Any definition of 'pest' must therefore be subjective.

However, perhaps we can regard a pest as 'an organism that, at a given place and time, is undesirable', noting that the nature of the undesirability may be a direct threat to health or property (shelter, food etc.) or may be simply related to comfort or aesthetics. The work of the urban pest control operator may involve dealing with the following kinds oforganisms:

Structural pests — insects (mainly termites and wood boring beetles) and fungi that destroy wood.

Pests that carry diseases — organisms that, owing to their activities, may carry diseases and, owing to their co-existence with humans, may transmit diseases to people (eg cockroaches, rodents, birds).

Stored products pests — organisms (mainly insects, beetles and moths) that infest, consume and contaminate stored foods, usually living and breeding within the raw or processed products (eg flour beetles, grain moths).

Pests of fabrics — organisms (mainly insects) that attack materials such as carpets, cotton, linen and paper (eg carpet beetles, clothes moths, silverfish).

Pests that bite, sting or irritate humans — organisms (mainly insects) that annoy people or their pets by biting, stinging or irritating (eg fleas, bedbugs, bird lice, mites). Disease transmission may also result.

Miscellaneous pests — organisms that occasionally cause some concern or annoyance (eg earwigs, amphipods, thrips, snails, slugs).

PEST ECOLOGY

An investigation of the conditions within which a particular organism lives and its relationship to other living organisms and to its environment, will provide information about the ecology of that particular organism. The ecology of an organism can therefore be viewed as the combination of factors that determine its abundance and distribution (and hence its potential for pest status). Thus, the principal ecological factors are:

1 climate/weather (temperature, moisture, light, wind);
2 food;
3 other organisms; and
4 shelter or habitat.

Climate/Weather

The different climates of various regions of the earth are often found to support quite different populations of plants and animals. It is often the case that warmer climates (eg tropical rainforest) sustain a greater abundance and diversity of organisms than cooler climates (eg polar). In addition to the broader considerations of climate and weather, the relatively small size of many pest organisms necessitates consideration of micro environments, that is, the conditions that prevail in the immediate region of an organism's activities. Organisms that share the dwellings of humans often do so successfully because, within these buildings, they find and utilise micro environments that provide them with the warmth and moisture they require.

Temperature

Life itself depends on an extraordinarily complex arrangement of biochemical reactions that can operate only within a certain range of temperatures. Although a particular organism may be able to survive over a fairly broad temperature range (eg 5–45°C for a given insect), particular activities (eg food-seeking, reproducing, flying) are usually governed by a narrower temperature range. For example, cockroaches living in a sewerage system in a temperate region may survive throughout the year, but the warmer conditions of summer (eg 30°C and higher) may well prompt increased activity, food-seeking, flying and perhaps the development of another generation. Many insects are more active and abundant in warmer conditions.

The temperature requirements of pest animals vary. Some find year-round warmth inside buildings and machines, while others may need summer warmth to boost their activities. Rats may avoid cold by invading buildings in autumn and winter. The work patterns of pest control operators often reflect this variation in requirements and the seasonal temperature cycle.

Moisture

Organisms can obtain water, essential to all life, in a number of ways. Environmental moisture or precipitation, surface water, water vapour in the air (humidity), and the water contained in food.

The moisture content of grain and wood is sufficient to support the activities of insects (wood borers and grain beetles) that specialise in these materials. Rats that infest buildings in which fresh vegetable matter (a food high in moisture content) is available may not need to supplement that diet with free water. However, dripping taps, drains and nearby canals may provide water, if needed. Rats infesting a grain silo, although deriving some moisture from the grain, usually have a greater demand for free water.

Humidity can greatly influence the activity of various organisms. In an enclosed, poorly ventilated subfloor area, the moisture content of the timber may be so high that the timber is susceptible to attack by destructive fungi. More generally, periods of warmth, combined with relatively high humidity, can promote the quick and abundant development of immature fleas, resulting in a 'flea plague'.

Some termite societies, with perhaps millions of individuals to assist, can actively create and maintain the very high relative humidity that promotes their abundant development. Mud tunnels and packing are often used by termites to retain moisture. They frequently move mud into building timbers to retain moisture. Most of the moisture is the result of their body metabolism and water available in the nest or soil.

Light

Perhaps the most pertinent aspect of light in the context of pest ecology is that, over millions of years, many organisms have established a pattern of activity that is governed by the regular cycle of light and its absence — day and night. Cockroaches and rodents, often sharing accommodation with humans, are active mostly at night (or perhaps more accurately, after lights are out). Such night-active organisms are usually referred to as nocturnal. So defined is this pattern of activity that it is not uncommon for infestations to exist without the human occupants being aware of them. Some insects are most active at the twilight of dawn or dusk (eg the feeding behaviour of many mosquito species), and this type of activity is referred to as crepuscular. Many insects are active during daylight hours and these are referred to as diurnal species.

In insects, changes in day length may trigger preparations for the yearly cycle of favourable and unfavourable conditions (eg the need for hibernation).

Wind

The bush fly, perhaps one of Australia's most notorious and widely known animals, depends entirely on warm northerly winds each spring for its distribution to the more southern regions of Australia. Occasionally, conditions in fruit and other crop-growing areas suit the development of a particular insect. Winds can then bring enormous populations into cities, often leading to the invasion of buildings. The sudden appearance of certain moths, thrips and other insects in great abundance can motivate householders to seek the services of a pest control operator (when, in fact, there is usually nothing that the operator can reasonably do).

Food

The growth, development and abundance of animals are greatly affected by the availability of food, its quality and its quantity. In food-handling establishments that cease activities at night and are not cleaned until the following morning, the number of infesting cockroaches or rodents is likely to be much greater than in places where thorough cleaning is carried out immediately.

Some cohabitants with humans (eg cockroaches, rats) are omnivorous, that is, they are able to eat almost anything, and this is a distinct advantage. Broadly, insects feeding on foods deficient in some way (eg low in moisture or protein) probably take longer to develop and may become small adult insects, which in turn do not lay the normal complement of eggs. Other cohabitants with humans are much more specialised in their food requirements: some feed specifically on blood (eg adult fleas), others on certain kinds of stored food (eg flour beetles), and others on the house timbers (eg wood borers and termites).

Other Organisms

The role of other organisms may be viewed in two ways:

Organisms of the same species The amount of reproduction and survival that occurs can often be influenced by overcrowding. Too much demand for the same kinds of resources can limit the size of a population. Under crowded conditions with limited food supplies, cockroaches may indulge in cannibalism. On the other hand, a particular habitat may be so sparsely populated that the animals have less chance of finding mates and reproducing.

Organisms of different species Most organisms have parasites or predators. The creation of a habitat in the roof space of a house by starlings can create habitats for other organisms. Bloodsucking bird mites that reside in the nests may, under favourable conditions, reproduce at such a rate that great numbers migrate down into the living quarters (perhaps through wall vents) to irritate humans. Carpet beetles breeding in nesting material also may venture into the house, to attack woollen goods. Furthermore, the bird droppings may contain fungal disease organisms, which may become airborne and infect humans.

Sometimes, borer-infested timber in buildings may seem to emit large amounts of borer dust. Close examination may reveal the activity of a hairy little beetle that moves through borer tunnels, seizing, killing and devouring the wood borers.

Shelter or habitat

An organism's habitat is the place where it lives. Organisms such as wood borers and grain feeders live mostly in the very food they consume. Access to pests here can be difficult. Even cockroaches inhabiting a kitchen spend most of their time hidden away in cracks and crevices, appliance motors, wall cavities etc., often making access to them incomplete. Birds and rats, being larger animals, tend to be more obvious in their habitation of buildings.

In broad terms, the factors that determine the suitability of a given habitat are access to food and water and immediate weather conditions, particularly temperature. Variations in construction and utilisation by humans create suitable habitats for a variety of organisms.

Familiarity with the ecology of pest animals is a most important first step towards their control.

TYPES OF CONTROL MEASURES

There are many different ways in which humans can control the invasion of buildings by undesirable organisms:

1 Physical methods;
2 Cultural methods;
3 Biological control;
4 Chemical control:
  a. Pesticides
  b. Insect Growth Regulators (IGRs).

Physical methods

Physical barriers are often used to prevent the entry of animals into buildings. Householders install flyscreens to prevent the entry of flying insects and pest control operators use the same principle to exclude birds, rodents or possums from buildings.

Physical methods of detection, capture or killing are sometimes used, but not as much as in the past. Traps are still used in the capture and subsequent release (elsewhere) of possums from roofs; mouse and rat traps are still used by householders, although perhaps only occasionally by operators. The rather old concept of sticky flypaper, although seldom used these days, inspired the development of two-sided sticky tapes for cockroach control, and even glueboards for rodent control. In some households, one of the oldest methods of physical pest control, the humble fly swatter, still has its place.

Cultural methods

In cultural methods of pest control, conditions of the pest environment are manipulated so as to make it less favourable for the pest's activities.

Pest control operators rely mostly on cultural methods to control attack on buildings by wood-destroying fungi. Houses are sometimes built with inadequate subfloor ventilation and this creates high humidity, which increases the moisture content of the timber and makes it suitable for attack by wood-destroying fungi. Often, the activity of this structural pest of timber can be halted simply by installing sufficient and proper ventilation, which will have the effect of reducing the humidity and thus allowing the timber to 'dry out'. Dry timber is unattractive to the wood decay fungi.

Hygiene and sanitation measures can alter the habitat of certain animals sufficiently to control their numbers. Cockroaches may be controlled to some extent by being denied access to food, either as scattered wastes (by thorough and immediate cleaning of food preparation areas) or in open, accessible containers. A substantial proportion of the dust that collects in houses (under beds, on top of wardrobes etc.) is human skin sheddings, an organic material that, because of the resourcefulness of the animal world, supports a number of organisms (eg cat flea larvae). The apparent rareness of human flea infestations is at least partly attributable to the introduction of the vacuum cleaner, just as the rareness of body louse infestations is probably attributable to regular personal washing and the introduction of the clothes washing machine.

Preventive cultural methods are becoming, as they should, more and more important. Commercial kitchens are often designed to facilitate thorough cleaning, with, for example, equipment up off the floor, and with an absolute minimum of cracks and crevices that would otherwise potentially harbour cockroaches. More often now, buildings are constructed according to guidelines that embrace practices designed to deter the activities of wood-destroying organisms such as decay fungi and termites.

Biological control

The introduction, perhaps from another country, of a parasite or predator to eradicate a particular pest is a control method that has seen some remarkably successful case histories. An early incident in Australia involved the control of a cactus: the prickly pear. After its introduction from overseas, this weed rapidly spread and, by 1925, had overrun thousands of square kilometres of sheep and cattle land throughout Queensland and New South Wales. In that year scientists introduced a moth from South America, *Cactoblastis cactorum*. Larvae, hatched from eggs laid in the cactus, fed on the plant so voraciously and survived into adulthood so well that, by 1935, the plague was over.

The use of this kind of biological control is largely restricted to the agricultural, horticultural and forestry contexts, usually researched and handled by government departments. In the urban pest control context there have, as yet, been no major applications of biological control. Investigations in America are examining the control potential of a wasp that parasitises the egg case of the brownbanded cockroach. Research into fungi and nematode worms that can parasitise termites may result in biological control options for termite control in the future. Home gardeners in Australia can now purchase (by mail order) a particular species of bacteria for the control of caterpillars, and predatory mites for the control of two spotted mites. Biological control of mosquito larvae is now feasible using a product containing the bacteria *Bacillus thuringiensis*. When ingested by larvae it causes destruction of the midgut and death, usually within 24 hours. Adult mosquitoes are not affected.

Chemical control

The use of chemicals to control pests falls into two broad categories. At present, urban pest control procedures rely largely on the use of poisonous substances, *pesticides*, in order to kill pest plants and animals. Often, but not always, pesticides have a relatively broad spectrum of activity and hence are potentially poisonous to a wide range of living organisms, including mammals such as humans and their pets.

The development of *Insect Growth Regulators* (IGRs) has involved research into the biochemistry of pest insects with the intention of identifying natural chemicals (eg hormones) and/or physiological processes (eg production of the chitin/cuticle) that play an important role in the insect's development. By mimicking and/or creating chemicals that disrupt very specific physiological processes within the pest insect, these developments are providing chemical control 'tools' that offer significant advantages in relation to the safety of non-target animals.

Pesticides

Although some form of physical and cultural pest control has been used for hundreds of years, with varying degrees of success, and although the future of pest control may have its roots in current research work involving the often complex biological control methods, there is at present an enormous reliance on pesticide chemicals.

Pesticides are substances which kill organisms by exerting a toxic (poisonous) effect which interferes with certain normal life sustaining processes.

The early uses of chemical pesticides revolved largely around inorganic substances of mineral origin (eg sulphur, arsenic) and organic substances of plant origin (eg nicotine from tobacco, pyrethrum from certain daisies, even garlic).

Perhaps the biggest step forward in the development of synthetic insecticides occurred in the early 1940s, when, with the pressure of war (a context in which insects have always been noted for their success at killing humans by disease transmission), dramatic advancements were made towards producing highly insecticidal compounds such as DDT. Of course having origins such as these, it is not surprising that some of these insecticides were quite generally toxic materials, harmful to a variety of life forms including humans. In more recent years there has been an attempt to widen the gap between toxicity to insects and toxicity to humans and other mammals. In some quarters this has been achieved with remarkable success.

The pesticide industry, although largely responsive to the needs of agricultural pest control, has developed a range of weaponry that is now tailored to the needs of the urban pest control operator. The characteristics of pesticides (eg stability after application, specificity of activity) vary greatly, as do the kinds of formulations available for particular applications:

1 Some chemicals are used in relatively high volume saturation of soil, so as to contaminate the soil and form an effective barrier against termites (perhaps for some years).
2 Some chemicals are used in lower volume spraying on surfaces, so as to leave a film of pesticide that can be picked up by crawling insects. These chemicals can remain active from days to weeks to months.
3 Some chemicals are used in very low volume treatment. Space sprays (eg aerosols) may often facilitate flushing out, quick knockdown and kill of insect pests. Such chemicals may be stable for only a few hours.
4 Dust formulations are often used to give some degree of control in places where wet sprays must be excluded for reasons of safety (eg in electrical motors).
5 Bait formulations are increasingly used for the control of a variety of pests (notably ants, cockroaches and termites).
6 A variety of other types of formulation are used (eg lacquer, smoke generators).

Our present reliance on pesticides for the control of animals invading buildings cannot be overstated. Yet, despite the wide range of chemicals available, total control or eradication of pests in buildings is not always achieved. Probably, in many such cases, this is because only part of an interbreeding population comes into direct contact with the treatment. This may be due to faulty applications by the operator or to limitations on access. The reintroduction of pests with incoming goods also may make total control difficult to achieve. Often it is quite clear that chemicals alone are not enough. Intimate familiarity with the ecologies of pests can enable operators to exploit a variety of control measures, leading to safer, more effective pest control.

Insect Growth Regulators

Research scientists are continually investigating alternative control measures, often by tampering with some aspect of the biology/biochemistry of particular pest organisms:

Juvenile Hormone Analogues (JHAs) A special gland in the head of insects secretes a chemical known as juvenile hormone, which, as its name implies, controls the insect's moulting and development during its immature life. To allow the progression from immaturity to maturity, secretion of juvenile hormone is stopped, so that the cells that will comprise the adult insect can develop. The development of juvenile hormone-like compounds (analogues) provides chemicals which so disrupt normal development that the insect dies or the adults become sterile.

Chitin Synthesis Inhibitors (CSIs) Chitin is a component of insect cuticle that plays an important role in its protective characteristics. CSIs appear to interfere with the normal production of chitin and hence result in insects with defective cuticles, a condition that may result in the inability to moult properly, excessive water loss and other physiologically deleterious effects.

Integrated pest management

The concept of Integrated Pest Management (IPM) is taken here to imply an approach to pest control which:

1 relies on an understanding of the ecology of the pest (in particular, those factors which favour its development where this is undesirable);
2 draws from this knowledge non-chemical approaches that will make the environment less suited to the development of the pest population; and
3 may involve, in the control program, the judicious and sensitive use of pesticides, when necessary.

The primary objective of IPM is to minimise any harmful effects that may result from the use of pesticides. A key component of all IPM programs is a thorough inspection and survey that may involve monitoring of pest populations. German cockroach infestations, in household kitchens, restaurants, bars, food warehouses and other premises, often present a constant, regular need for attention by pest control operators. While one operator may treat such premises, sometimes with great frequency, using the same applications of the same chemical time after time, another may consider a more integrated kind of strategy, employing chemical, physical and cultural control techniques. The success of this strategy may rely heavily on the education and co-operation of the client. However, educating clients about physical and cultural techniques may not be easy.

Physical Control

1 Incoming goods should be inspected to ensure that the insect is not being reintroduced.
2 Goods and equipment should be above floor level, to allow for cleaning, inspection and treatment and to reduce harbourage potential.
3 Cracks and crevices should be filled so as to limit the number of harbourage areas and the insects' access to them.

4 Gaps around pipes and ducting that enter through floors and walls should be sealed off if suspected of allowing insect passage.

Cultural Control

Sanitation and hygiene are an important integral part of controlling scavengers such as the German cockroach.

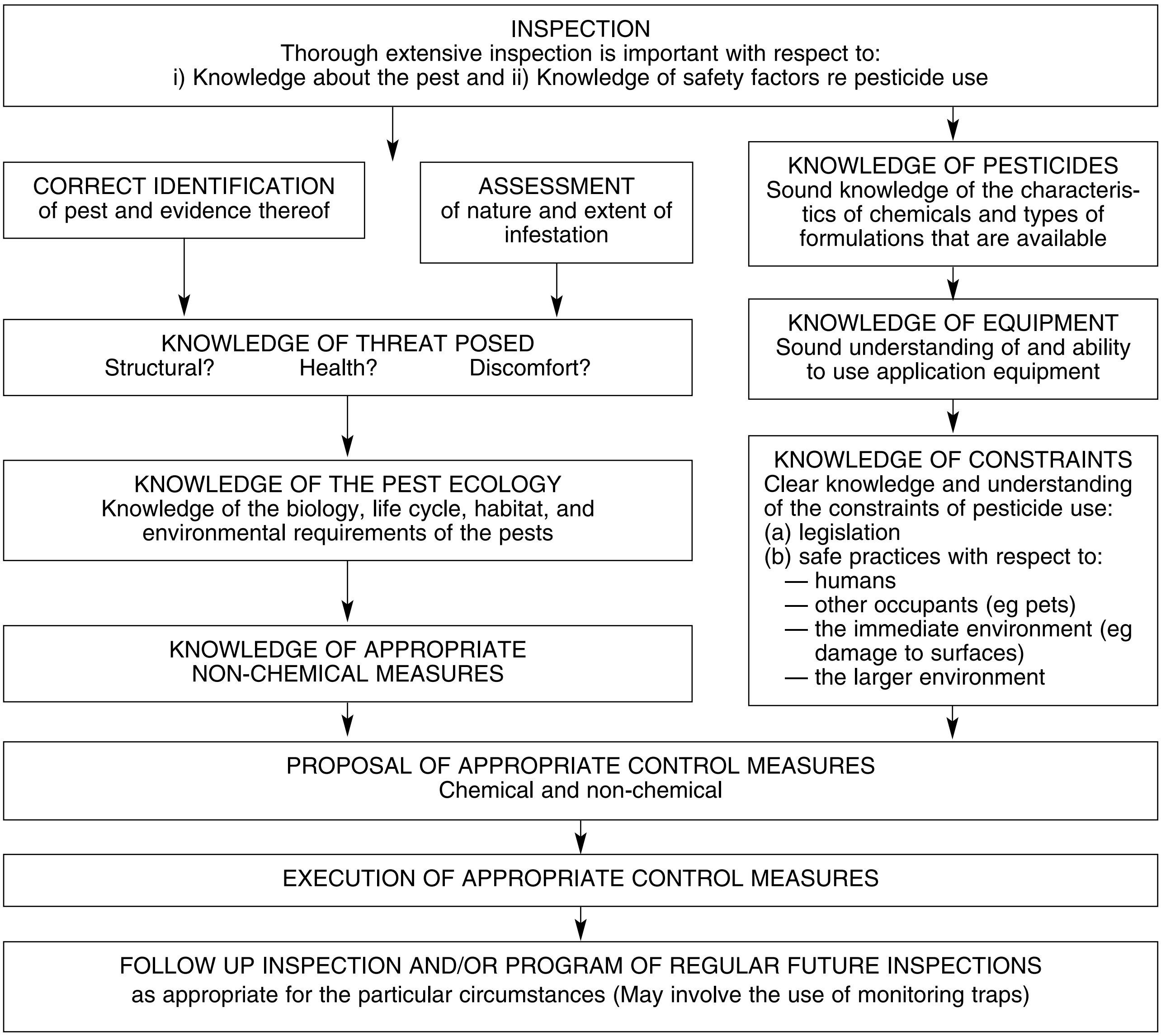
1 Waste foods left exposed after human feeding or food-processing should be disposed of thoroughly and promptly, not left overnight.
2 Wastes should be enclosed in tight sanitary containers.
3 Stored foods should be kept in tightly closed containers.

Chemical Control

Thorough inspection of the premises may indicate a number of actual or suspected harbourage areas, and appropriate insecticide formulations may be applied in these locations. It may be necessary to consider a variety of techniques, suitable for different locations: surface spraying, treatment of cracks and crevices, space spraying, dusting and baiting. It may also be necessary to ensure that the particular chemicals used are not ones to which the insect concerned has developed a high degree of resistance. Placement of cockroach glue traps at various locations can provide a means of ongoing monitoring to help assess the effectiveness of control strategies.

Changes that make the environment less suitable to pests' survival, combined with thoughtfully designed applications of chemicals, can provide the safest, most effective means of dealing with many of the pests that invade buildings.

FIGURE 1.1
Approaching a pest problem



APPROACHING A PEST PROBLEM

The work of a pest control operator can require an enormous variety of talents: carpentry skills (eg in cutting floor traps for access to subfloor areas); climbing skills (eg on difficult bird-control jobs); a knowledge of electrical, plumbing and general building practices (eg in avoiding accidents); and even psychological skills (eg in consoling a client advised of extensive damage to house timbers, or in dealing with pest problems that exist only in the client's mind). In broad terms, however, the basic steps and requirements in approaching pest problems may be summarised as in Figure 1.1 (page 7).

The most important first step in approaching any pest problem is, of course, a thorough inspection. This will allow for:

1 correct identification of the pest(s) present (eg borer damage may be caused by the furniture beetle, the powderpost beetle or the European house borer, but the implications for control of these pests are radically different);
2 assessment of the nature and extent of the infestation; and
3 familiarisation with the environment in which control measures are to be undertaken (eg pets should be removed, and food protected from contamination).

The operator should have a sound knowledge of the threat posed by various animals in and around the building. A client who has found termites in a woodpile by the garage may justifiably wish to know whether these termites are a threat to buildings. Familiarity with the ecology of the pest being dealt with will be of invaluable assistance to the operator in both proposing and executing appropriate control measures. A working knowledge of the chemicals, formulations and application equipment to which operators have access is essential, as is familiarity with the constraints of government legislation and with safe pesticide handling practices. Taken together, these different sorts of knowledge should enable the pest control operator to propose control measures that are safe, effective and efficient.

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CHAPTER 2

INSECTS & HUMANS

The types of live organisms that share people's dwellings and food range from microscopic fungi to birds, possums and rats, but the group of animals that has exploited buildings most successfully is the insects. Measured by their great abundance and diversity, insects are by far the most successful group of animals on earth; and since they were here millions of years before humans, it is not surprising that they have had a significant impact on our existence.

Insects in many situations are helpful to humans. However, in many urban and rural (agriculture and horticulture) environments, insects of many different types have achieved pest status and are responsible for enormous expenditures on control. Various factors — structural, physiological and behavioural — contribute to the success of insects in competition with humans. Because of this success, the role of insects in disease transmission has been a constant threat to human welfare, and many urban pest control procedures are concerned with reducing the threat to human health.

INSECTS HELPFUL TO HUMANS

The continued supply and range of fruits, vegetables, seeds, flowers and other plant parts that we enjoy is often largely attributable to the activities of the insects that pollinate plants. Other insects provide us with products like silk, beeswax, shellac and, of course, honey. In nature, insects play important roles in various food chains. They themselves are the food of many higher animals (eg reptiles, birds, mammals). Many are parasites or predators, attacking animals (often other insects) that may be pests of humans. Some, with a scavenger habit, perform the valuable service of 'cleaning up' dead plants, animals and animal droppings. Insects can also provide aesthetic pleasure (eg butterfly farms).

INSECTS HARMFUL TO HUMANS

Humans have become extremely reliant on the organised growing and raising of plants and animals for food. Some insects squander these efforts by chewing the leaves, flowers, roots, fruits or stems of plants. Others reduce vigour by sucking sap, or even by settling in and causing abnormal plant growth. Further, in doing so, many transmit viral, bacterial, fungal or other kinds of debilitating diseases to plants. Some insects bite, sting or drink the blood of farm animals, again possibly transmitting disease. Humans themselves are subject to being bitten or stung by insects, and possibly infected with diseases carried by them. As well, many of the possessions of humans (eg stored foods, clothing, artefacts, shelter) are susceptible to damage or contamination by insects.

It has often been said that insects, as a group, are better equipped to occupy the earth than humans.

WHAT MAKES INSECTS SUCH SUCCESSFUL COMPETITORS WITH HUMANS?

Insects comprise about three-quarters of all the different species of animals that live on earth. Those insect species that, because of their activities, have become pests to humans have for a long time necessitated huge expenditures on control. While there exists great diversity in form and function among insects as a group, a number of general characteristics may contribute to their success as competitors with humans.

Size

Insects range in size from those which are nearly as minute as some single-celled organisms to those which are as large as the smaller mammals. Overall, therefore, they are relatively small compared to most other animal life forms, and this can be regarded as a distinct advantage.

One disadvantage of such small size in animals is that, because of the ratio of body surface area to body volume, moisture is lost more easily than in larger animals. Conservation of moisture is critically important to any life form, and insects have accommodated to this problem by developing, in most cases, a remarkable, protective body-covering that is discussed below.

The advantages of small size are best appreciated by considering the enormous range of habitats available. Lice can live and feed for their entire lifespan on just one part of the host animal. Hundreds of flies can develop from the droppings of one large grazing animal. Thousands of cockroaches can find living space in the cracks and crevices of a kitchen, along with enough food (often just the scraps left lying around) and water to sustain an enormous population. The small size of insects has allowed them to exploit a great range of habitats provided by larger animals, including humans.

Large numbers and rapid reproduction

Insects compensate for their relatively small size by producing huge numbers of offspring, which often develop quickly into reproductively mature adults. The German cockroach, a very prevalent pest of kitchens, may undergo four generations per year; and as each female produces a number of egg cases that may each hatch 30–40 offspring, the population in a given habitat can be enormous. This rate of reproduction, added to their small size and flat body shape, makes it not surprising that more than a thousand German cockroaches may be found residing in the cracks in one butcher's block. How many, then, can develop where there is access to wall voids and other suitable habitats?

By and large, most female insects lay large numbers of eggs in any location that is likely to facilitate the feeding of the young insects after they hatch. As well, most insects undergo a relatively rapid development and life cycle. These two factors together (large numbers and rapid reproduction) provide a key to the doorway of adaptability.

Adaptability

When life forms sexually reproduce at a rapid rate and in large numbers, they create a vast genetic pool. Creating a large population with a great deal of genetic variability means that much selection can operate, whereby populations can adapt to a vast range of environ-mental conditions. Insects have a remarkable potential to adapt to different conditions and this is perhaps their greatest asset in their competition with humans for their food and shelter.

Over millions of years of exploiting different food sources, insects have evolved a diverse range of mouthpart types for different diets. The more primitive chewing mouthparts, found in present-day cockroaches, have in some insects been developed (through long periods of evolution) into equipment that can pierce tissue (plant or animal) and suck up the juices therein. This development alone opened a vast new food source.

The ability and inclination of insects to adapt to different conditions and exploit different environments has even led to changes in the way they grow up. While the more primitive insects (eg cockroaches, termites) undergo only minor changes as they grow up and become adults (perhaps only the acquisition of wings and reproductive organs), higher insects go through a kind of specialisation in their development. Flies, beetles, fleas and moths undergo a complete metamorphosis, that is, a complete change in form as they grow up. Such insects have adapted different stages of growth for different functions. The young stages (larvae) are virtually eating machines, starting life by finding themselves in or on an appropriate food source and spending their larval life eating and building up reserves. When enough food has been accumulated, the animal changes into a different form (the pupa), often protected inside a cocoon, and inside this, the remarkable transformation occurs: a grub changes into an adult beetle, a caterpillar into an adult moth, a caterpillar-like grub with chewing mouthparts into an adult flea that has piercing and sucking mouthparts. The adult's lot in life is to find a mate and produce the next generation. Feeding is relatively unimportant to some adult insects of this kind, except for the females, which may require protein and other nutrients for egg development.

In more recent times, again owing to their rapid life cycle and huge genetic variability, many strains of insects have adapted to chemical control by developing resistance to pesticides that have been in use for less than 50 years.

Body covering

Insects, unlike higher animals, have an exoskeleton, that is, a skeleton on the outside of the body. This body covering or integument (often referred to as the cuticle) is made of chitin — a tough, light material that can vary in flexibility but must be periodically shed and replaced as it grows. The integument covers and protects internal organs and acts as a framework for muscle attachment, which enables locomotion. It also plays a very important role in water retention. It is strengthened, in those insects that need this, with sclerotin and waterproofed with a waxy layer.

The integument may be quite flexible on an immature wood-boring beetle or grub, which may be well protected within the timber that it is feeding on and needs the flexibility, as its lot in life is to eat, grow and accumulate the reserves needed for its change or metamorphosis into an adult beetle. The adult beetle, whose lot it is to find a mate and create the next generation, needs a much thicker, more protective cuticle, as its activities expose it to a much greater range of conditions than it encountered when it was a grub in timber.

Other means of protection

As well as a protective body covering, insects have developed many different means for protection against adversities. Softer-bodied caterpillars whose habits (eg feeding on foliage) expose them to attack by predators may develop protective bristles, spines, irritating hairs, or colouration that provides camouflage or even deceit (by creating the illusion of being a larger, more threatening animal), or any combination of these devices.

Insects can slow and almost halt their growth and development at various stages in order to make the most of more favourable conditions when they occur. Flea pupae may remain as pupae for long periods, being stimulated to emerge as adults by vibrations. Energy costs as a pupa are minimal, certainly less than those of an adult flea, which moves more, consumes more oxygen etc. As vibrations are likely to be caused by a larger animal that is likely to be a suitable host from which to obtain a blood meal, it is more efficient, from the viewpoint of the flea's well-being and inclination to produce the next generation, to wait until its first blood meal declares its presence by causing vibrations.

Flight

Insects were the first form of animal life to develop the ability to fly and this facility has no doubt played a very important role in their success, both in general terms and in relation to their competition with humans. Although some flightless insects (eg bedbugs) can still effectively disperse to exploit new environments (probably mostly by the human error of transporting them around), the power of flight, a facility reserved for the reproductively mature adult, cannot be overstated as an aid to dispersion and the exploitation of new environments. Certainly, for insect pests of crops, and to some extent for insect pests in urban structures, the ability to fly is an important asset in their struggle to exploit humans and all their environments.

INSECTS AND DISEASE TRANSMISSION

A great many of the disease-causing organisms that have plagued humans and their animals and plants since time immemorial owe much of their success to insects. Broadly, there are two quite different methods by which disease organisms have exploited insects as a means of conveyance:

Biological or cyclic transmission This is the much more sophisticated and highly evolved method, whereby the insect vector plays a specific and quite necessary role in the life cycle of the disease organism (eg malaria, dengue fever, encephalitis).

Mechanical or passive transmission The insect carrier becomes internally or externally contaminated with the disease by feeding or walking on infected material (eg animal excreta) and then contaminates food or food-handling facilities. Diseases charged with this means of transmission include dysentery, hepatitis, gastroenteritis and *Salmonella* food poisoning, to mention only a few from a very long list.

In the case of mechanical transport of disease organisms, it is important to note that the insects are, for the main part, only 'charged' in relation to their role in disease transmission (ie it is very difficult to categorically prove). For many of the cyclically transmitted diseases, insects have been 'charged and proven guilty' (eg malaria, which, conveyed by the anopheline mosquito, still claims hundreds of thousands of human lives annually). The evidence against insects as mechanical carriers of disease (eg cockroaches, flies) remains only circumstantial. Perhaps the main reason for this difficulty is the multitude of other means of transmission that may exist concurrently (eg contaminated water supplies, unsanitary food preparation, dirty hands etc.). It is likely, although arguable, that many cases of food poisoning are related to the activities of insects such as flies. It is relatively seldom that victims associate the disorder with insects; and unfortunately, to prove such an association would be a very difficult task indeed.

In some societies it can be rather easy to become complacent about the presence of insects that may be harbouring enormous numbers of disease organisms. These more fortunate societies are not geographically located within areas that are the domain of the many cyclically transmitted diseases (eg sleeping sickness conveyed by the tsetse fly, covers 10 million square kilometres of Africa). Moreover, these societies have a high standard of sanitation and hygiene, so that water supplies are clean and entirely separate from human wastes.

However, such complacency is misplaced; for despite the most modern efforts to improve sewage treatment and waste disposal, insects remain a link between disease-contaminated wastes and food and food-handling facilities.

In many developed urban communities, the role of pest control operators in relation to public health involves dealing mostly with mechanical carriers of disease. In many areas, cockroaches and flies are perhaps the most notorious offenders in relation to the mechanical transmission of disease organisms.

Cockroaches

Of the almost 4000 species of cockroach that exist, only about six species have become serious pests of homes and industry in Australia. Being nocturnal creatures, they usually become active after dusk or after human activity has ceased for the night. Cockroaches that roam kitchens while occupants are asleep may be residents of the kitchen (hiding by day in cracks, crevices, warm motors of appliances etc.) or itinerant visitors arriving from grease traps, subfloor areas or drainage/sewage networks.

Numerous studies have been conducted to investigate the incidence of disease contamination of cockroaches. Usually, cockroach specimens collected from various locations are allowed to walk over plates of bacteriological medium, which, when later incubated, give some indication of the disease organisms present on the cockroach body. Typically, results often show positive for at least one or more food poisoning bacteria, suggesting that field-collected cockroaches are quite capable of transmitting pathogenic diseases (mostly coliforms and *Staphylococcus*) to humans.

Flies

In some respects flies present quite a different problem to cockroaches. One significant difference between flies and cockroaches, from a control viewpoint, is that flies are such competent fliers. Their breeding grounds, where the maggots feed and develop, may be located in garbage dumps far removed from the kitchens in which they annoy people and threaten their health as flying adults.

In terms of disease transmission, flies are charged with transmitting more than 65 pathogenic organisms. These can be transmitted not only by being carried on the legs and bodies of flies, but also by the flies' feeding habits. Flies feed indiscriminately on excreta and food for human consumption, and this activity may well involve regurgitation prior to sponging up the food.

The great mobility of flies, often exercised during daylight when more foods are exposed and handled, coupled with their feeding habits, presents a very real threat to human health. Control measures, including physical, cultural and chemical approaches are usually essential. Breeding sites should be minimised, premises screened, sanitary procedures adopted and, when necessary, insecticides applied.

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In summary, many crawling and flying insect pests have been implicated with carrying disease organisms harmful to humans. A sound approach to minimising risk of infection by food poisoning and other such pathogenic organisms usually involves several critical components:

- thorough inspections and pest monitoring programs
- accurate identification of pests
- knowledge of the pest's ecology/life cycle/habits
- modification of physical and cultural conditions to prevent/discourage pest activity (eg screening and hygiene/sanitation improvements)
- safe use of appropriate chemical control measures when deemed necessary.

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CHAPTER 3

INSECT STRUCTURE & FUNCTION

Proper insect-pest management relies on an understanding of pest ecology, and this in turn requires a basic understanding of the structure and life processes of insects. This involves looking at the structure and function of insects, both internally and externally, and at insect communication and behaviour.

EXTERNAL STRUCTURE AND FUNCTION OF INSECTS

Body covering (integument)

The *integument* or body covering of insects varies in the degree to which it has been hardened or sclerotised. Termite workers that dwell in the moist, protected confines of underground tunnels may have a soft integument, while adult leaf beetles that lead a more exposed life tend to have a rather thickened, protective body covering.

The integument of an insect has three functions:

1 physically to protect the internal organs;
2 to act as an (exo)skeleton for muscle attachment; and
3 to reduce water loss from the body.

Broadly, the integument comprises three layers:

The basement membrane A thin, non-cellular inner sheath of connective tissue that lines the body cavity.

The epidermis The epidermis is the outermost living cell layer of the insect. Most of the cells comprising the epidermis secrete the cuticle of the integument which is the outermost non-living layer of the insect. Some epidermal cells are specialised and have developed as sense organs; others as dermal glands which form a duct through the cuticle to its surface. Substances secreted by the dermal glands may include wax, pheromones (facilitating communication with other individuals of the same species) and even defensive substances.

The cuticle The secreted non-cellular outer layer of the body wall. The cuticle itself has two layers:

Procuticle — usually the bulk of the cuticle, composed almost entirely of protein and chitin, which is a nitrogenous polysaccharide similar to cellulose. The outer part of the procuticle, the *exocuticle,* is usually darker and often much harder than the inner *endocuticle*.

Epicuticle — the very thin outer covering of the cuticle, comprising an inner (*cuticulin*) layer and an outer waxy layer that is important in preventing water loss from the insect's body to the outer environment.

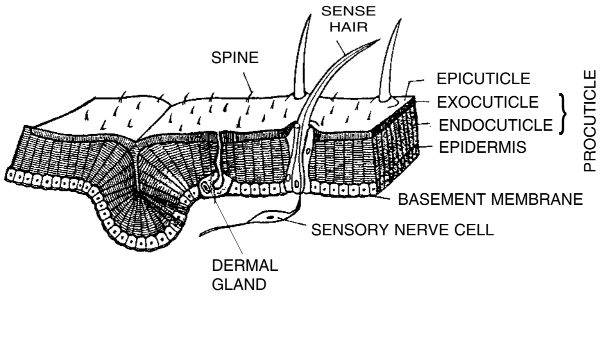


Figure 3.1 Diagrammatic lateral section of the integument (body wall) of an insect

Because the integument encloses the insect body, it must of necessity entail modification. As most insects mature, they periodically shed their cuticle (ie moult) and produce a new, larger cuticle, until adulthood. To accommodate short-term needs for change in size of the body covering (eg following food ingestion, and to enable movement), the integument is not of uniform thickness and hardness all over the body. Instead, particular 'plates' of the body wall (specifically, exocuticle) are hardened, and the plates are joined by softer, more flexible cuticle that is normally protected underneath the harder plates. When the insect requires some expansion of the more flexible membranous cuticle (eg after engorgement), the more rigid plates separate. As well, the insect must be able to receive external stimuli through the body covering. This is achieved largely by the development of certain epidermal cells into sensory devices, which may, for example, take the form of a seta or sensory hair protruding from the integument.

The use of contact insecticides relies on penetration of the cuticle by the insecticide, unless the insect's grooming habits facilitate oral entry. The primary barrier to the entrance of most insecticides is the waxy (and to some extent cement-like) layer of the epicuticle. Some insecticides may travel sideways in the procuticle, gaining entry at the tracheal (or breathing) system, or other locations. The thinner, membranous cuticle that occurs between the thicker plates of body covering and that covers sensory hairs provides little resistance to the penetration of insecticides.

General body plan

The adult insect body is characteristically divided into three parts: *head, thorax* and *abdomen.* It is thought to have evolved from a many-segmented, many-legged, worm-like animal. During evolution from this creature, the first 5 segments fused to form the head; the legs associated with those segments becoming mouthparts; the next three segments formed the thorax, which retained legs and, with the later development of wings in some insects, became the centre for locomotion; the other segments lost their legs and formed the abdomen, which served mainly for digestion and reproduction.

A number of terms are useful for purposes of orientation:

Anterior — at or near the front or head end of the body.
Posterior — at or near the hind end of the body.
Lateral — at or near the sides of the body.
Dorsal — at or near the top or upper section of the body.
Ventral — at or near the underside or lower section of the body.

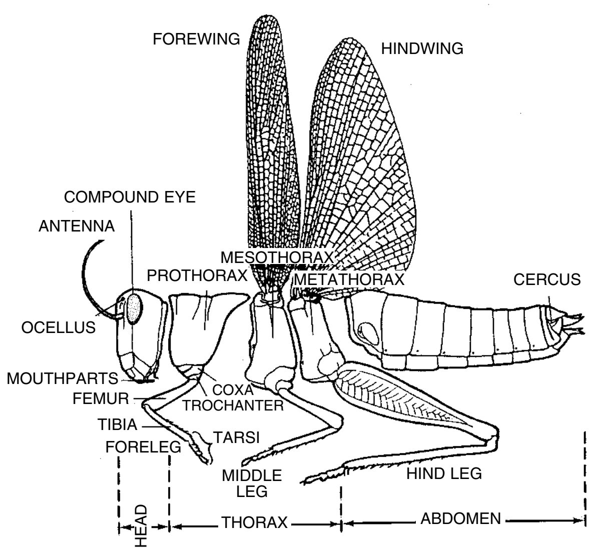


Figure 3.2 Outline of the lateral view of an insect (grasshopper) with main body regions separated

Head

The head of the adult is the anterior body part and bears the major sense organs (antennae and eyes) and mouthparts.

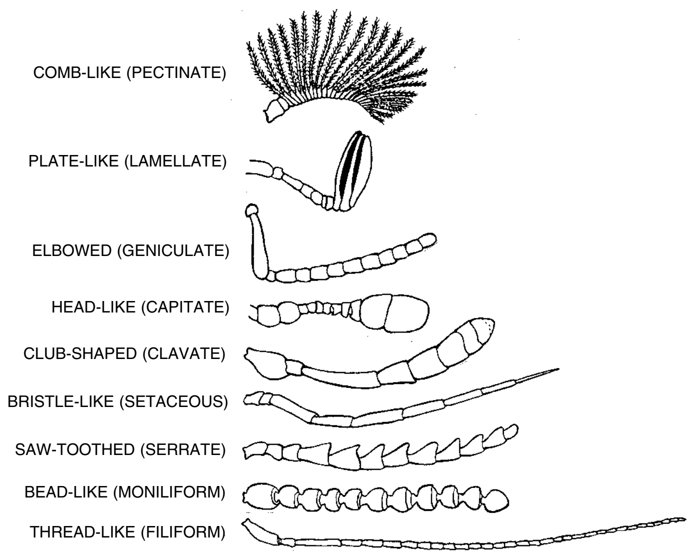


Figure 3.3 Some common types of antennae

Antennae

Typically, the antennae comprise a movable pair of segmented appendages arising from the face (often between the eyes). Much reduced in some immature insects, antennae of different shapes and sizes are found on different insects, and they often serve as useful diagnostic features in insect identification. The surface of the antennae is usually abundant in sensory devices that facilitate the senses of touch (feeling), sound (hearing), smell and, on some insects, taste. Having such a close proximity to the insect brain, sensory devices with their nervous connections to the brain probably play an important role in the route of entry and action of many insecticides.

Eyes

Compound eyes The compound eyes of insects are usually easily recognised as large paired organs situated on each side of the head. While most adult insects have compound eyes, some (eg worker or soldier termites) do not. The surface of the compound eye is covered with minute *facets* (sometimes up to 25,000 per eye), each of which represents the lens of an eye unit or *ommatidium*. The manner of image formation by insects is unclear; however, it is likely that a mosaic pattern is perceived. The primary function of compound eyes is probably movement perception, but the ability to perceive distance and colour may be present in some insects.

Figure 3.4 Head of robber fly showing the many eye units

Simple eyes There are two types:

Ocelli — Many adult insects, and immature stages of insects with an incomplete metamorphosis, have, as well as compound eyes, two (or more often three) simple eyes known as ocelli. These are usually located on the front of the head, between the compound eyes, and seem to perceive only changes in light intensity. Information collected by the ocelli may play a role in the insect's development of daily activity patterns.

Stemmata — The immature stages of insects with a complete metamorphosis (larvae, eg maggots and caterpillars) have no compound eyes. Instead, they have simple eyes known as stemmata. These are variable in form and probably detect movement, shape and, in some cases, colour.

Mouthparts

The mouthparts of insects originate from paired arthropod limbs. Over millions of years of insect evolution, the more primitive condition of mandibulate or chewing mouthparts (as found in cockroaches), has given rise to a variety of modifications which have enabled groups of insects to exploit new and different food sources. Observation of, and knowledge about, the different insect mouthparts can aid in insect identification, in understanding their biology and habits, and in certain aspects of control. Insecticide residues on plant parts, for example, may be entirely bypassed by an insect that pierces the tissues and sucks uncontaminated plant sap.

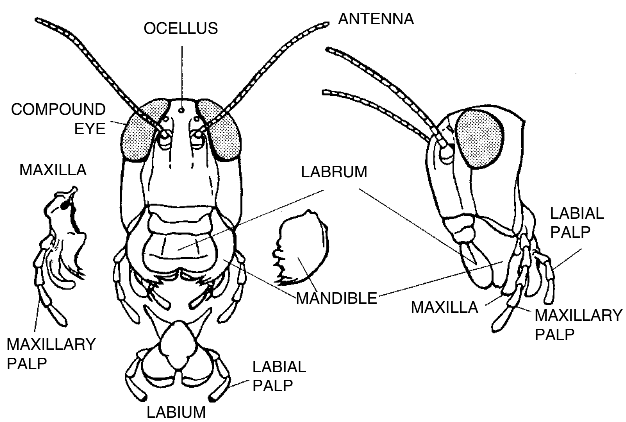


Figure 3.5 Mandibulate (chewing type) insect mouthparts

While there exist many different kinds of insect mouthparts, three types are most commonly encountered:

Mandibulate (or chewing) mouthparts A vast number of insects have mandibulate mouthparts, which enable them to chew up and ingest a huge variety of materials. Many insects are regarded as pests of humans because they chew and eat our plants, stored foods, fabrics, shelter etc. Mandibulate mouthparts mostly comprise six parts:

The labrum — a broadly flattened plate that hinges to the face and serves as a kind of 'upper lip'.

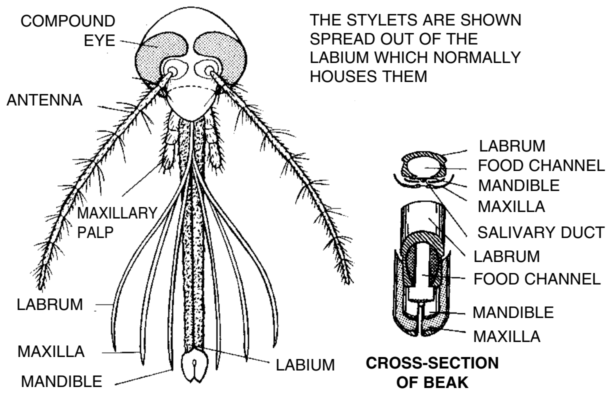
Paired mandibles — hardened, unsegmented jaws that are hinged to the face so that they open and close from side to side. Usually, mandibles have surfaces for cutting and grinding.

Paired maxillae — segmented structures that may act as

supplementary jaws for handling food.
Paired maxillary palps — segmented appendages, attached to the maxillae, that serve mainly as sensory organs for smelling and tasting food.
The labium — a composite structure that serves as the 'lower lip' and is involved with food handling.
Paired labial palps — segmented appendages that are often important in smelling and tasting food.

Insects with mandibulate mouthparts include cockroaches, silverfish, earwigs, termites, booklice, beetles, and immature stages of butterflies, moths and fleas. Many of these insects are pests of humans as a result of their feeding habits.

Figure 3.6 Piercing and sucking mouthparts of the female mosquito



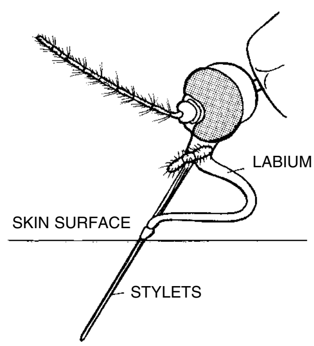


Figure 3.7 Lateral view of female mosquito mouthparts piercing skin

Piercing and sucking mouthparts During insect evolution, the basic parts making up the primitive mandibulate mouthparts were modified so as to enable the insect to pierce tissue and suck juices. This development allowed insects to exploit new food sources. For example:

1 the plant suckers (eg aphids, scales, leaf hoppers, cicadas) suck plant sap;
2 small animal predators (eg assassin bugs, water striders) suck the body juices of insects and other small animals; and
3 larger animal parasites (eg adult mosquitoes, adult fleas, bedbugs, lice) suck the blood of large animals such as birds and mammals.

In the main, the ability to pierce tissue and suck juices has been achieved by converting the mandibles and maxillae into elongated *stylets*, which, fitted together, form a hollow needle that is often sheathed by the *labium*. The entire structure is often referred to as a *beak*, which, when pressed against tissue, allows the hollow needle to penetrate. The needle itself has a *salivary duct*, which serves to inject saliva into the victim (often incorporating anti-coagulants to keep juices free-flowing), and a *food channel* for sucking up juices into the digestive system. The injection of saliva into other organisms often causes irritation and, more importantly, serves as an effective means of disease transmission to plants and animals, including humans.

Sucking mouthparts Some insects have developed rather specialised mouthparts that mainly enable them to ingest available liquids. Broadly, there are two types of sucking mouthparts:
Sponging type — as found in many adult flies (eg common house fly). The mouthparts have evolved into a *proboscis,* which ends with a *sponging surface.* Liquids may be sucked up the food channel; or because saliva can be secreted onto food, semi-solid or solid foods (eg sugar) can be made liquid and subsequently ingested.

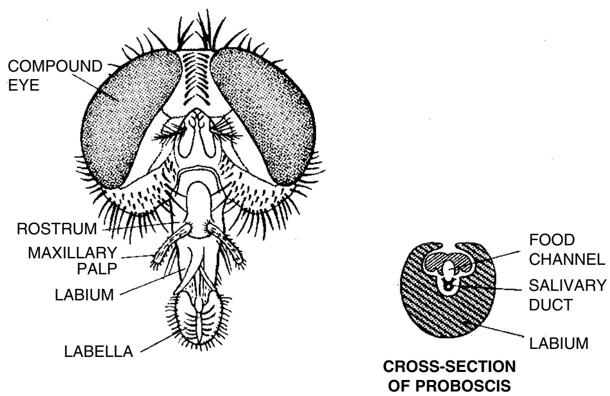


Figure 3.8 Sponging-type sucking mouthparts as found in some adult flies

Siphoning type — as found in many adult moths and butterflies. A proboscis with only one channel for food serves for the intake of any available liquids (eg nectar, honeydew). The proboscis is normally coiled up, being temporarily uncoiled during feeding. The labial palps can be rather prominent. Clearly, such mouthparts are very limited in their capacity to do damage to humans or stored goods and other materials. In the case of moths, only the immature caterpillar with its mandibulate mouthparts is directly capable of damaging materials.

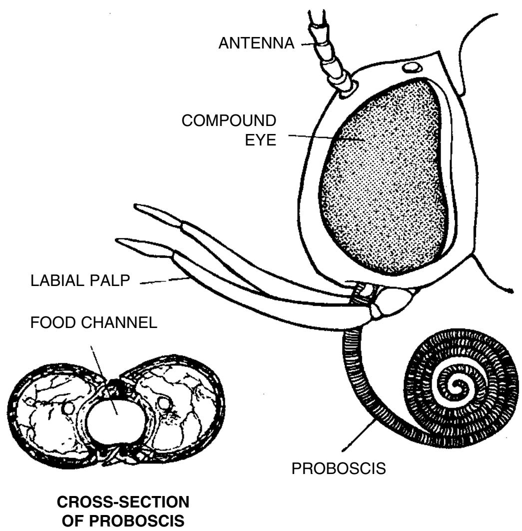


Figure 3.9 Siphoning-type sucking mouthparts as found in adult moths and butterflies

Other types of mouthparts There are some other mouthpart modifications, which are quite distinct from those described thus far:
Chewing-lapping type — as found in bees.
Rasping-sucking type — as found in thrips.
Filtering type — as found in various aquatic larvae.
Cutting-sponging type — as found in various adult flies.
Mouth-hook type — as found in fly larvae.

Thorax

The thorax, that region of the insect's body that lies between the head and the abdomen, is largely specialised for locomotion. It comprises three segments:
The prothorax — which bears the forelegs.
The mesothorax — which bears the middle legs and forewings (if present).
The metathorax — which bears the hindlegs and hindwings (if present).

As well, each thoracic segment usually bears laterally a pair of *spiracles* or breathing apertures. The plate located dorsally on the prothorax, called the *pronotum*, is well developed in some insects, serving to cover and protect much of the thorax and sometimes the head.

Legs

The insect leg generally comprises:
The coxa — which articulates with the thorax.
The trochanter — often a relatively small joint-like segment.
The femur — often rather elongated, sometimes modified.
The tibia — often rather elongated, sometimes modified.
The tarsus — itself comprising 2–5 segments and often a pair of claws. Often, small pads (*pulvilli*) beneath the claws allow for a better purchase on smooth surfaces.

The legs of insects, of course, serve as their chief means of terrestrial locomotion. While the legs of cockroaches may well be viewed as adapted for walking and running, a great variety of leg modifications can be observed among insects. The femur and tibia of the forelegs of praying mantids are endowed with spines and spikes to facilitate prey capture, while the forelegs of mole crickets are highly modified as digging tools. The hind femurs of grasshoppers are highly developed for jumping, while those of the honey bee are developed as pollen-carrying combs.

Wings

Insects are the only winged invertebrate life forms. Most insects have two pairs of wings, and these are functional only during the adult stage. Some wingless insects (eg silverfish, springtails) have never developed wings, while others (eg bedbugs, fleas, lice) probably had winged ancestors but had no need to maintain wings because of their very specialised, parasitic lifestyle. Some insects (eg reproductive termites) discard their wings after use.

Typically, wings are sac-like expansions of the lateral body walls, comprising basically two layers of integument. The upper and lower layers are partly fused, leaving a system of narrow, blood-filled channels (continuous with the blood-filled body cavity), into which grow nerves and tracheae (the 'pipes' of the breathing system).

Figure 3.10 A beetle showing the elytra and membranous wings

Transparent wings are generally referred to as *membranous*. The forewings of insects such as cockroaches and grasshoppers are slightly thickened and leathery, affording protection for the hindwings and abdomen. Such modified forewings are called *tegmina* (sing. *tegmen*). The greatly thickened forewings of beetles and weevils are called *elytra* (sing. *elytron*). True flies (Order Diptera) possess only one pair of real wings. In place of hindwings, these insects have club-shaped balancing organs called *halteres*. The colour of moth and butterfly wings depends on thousands of tiny, overlapping scales attached to their wings.

From the viewpoint of chemical control of flying insects, the wings often serve as a relatively large surface area for the action of contact insecticides.

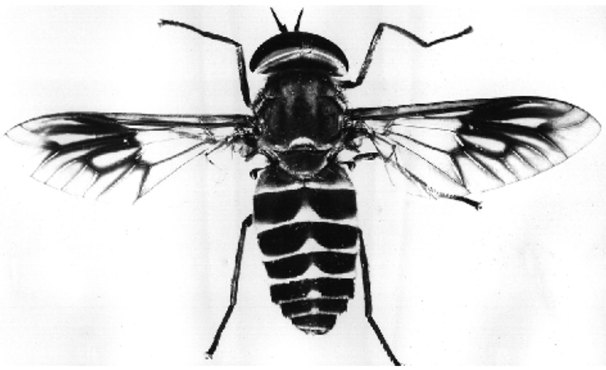


Figure 3.11 A March fly showing the club-shaped halteres

Abdomen

The abdomen is the posterior region of the insect and usually comprises up to eleven segments. Generally, eight segments are clearly visible, and each carries laterally a pair of *spiracles* or breathing apertures. The segments allow for some flexibility, as internally the abdomen houses most of the digestive and reproductive organs and these may require expansion, if only temporarily.

Appendages to the insect abdomen are few:

Cerci If present, these are often leaf-shaped and usually attached to the last abdominal segment and may serve sensory functions (eg detecting touch, air movements and perhaps sound).

Reproductive appendages These are often highly specialised and complex. In the male they comprise the *penis*, associated structures and often a pair of *claspers*, and in the female a well-developed *ovipositor* (for placing eggs in protected sites) and associated structures.

Prolegs The rather elongated larvae of moths, butterflies and certain other insects may have fleshy, unjointed projections of the abdomen. These usually function as legs to supplement the three thoracic pairs in locomotion. The projections are called *prolegs*, and moth and butterfly caterpillars may have up to five pairs of prolegs during their larval life.

The digestive system of insects terminates at the posterior of the abdomen with one orifice, the *anus*.

INTERNAL STRUCTURE AND FUNCTION OF INSECTS

General internal body plan

While plants capture and utilise energy from the sun, animals consume plants or other animals as their food source. The food ingested by insects and other animals is, with the aid of oxygen taken in by breathing, broken down in an energy-yielding process that enables the animal to grow, move and do many different kinds of energy-costing work. The basic plan by which insects are able to utilise food and oxygen differs markedly from that used by higher animals such as humans.

Before considering the particular systems that serve various purposes within the insect body, it may be worthwhile to first examine the general plan.

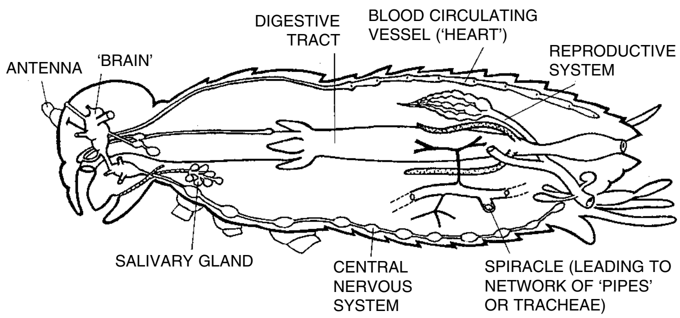


Figure 3.12 The general internal body plan of insects

The insect body may be regarded as being rather like a 'capsule' (of cuticle) that supports inside it a variety of tissues and organs and contains the blood that bathes all these tissues and organs. The blood is circulated by means of a dorsally located 'tubular pump'. The digestive system, basically a tube running through the capsule (with an opening at each end), is able to absorb useful nutrients from the food ingested. Nutrients absorbed through the gut wall in this manner are picked up by the blood, which, in circulating, bathes all the tissues and organs that require these nutrients for growth and development. As well, the digestive tract has processes that, on being bathed by blood, absorb waste products from it, to excrete them along the latter part of the digestive tract.

Oxygen is delivered to cells by a network of pipes that start at the capsule surface as holes (*spiracles*) and then branch into smaller and smaller pipes to deliver oxygen to the cell sites that require it.

The central part of the nervous system is a ventrally located double nerve cord that branches into finer nerve cells, which ramify throughout the body (including its surface) to collect information and allow tissues to act on it. Further control of body processes and behaviour is achieved by the production, by certain glands, of 'chemical messengers': hormones for regulating the body of an individual insect, and pheromones for relaying information between individuals (of a given species).

The reproductive systems of insects, generally found within the body cavity towards the posterior of the abdomen, serve to facilitate the development of sperm in males and eggs (usually fertilised with sperm) in females. Insect musculature allows for processes ranging from running and flying to the more 'automatic' functioning of the tubular pump that circulates blood. Finally, as food is not always freely available to insects, most have a system for converting food into a storable form for use when required in the future.

Blood circulation system

Blood being circulated within an animal provides a means of chemical exchange between the different organs. The main functions of blood in most higher animals may include distribution of food nutrients, carriage of waste products, circulation of hormones and often distribution of oxygen (as in humans). In most insects, blood circulation plays no role in the delivery of oxygen; instead, a network of pipes performs the function more directly.

Unlike the arrangement of arteries and veins in humans, insect blood fills the body cavity (*haemocoel*) of the insect and thus bathes the organs and tissues. The blood itself (*haemolymph*), often colourless, comprises a liquid (*plasma*) and cells (*haemocytes*) that may function in the clotting of wounds, defence against foreign organisms and other processes.

To achieve effective blood circulation, insects have a muscular *dorsal blood vessel* (a tube comprising the heart and aorta) which has a series of inlet valves (*ostia*). By the ordered intake of haemolymph, the closing of valves and contraction, haemolymph is pushed forward. Then, often with the aid of various diaphragms and pumping structures appropriately located, the haemolymph circulates throughout the haemocoel and into legs, antennae and other appendages.

As well as distributing nutrients obtained via the gut wall, the haemolymph accumulates a variety of metabolic waste products. Such wastes are collected from the haemolymph by the *Malpighian tubules* (part of the digestive and excretory system) and directed to the hindgut for excretion.

It is likely that insect haemolymph plays an important role in the distribution of contact insecticides, which act by penetrating the cuticle. As the haemolymph bathes the nervous system, insecticides contacted and absorbed through various parts of the body (often legs and abdomen) may be effectively carried to the target tissues.

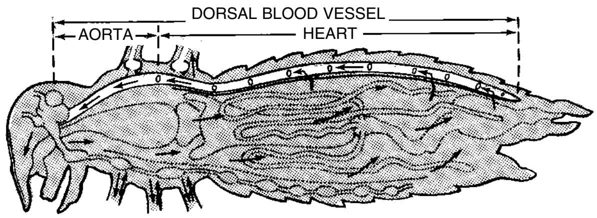


Figure 3.13 Blood circulation in insects. Diagrammatic lateral view showing the role of the dorsal blood vessel in blood circulation.

Digestive and excretory system

Insects find and select the food they ingest by means of visual, chemical (smell or taste) and tactile cues. The digestive tract, which receives the food, forms a tube down the length of the insect, with the *mouth* opening at the anterior end and the *anus* at the posterior. In most insects, saliva, produced in the *salivary glands*, is mixed with the food. In chewing insects (eg cockroaches) this takes place in the mouth and may allow for some 'predigestion', while in insects that pierce and suck (eg adult fleas), the saliva is injected into the host's bloodstream and often contains anti-coagulant properties.

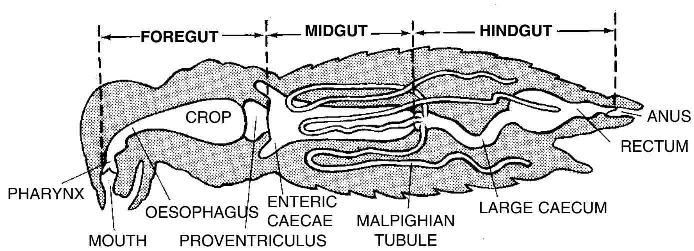


Figure 3.14 The digestive and excretory system of insects. Diagrammatic lateral view showing the various sections of the digestive tract.

Broadly, the digestive system comprises three regions: *foregut, midgut and hindgut.* Of these, the foregut and hindgut are lined with cuticle. The main functions of these regions may be broadly outlined:

The foregut Food entering the mouth cavity (*pharynx*) is passed down the tubular *oesophagus* to the *crop,* where it may be held for some time prior to being digested. Food from the crop passes through a muscular gizzard (the *proventriculus*), which acts as a valve to the midgut and may have grinding teeth (as in cockroaches, to enable further breakdown), sharp needle-like teeth (as in adult fleas, for crushing blood corpuscles) or other processes, depending on the diet.

The midgut This region is the primary site for digestion. The finger-like projections (*enteric caecae*) at its anterior give a greater surface area for the digestion process, which involves the secretion of various enzymes that break food nutrients into manageable molecules. The nutrients are absorbed through the midgut wall into the blood, which effectively distributes them around the body.

The hindgut The hindgut is that region of the digestive tract which usually extends from its joining with the *Malpighian tubules* through the *large caecum* and *rectum* to the *anus.* Waste products of digestion pass from the midgut through the hindgut and are thus expelled.

The *Malpighian tubules,* which may number from 2 to well over 100, serve a function similar to that of the kidneys of higher animals. The tubules are bathed in haemolymph and, by processes of diffusion, extract waste products from the blood to form a kind of urine, which is discharged into the hindgut. The *rectum* plays a regulatory role in excretion. It may add substances to, or absorb substances from, the excretion products in the hindgut. Commonly, water is reabsorbed from waste products before they are expelled.

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The precise nature of the function and structure of the digestive and excretory system of particular insects may vary, and are usually clearly linked to diet. In terms of nutritional requirements for survival, growth and development, insects need to take in at least a minimum selection of food materials. Energy-yielding molecules (eg sugars, fats) are often needed in large quantities. Amino acids (the building blocks of proteins), vitamins and minerals are probably the most basically important constituents of the diet. As well, although insects vary greatly in their demand for it, all require water, as all cell functions rely on its solvent properties.

Some insects (eg termites and certain wood cockroaches) do not produce enzymes able to break down cellulose, which is the main constituent of wood. Instead, they maintain an assemblage of symbiotic micro-organisms in their digestive tracts. The micro-organisms (perhaps protozoa or bacteria) facilitate the breakdown of cellulose into products that the insect can absorb and utilise.

The digestive system of insects has been widely exploited as an important route of entry for insecticides that can act as 'oral' or 'stomach' poisons. Clearly, control procedures of this kind may involve the preparation of baits for ingestion, but they may also exploit the grooming habits of insects, as is the case with the ingestion of dusts by termites, cockroaches and certain other insects.

Nervous and glandular systems

In very broad terms, animals have systems within their make-up that enable them to evaluate both their external and internal environments. By acting appropriately on the information thus monitored, animals can feed, grow, develop, reproduce and communicate effectively. In insects, much of this co-ordination is achieved by a complex integration of the operations of the nervous system (which controls the minute by minute behaviour of insects, including activities such as movement and feeding) and the glandular systems. The glandular systems include:

Endocrine Glands — responsible for internal secretions such as hormones, which are responsible for the control of longer term processes such as growth and development.

Exocrine Glands — which secrete substances to the outside of the body, for example pheromones and silk.

Nervous system

The nervous system of insects comprises a complex network of specialised cells that is capable of transmitting information (as small 'electrical' impulses) from one part of the body to another. The *nerve cells* along which messages travel are not directly connected to each other; adjacent cells are separated by a tiny fluid-filled cavity (*nerve synapse*). Messages travel across nerve synapses as secreted chemicals (*neurosecretions*), of which acetyl choline is the most common. Once the message is conveyed, these neurosecretions are rapidly inactivated by the action of *cholinesterase* enzymes.

The central nervous system (CNS) of an insect is present as a centrally located double nerve cord. This often runs the length of the body and has a number of swellings (*ganglia,* sing. *ganglion*), which are concentrations of nerve cells that usually

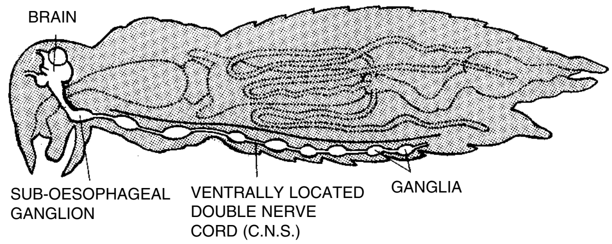

Figure 3.15 The central nervous system of insects. Diagrammatic lateral section showing the ventral nerve cord, ganglia and brain.

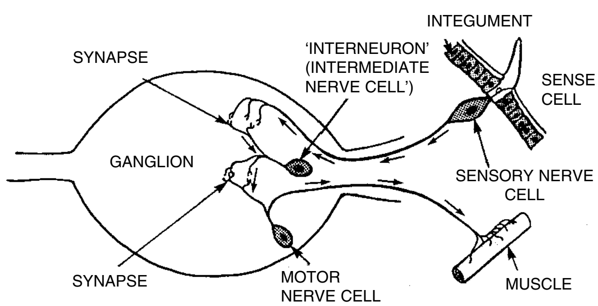

Figure 3.16 Diagrammatic representation of a part of the nervous system of an insect. Arrows show the direction of travel of a nerve impulse ('message') from a sensory cell (on the body wall), into a ganglion (CNS) and on to a muscle via its motor nerve cell.

have many nerve cells extending into adjacent parts. The ganglia can be regarded as centres for the co-ordination of information, and the head contains the two larger ganglia: the *sub-oesophageal ganglion* (below the oesophagus) and the *brain.* Generally, *sensory* nerve cells convey information from sensory devices to the CNS, and *motor* nerve cells convey information from the CNS to muscles etc which will act on it.

Insects have a variety of sensory devices for detecting information about the environment. Broadly, these may be summarised as follows:

Touch — tiny hairs, dome-shaped bumps or other structures, often distributed widely over the body but sometimes concentrated on antennae, cerci or other parts.

Smell — commonly hairs or pits, associated mostly with antennae and mouthparts.

Taste — commonly hairs or pits, found mostly on mouthparts but sometimes located on antennae and tarsi.

Sight — compound or simple eyes, found on the head.

Hearing — various structures found on abdomen, legs, thorax or other parts.

A great many of the synthetic insecticides currently used rely on disruption of the nervous system as their mode of action. Synthetic pyrethroids (eg permethrin) probably act on the nerve cells (axons), while the organophosphates (eg chlorpyrifos) and carbamates (eg propoxur) act by disrupting the action of cholinesterase enzymes at nerve synapses. The precise action of many of the insecticides that act as 'nerve poisons' is unclear.

Glandular systems

Endocrine glands

While the nervous system is well developed for controlling activities that require very quick reactions (eg fleeing from a predator), longer term changes, such as those associated with growth and development, are largely controlled by glandular secretions known as *hormones* — chemical 'messengers' secreted by certain glands into the haemolymph that exert an influence on specific target tissues or organs.

Certain cues (such as temperature change or gut distension), via the release of a 'brain hormone' into the blood, trigger the prothoracic glands (also called ecdysial glands) to secrete the moulting hormone called *ecdysone*, which in turn stimulates the production of the enzymes responsible for the production of insect cuticle (including the synthesis of chitin, that component of insect cuticle responsible for its strength).

The endocrine gland, known as the *corpora allata* (located behind the brain near the foregut), under the influence of the nervous system, secretes juvenile hormone which, while it circulates in the blood, maintains the insect in an immature, larval form. As the immature insect nears the end of its development, the corpora allata ceases secretion of juvenile hormone, and at the next moult, the insect becomes an adult. So, while juvenile hormone is present, the insect remains immature and when it is no longer present, the insect becomes an adult.

These aspects of the growth and development of insects have been exploited with the development of Insect Growth Regulators (IGRs), notably Juvenile Hormone Analogues (JHAs) and Chitin Synthesis Inhibitors (CSIs).

Exocrine glands

These glands secrete substances to the outside of the insect. Examples include salivary and silk glands, glands for defensive secretions and glands that secrete pheromones.

A *pheromone* can be regarded as a chemical 'messenger' that, when produced in a specific gland of an insect and then secreted, brings about a particular behavioural or developmental response in other individuals of the same species. Pheromones are often volatile chemicals received as odours, and some are transmitted between individuals by physical contact. Functions served by different pheromones include sex attraction (for mate-finding), caste regulation (as in social insects like termites), aggregation (facilitating the gregarious behaviour of cockroaches), trail-marking (important in food location for ants) and alarm indication (often used by social insects to warn of danger).

Synthetic pheromones (usually aggregation or sex attractant types) are used in traps for the monitoring of a range of stored product insect pests.

Reproductive system

Insects have developed reproductive systems that can produce enormous numbers of offspring. While some insects may produce less than 100 eggs in an adult lifetime, others may produce thousands per day. Most insects reproduce by means of locating a mate of the opposite sex (using sound, pheromones, visual displays or other means) and mating (often involving courtship behaviour followed by copulation). The female usually lays the eggs on or near an appropriate food source. Some insects (eg certain aphids, stick insects) can reproduce without fertilisation of the female's eggs by the male's sperm. This process is known as *parthenogenesis.* Most insect reproduction, however, relies on the fertilisation of females by males.

Male reproductive system

The reproductive system of the male insect is designed for the production and transfer of sperm. Located in the abdomen, a pair of *testes* produce sperm cells, which pass down the tubular *vas deferens* into sperm sacs (*seminal vesicles*), where they are stored. Secretions from the *accessory glands* are mixed with sperm cells before they pass down the *ejaculatory duct* to be secreted by the *penis*. Male genitalia usually comprise the penis and often a pair of *claspers,* which serve an important function in copulation.

Female reproductive system

The reproductive system of the female insect is designed for the production of eggs, sperm storage, fertilisation of eggs and egg-laying. Each female insect has a pair of *ovaries,* which may comprise one to several hundred *ovarioles.* Eggs produced

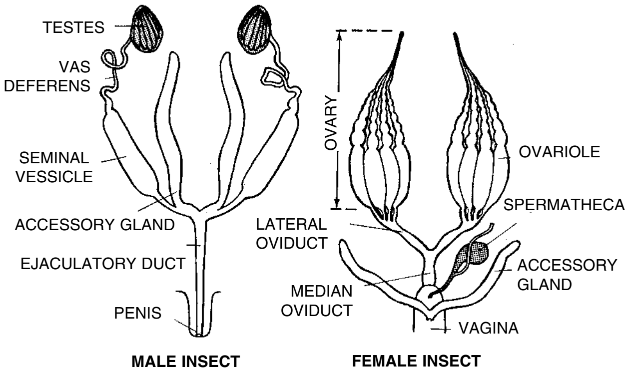

Figure 3.17 Generalised male and female insect reproductive systems

in the ovarioles pass down the *lateral oviducts* into the *median oviduct* (*vagina*). Eggs may be fertilised as they pass the opening of the *spermatheca* — an organ that stores sperm following copulation with a male. Eggs passing the *accessory gland* may be treated in some way. In some insects the eggs are made sticky, so as to be easily glued to leaves or other surfaces, while in cockroaches the eggs are encapsulated in batches with a protective egg case (*ootheca*). The external genitalia of the female are often in the form of a rather conspicuous device for egg-laying called the *ovipositor.* In most insects each individual female of the species is involved with producing new individuals. However, in social insects (eg termites, ants, bees) the majority of the population of a colony are often in effect sterile, and reproduction is carried out by the reproductive castes only. This may mean that a colony of more than 2 million termites relies entirely on the reproductive efforts of one pair of individuals.

Respiratory (breathing) system

All animals need oxygen for the breakdown of foodstuff molecules and for the utilisation of the energy therein. Carbon dioxide is a waste product of this process and must be expelled. In higher animals like humans, the blood plays an important role in delivering oxygen from the lungs to all body cells and in removing waste carbon dioxide from cell sites.

Most insects achieve this oxygen delivery and carbon dioxide removal by means of a network of pipes or air tubes. Commonly, insects have about ten pairs of openings, called *spiracles*, located on the sides of their thorax and abdomen. These open into pipes, are spirally thickened with cuticle, and are referred to as *tracheae.* While there are usually a few rather large longitudinal tracheal trunks, the tracheae branch and keep branching, becoming smaller in diameter until there are enormous numbers of tiny pipes (less than 1 micron in diameter) adjoining the cells of tissues and organs. These tiny pipes are called *tracheoles,* and their ultimate contact with cells allows for diffusion of gases into the cells themselves.

In sluggish insects this system operates entirely by diffusion of gases along the 'pipework' (tracheal) system, with oxygen being supplied to the cells and carbon dioxide being expelled. In general, spiracles can be closed, and this is likely to be in the interests of water conservation within the insect body. Insects that are very active (eg flying insects like house

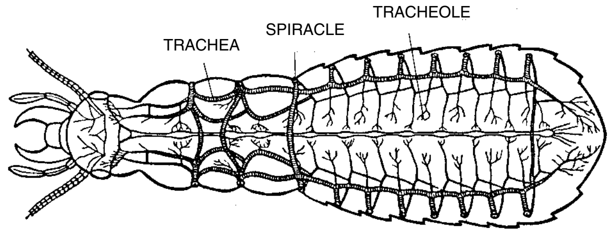

Figure 3.18 The respiratory (breathing) system of insects. Diagrammatic dorsal view showing spiracles, network of tracheae and tracheoles

flies and bees) have a higher demand for oxygen than sluggish insects. This higher oxygen demand is usually met by an expansion of certain tracheae to form *air sacs*. This condition, aided by deliberate ventilation (by way of contractions of certain muscles), facilitates the high rate of air exchange needed for energy-expensive activities.

The tracheal breathing system of insects serves as an important route of entry for certain insecticides. Fumigation practices rely on exposing insects to a toxic atmosphere, which kills when inhaled. Some insecticides are noted for this inhalation toxicity. Dichlorvos, for example, as well as being an oral and contact poison, is insecticidal when applied as a vapour and breathed in by insects. An example of this action is the use of dichlorvos-impregnated resin strips to control clothes moths in a closet. As well, it is possible that some contact insecticides become soluble in certain layers of the insect cuticle and thus travel laterally into the insect via the spiracles and tracheae.

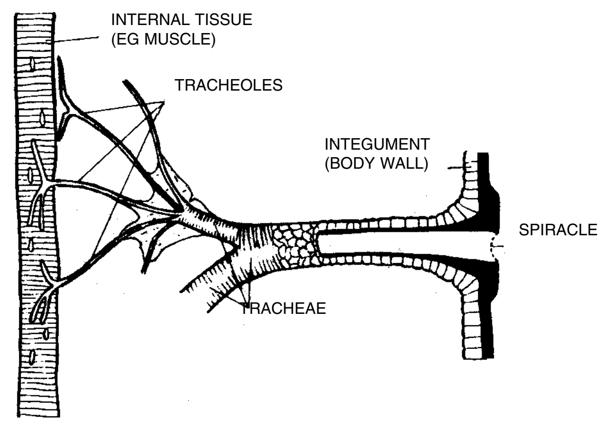

Figure 3.19 Diagram showing spiracles and tracheal network branching into finer tracheoles

Figure 3.20 Spiracles of a whitestemmed gum moth larva

Muscular system

The muscular system of insects — a rather complex arrangement of what is, in many, an enormous number of muscles — is the site for the final conversion of chemically stored energy to mechanical energy, manifest as movement. *Muscles* are basically bundles of strap-like fibres (with connections to the nervous system) that can do work because they can undergo contraction. Most animals employ muscles for gross movement (eg finding food or a mate, or avoiding unfavourable conditions), but muscles can also play an important role in internal processes (eg blood circulation and digestion).

Having an external skeleton, insects have much surface for muscle attachment. With appropriate kinds of skeletal joints between segments, the muscular system may facilitate walking, running, crawling, burrowing, swimming and, of course, flying. Owing to their small size, insects seem to be very strong in relation to their body weight: in some cases they are able to lift twenty-five times their own weight. However, it is in the power of flight that insects excel. Few other animals have developed muscles capable of contracting and relaxing so rapidly that wingbeat frequencies of more than 1000 beats per second are achieved. Their power of flight has made the insects one of the most mobile and widely dispersed groups of animals on earth.

Food storage system

Insects are not always able to procure food immediately it is needed, so most insects have *fat body* — a loosely organised aggregation of cells occurring throughout the body cavity. Often, fat body is apparent as irregularly shaped, whitish material packed around internal organs and inside the body wall, most commonly in the abdomen.

Young stages of insects often accumulate fat body — mostly stored lipids (fats), protein and glycogen — for use at a later stage. Many larval forms store enormous amounts of food, to facilitate the changes that occur during pupation and often to provide food reserves for the adult stage. Some insects do not feed during the adult stage, relying entirely for their energy on food reserves laid down during immaturity.

Fat body, in addition to acting as a food storage system, is also the site of many important metabolic processes (eg synthesis of certain proteins).

INSECT COMMUNICATION AND BEHAVIOUR

Perhaps the most singularly important characteristic of live organisms is the ability to respond to stimuli. In a changing environment this ability can facilitate responses that are in the best interests of the survival and reproduction of a given organism. Clearly, the behaviour of animals such as insects relies on an immensely complex integration of body processes, perhaps the most important of which are the nervous (including sensory) and chemical control systems.

Communication

Communication in insects relies on the transmission of a signal and its reception, so as to bring about a behavioural change in one or more individuals. There are three primary means of communication in insects:

Visual communication The sometimes complex colour patterns of moths and butterflies may serve as visual cues in mating procedures. Certain beetles (eg glowworms) can convert stored chemical energy into light energy, which is used to communicate information about mating. Even the highly refined camouflaging of some insects may be viewed as a kind of communication.

Auditory communication Most insects at some stage use sounds to communicate. The sound may be one produced 'normally' (eg the wingbeat of a female mosquito creating a mating response in the male), or it may be one produced specifically, which may involve vibrating certain organs (as in male cicadas attracting mates), rubbing together body parts (as in male field crickets making their advertisement), or even knocking the substrate with part of the body (as in disturbed termites). Sound produced by such means and received by the sensory nervous system of other insects may convey information about sexual attraction, alarm or aggression.

Chemical communication A widely exploited means of communication between individual insects of a given species is the secretion of pheromones. Insects may employ pheromones to aggregate individuals, indicate alarm, mark trails, control castes and, commonly, attract mates.

Behaviour

The observed behaviour of insects is probably a combination of innate (instinctive, inherited) and learned behaviour patterns.

Innate behaviour

Certain kinds of behaviour observed in insects involve an inherited (not learned) response or set of responses for a given stimulus. *Reflexes* — automatic or involuntary responses to stimuli — are common. An example of this type of innate behaviour is the extension of mouthparts by certain flies when the tarsi of their legs are allowed to contact sugar solution. Sensory receivers on the tarsi send a message along nerves in the leg to the central nervous system, which in turn sends a message to the mouthparts to extend. Reflex behaviour of this kind is very common among insects. *Kineses* — random movements initiated by a stimulus — also are common. An example of this type of behaviour is exhibited in many daytime-active insects. In the dark such insects tend to remain motionless. A certain amount of the stimulus, light, makes them move, and more light results in more activity and movement. Another type of innate behaviour, *taxes,* involves directed movement either towards or away from the stimulus (eg light, gravity, temperature). Cockroaches exhibit *thigmotaxis* — a behaviour that relies heavily on the sense of touch and brings about a tendency to seek and rest in tight crevices, so that much of the body is in contact with its surroundings. Many insects exhibit *phototaxis* — a reaction to light that may be positive (attracting the insect to the light source) or negative (repelling the insect away from the light). Much of the behaviour observed in insects is a result of inherited behaviour patterns that can often be interpreted as reflexes, kineses and taxes.

Learned behaviour

Aspects of insect behaviour that can be regarded as learned involve adaptive changes in individual behaviour that result from experience. Habituation to a stimulus is one example of a learned behaviour. Certain adult flies are normally repelled by the odour of peppermint oil; but if the flies are grown (as maggots) in the presence of the oil, the reaction of adults is one of attraction rather than repulsion. What is often called exploratory learning can be observed in various bees and wasps — recognition and memorising of particular landmarks facilitate travelling to and from the nest.

The question of whether insects are able to reason is arguable. Reason implies an ability to solve problems by deducing from information amassed by different experiences. Most would argue that insects do not have this ability, but some would argue that the ability to use tools implies reasoning ability. In certain ants that inhabit tropical trees, the larvae are able to produce silk. When some adults hold leaves together, other adults, each holding a larva, literally sew the leaves together with silk produced from the larvae. The question of reasoning or intelligence in insects will probably always remain arguable.

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CHAPTER 4

INSECT GROWTH & METAMORPHOSIS

Insect growth by necessity involves periodic moulting and is controlled by various factors. The evolution of insects has led to the development of different ways of 'growing up'. Insect 'metamorphosis' refers to the change in form that an individual insect undergoes during its development towards adulthood. While some insects change only slightly in form from hatching to adulthood, others undergo drastic changes that result in complete dissimilarity in form between the young stage and the adult that it becomes. This chapter considers three types of insect metamorphosis:

- Primitive (or ametabolous), for example silverfish
- Gradual (or hemimetabolous), for example cockroaches
- Complete (or holometabolous), for example fleas.

INSECT GROWTH

The life cycle of most insects, after hatching from an egg that is usually located on or near suitable food, comprises two main stages:

1. *Immaturity* — The insect undergoes a growth phase that involves several moults and may take days, weeks or years, depending on the species.
2. *Maturity* (adulthood) — This usually involves no moulting and is mostly concerned with finding a mate, reproducing and dispersing. Again, this may encompass days or years, depending on the species.

The process of moulting (*ecdysis*) is necessary during immaturity because insects undergo what are often rather rapid changes in size. The cuticle of insects allows for only limited growth, so periodically the cuticle must be split and shed, so that a new cuticle, forming underneath the old, can expand and harden to suit the growth rate. The number of moults varies with species and growth conditions. Some insects moult only three times (eg the housefly); perhaps most moult about 5–6 times (eg cockroaches); but others moult many more times. The form in which an insect appears after each moult is called an *instar* (so that people who work with insects can refer, for example, to a first instar larva or third instar nymph).

Rate of growth is affected by various factors. Temperature, for example, plays an important role. Most insects can probably survive temperatures from 10° to 40°C but most rapid development probably occurs at about 30°–35°C. At 10°C housefly maggots require more than a month to complete this immature stage; at 30°C as little as 5 days. Quality of food also can affect growth rate. Blowfly maggots feeding in the nutrient-rich meat of a carcass may need only a few days to complete this immature stage, while various wood-boring grubs feeding on relatively lower-nutrient wood fibre may require up to several years to mature. For these and other reasons, the length of life cycle of various insects is usually given as a range. For example, the life cycle of the furniture beetle may be given as 1–3 years, variations between 1 and 3 years being attributable to temperature, quality of food or other factors.

Often, during the development and adulthood of insects, a portion of their life cycle may be spent in a kind of dormancy or what appears to be a state of suspended animation. The simplest form of dormancy is referred to as *quiescence* or *hibernation* and this condition is usually brought on by adverse environmental conditions (eg, most typically, very cold temperatures). The inactivity usually ceases when environmental conditions become favourable. This suspension of activity (and some physiological processes) may occur during any stage of the life cycle (from egg through to adult).

A more complex form of dormancy, in which onset may occur before the adverse conditions (eg before temperatures fall dramatically) is referred to as *diapause*. Here, initiation and termination of dormancy are dependent on hormonal changes that result from environmental effects (eg photoperiod; that is, length of day and/or temperature changes) or genetic programming.

These mechanisms represent an important adaptation that has allowed insects to exploit an enormous range of environments that may, at certain times, be inhospitable (perhaps due to adverse temperatures, lack of moisture or even unavailability of food).

INSECT METAMORPHOSIS

In insect evolution there has been a general trend towards specialisation in form and function of the different stages of growth. The term 'metamorphosis' means 'change in form', and in this context it refers to change in form after hatching from the egg. There are three important types of metamorphosis.

Primitive (or ametabolous) metamorphosis

Example: silverfish.

Sometimes referred to as 'no metamorphosis', this very primitive condition involves only slight changes in form during growth. Perhaps the most marked development is the formation of reproductive organs. Unlike other types of insect growth, moulting may continue after maturity is reached and the total number of moults is often large and variable. Diet and habits of the young are identical to those of the adult. This type of metamorphosis may be summarised as:

egg ➞ young (undergoes moults) ➞ adult (may continue moulting)

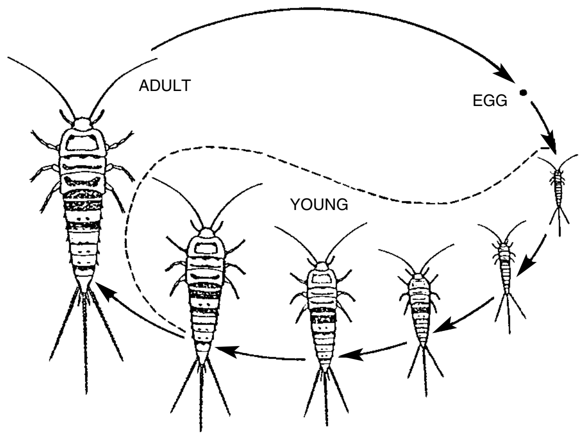

Fig 4.1 Primitive metamorphosis: Example — silverfish

Gradual (or hemimetabolous) metamorphosis

Examples: cockroaches, bedbugs, termites, lice.

Insects that undergo a gradual metamorphosis experience more observable changes in their form during growth, but they retain essentially the same basic structure. Changes may involve the development of wings (often observable as external wing pads in the immature stages) and reproductive organs in the adult. Colour differences sometimes occur between the immature and mature forms. The immature stages of insects that undergo a gradual metamorphosis are called *nymphs*.

Essentially, nymphs are similar to adults in relation to diet, habit and structural features such as antennae, mouthparts and general body form (excepting wings and reproductive organs).

This type of metamorphosis may be summarised as:

egg ➞ nymph (undergoes moults) ➞ adult

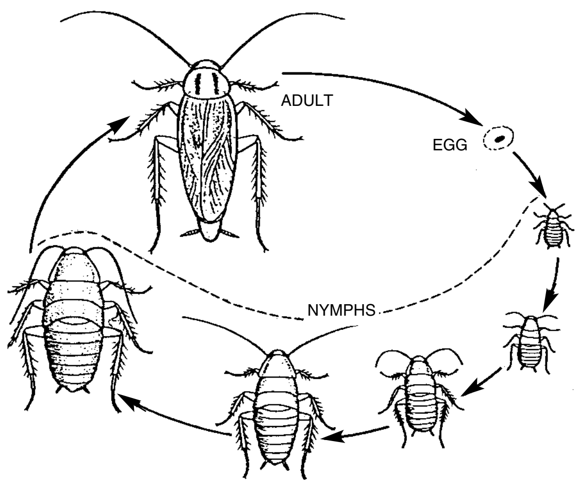

Figure 4.2 Gradual metamorphosis: Example — cockroaches (Order Blattodea)

Other insect orders that undergo this type of metamorphosis include:

Order Phasmatodea — stick insects
Order Psocoptera — booklice
Order Phthiraptera — lice
Order Hemiptera — bugs
Order Odonata — dragonflies
Order Isoptera — termites
Order Mantodea — praying mantids
Order Dermaptera — earwigs
Order Orthoptera — grass-hoppers, crickets

Complete (or holometabolous) metamorphosis

Examples: flies, beetles, fleas, moths, ants, wasps.

For insects that undergo a complete metamorphosis, the specialisation of life stages is most clearly evident. After hatching from the egg, the immature form, in this case called a *larva*, usually bears no resemblance whatsoever to the adult form that it will eventually become. Instead, the larva often appears to be little more than an eating machine. The fly larva (maggot), for example, appears to be without legs, antennae, eyes, head capsule, and so on; it is specialised for feeding, growing and storing food and has none of the 'sophisticated' sensory equipment that adult flies use in finding food, mates, egg-laying sites and the like.

When feeding is completed, the larva transforms into a *pupa*. Larvae usually pupate in hidden, protected places as the pupal stage is mostly inactive and hence possibly at risk. Some insects camouflage the pupa in cocoons made of various materials. Within the pupal case, profound changes occur. Cells reorganise; certain cells carried during larval life are, for the first time, activated: and the rebuilding of a 'new' live organism ensues.

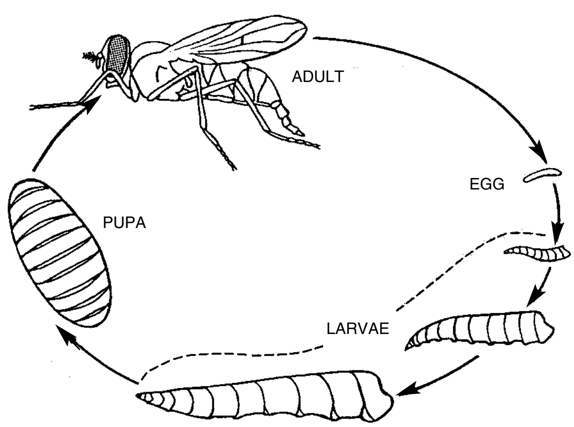

Figure 4.3 Complete metamorphosis: Example — flies (Order Diptera)

When the transformation is complete and the adult is ready to emerge, it usually splits the pupal case by 'swallowing' air. Some insects need to chew their way out, as many wood-boring beetles do (leaving tell-tale borer holes). The adult that emerges is usually entirely different in appearance and structure from the larval stage and is mostly concerned with mating, reproducing and dispersing. Its diet and habitat are usually entirely different from those of the larva.

This type of metamorphosis may be summarised as:

egg ⟶ larva (undergoes moults) ⟶ pupa (mostly stationary) ⟶ adult

Other insect orders that undergo this type of metamorphosis include:

Order Neuroptera — lacewings
Order Coleoptera — beetles and weevils
Order Siphonaptera — fleas
Order Lepidoptera — moths, butterflies
Order Hymenoptera — ants, bees and wasps

A sound knowledge of insect pest life cycles is essential in approaching pest problems. In domestic flea control, for example, it is important to recognise the animal forms involved. The larvae (barely mobile, legless grubs, with chewing mouthparts that eat virtually anything), the pupae (immobile and usually protected in a cocoon) and the adults (much more active, mobile forms that, with piercing and sucking mouthparts, are restricted to a blood diet) must all be considered in control procedures. In the case of fleas it is the adult form that is most overtly the pest, but often the reverse is the case. The huge appetite of the larval (or growing) stage causes it to be the stage most directly involved in the gross damage caused by clothes moths, carpet beetles, wood borers and many other pests.

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CHAPTER 5

CLASSIFICATION & NAMING OF INSECTS & OTHER ANIMALS

The correct scientific and common names of just three different insects that may be found as active timber borers in buildings are:

Anobium punctatum (furniture beetle)
Lyctus brunneus (powderpost beetle)
Hylotrupes bajulus (European house borer).

These three insects differ dramatically in appearance, type of timbers attacked, and implications regarding the threat they pose and the action that should be taken. In a Timber Pest Inspection Report, referring to any one of these insects as merely 'active borer' would be clearly inadequate: the correct common or scientific name must be given. For most purposes, the use of correct common names in urban pest control procedures is sufficiently informative. However, common names can, and often do, differ from country to country, and sometimes they even differ within a country. Where precision is required or information about a particular animal is sought, it is most useful to use the correct scientific name.

The scientific names of animals tell us something about the way they fit into the broad classification of all animals, and this system itself reflects the evolution of animals and their relationships to one another. The work of pest control operators, by its nature, brings them into contact with a variety of live organisms. A basic understanding of classification and command of the use of common and scientific names is important in this type of work.

ANIMAL CLASSIFICATION

The branch of science that is mostly concerned with the classification of living organisms is called taxonomy. Differences between taxonomists worldwide can result in different classification systems, hence other references may differ in the system of classification that is used.

In broad terms, living organisms are classified according to structural characteristics at seven different levels:

Kingdom
Phylum
Class
Order
Family
Genus
Species

For the purposes of this brief overview of classification, living organisms may be viewed, at the most basic level, as belonging to one of the following kingdoms:

Monerans	(bacteria)
Protists	(algae, protozoans, slime moulds)
Fungi	(fungi, moulds)
Plants	(non-flowering and flowering plants)
Animals	(animals)

Within the Animal Kingdom, each animal belongs to a particular phylum (pl. phyla), for example:

Phylum Porifera	Sponges
Phylum Coelenterata	Jellyfish, corals
Phylum Platyhelminthes	Flatworms, tapeworms, flukes
Phylum Annelida	Roundworms, earthworms
Phylum Mollusca	Snails, slugs, clams, oysters etc.
Phylum Arthropoda	Insects, spiders, mites etc.
Phylum Chordata	Backboned animals (reptiles, birds etc)

Humans, of course, belong to Phylum Chordata; and although we share this distinction with some of the animals that invade our buildings (eg rats, mice, birds and possums), the group that contains by far the most prolific and successful invaders of our buildings is Phylum Arthropoda.

The characteristics that are common to members of Phylum Arthropoda include:

1. a resistant outer body-covering of cuticle (which may be shed periodically);
2. a segmented body;
3. jointed appendages (Greek *arthro* = joint, *poda* = foot); and
4. bilateral symmetry (ie identical on both sides).

This group of animals represents the largest and most diverse phylum in the Animal Kingdom. There are close to a million described arthropod species (probably more than 6 million in total), and these comprise about 75% of known animal species. The vast majority (about 90%) of the arthropods described so far are insects.

Each phylum is, in turn, divided into a number of classes, each of which represents a group of animals that, as well as displaying the basic characteristics of the phylum, have certain other features in common.

Figure 5.1 outlines just six of the more relevant classes in Phylum Arthropoda (the enormous range of arthropods is not fully represented in this simplified overview). The sorts of characteristics used to distinguish between arthropod classes involve largely structural features, such as number of body segments, number of legs and presence of antennae.

For example:

- Class Diplopoda (millipedes) contains animals that have many body segments that are rounded, each carrying two pairs of legs, and they have antennae.
- Class Chilopoda (centipedes) contains animals that have many body segments that are flattened, each carrying only one pair of legs, and they have antennae.
- Class Arachnida (eg spiders) contains animals that mostly have two body segments, four pairs of legs, and antennae are absent.
- Class Insecta (the insects) contains those arthropods that have three body segments, three pairs of legs and a pair of antennae.

Members of Class Malacostraca (which are mostly aquatic), Class Diplopoda and Class Chilopoda are only rarely pestiferous, owing largely to their dependence on the very moist conditions that exist under logs, in leaf litter and in similar environments. Class Arachnida, and especially Class Insecta, contain animals that have developed beyond this primitive need for a moist environment. Some arachnids and many insects have exploited a vast range of environments; in doing so, many have achieved considerable pest status.

With more than 750,000 known species of insects, it is again necessary to organise and classify within the class. This is achieved by dividing each class into a number of orders, each of which contains class members that have in common certain features.

For example, insects with only two wings are 'true flies' and belong to Order Diptera (*di* = two, *ptera* = wings).

Again, based largely on structural features, each order is broken up into a number of families. Within Order Diptera, for example, there are almost ninety families. Family Culicidae contains mosquitoes, Family Syrphidae hover flies, and Family Calliphoridae blowflies. Further structural characteristics divide each family into a number of genera (sing. genus), and the members of each genus have much in common. Each genus then contains one or a number of species, and a species represents a population of similar interbreeding individuals (ie two organisms are considered to be members of the same species if they can interbreed naturally to produce healthy fertile offspring).

The bush fly (*Musca vetustissima*) and house fly (*Musca domestica*), having much in common, belong to the same genus (*Musca*), but being different species they cannot interbreed. Table 5.1 outlines the classification of a few familiar animals.

In this discussion of the grouping and classification of animals, only the basic categories have been considered. Optional categories prefixed by 'super' (above) or 'sub' (below) may also be encountered. For example, a superfamily is a group of families, while a suborder is a division within one order.

This system of classification, somewhat akin to placing animals in 'pigeonholes' at different levels, provides a mechanism for retrieving information about individual animals or groups of animals. Furthermore, it forms the basis for the scientific naming of animals.

FIGURE 5.1
Simplified overview of the classification of some arthropods and related animal groups

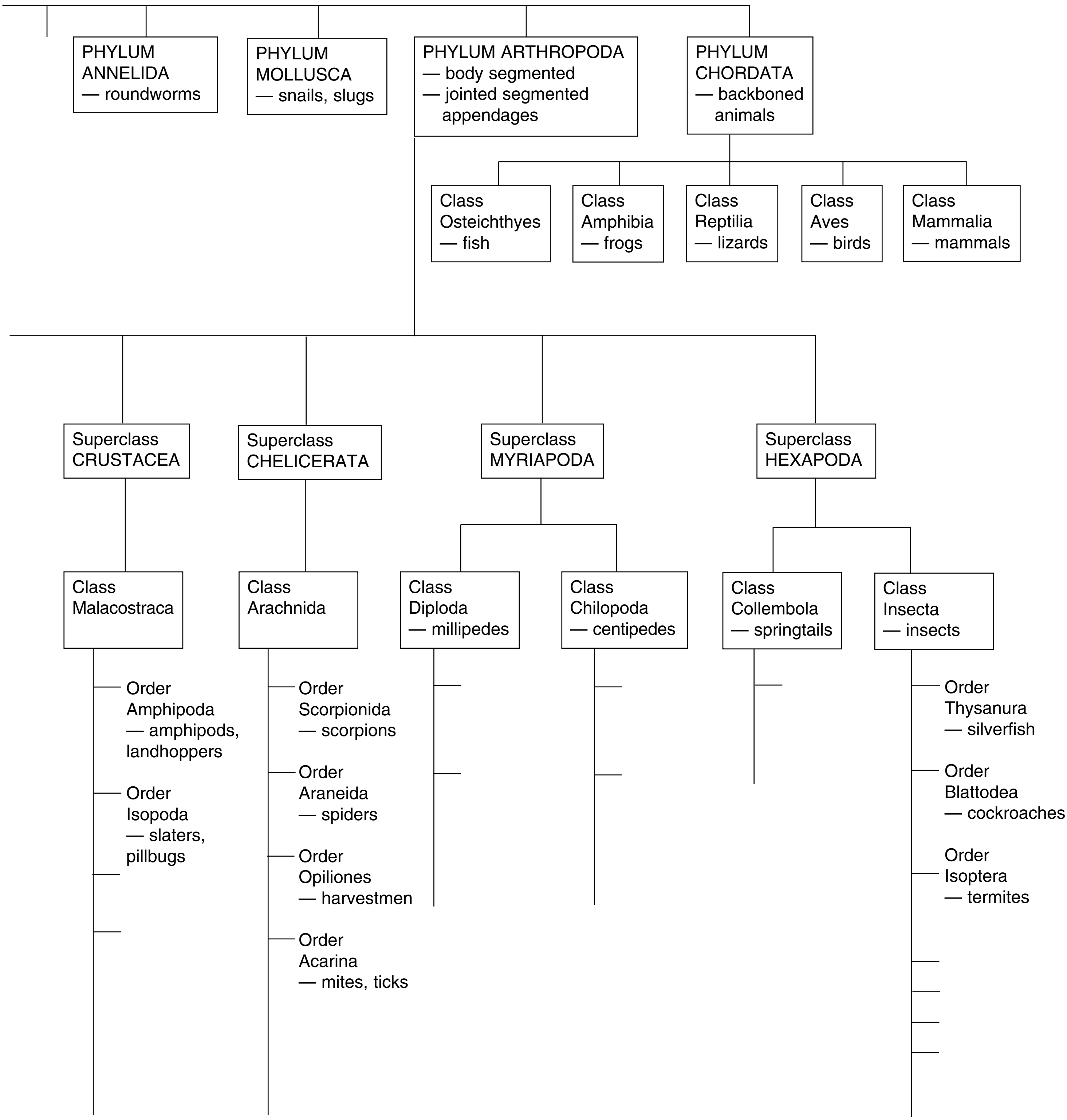

TABLE 5.1
The broad classification of some familiar animals

Classification grouping	American cockroach	Smokybrown cockroach	German cockroach	Norway rat	Humans
Kingdom	Animal	Animal	Animal	Animal	Animal
Phylum	Arthropoda	Arthropoda	Arthropoda	Chordata	Chordata
Class	Insecta	Insecta	Insecta	Mammalia	Mammalia
Order	Blattodea	Blattodea	Blattodea	Rodentia	Primates
Family	Blattidae	Blattidae	Blattellidae	Muridae	Hominidae
Genus	Periplaneta	Periplaneta	Blattella	Rattus	Homo
Species	americana	fuliginosa	germanica	norvegicus	sapiens
Scientific name	*Periplaneta americana*	*Periplaneta fuliginosa*	*Blattella germanica*	*Rattus norvegicus*	*Homo sapiens*

NAMING ANIMALS

All animals that have been formally described and recognised have a scientific name. Some of these have acquired a common name also, but this, unlike the scientific name, may vary from country to country and even within a country. There are some fundamental rules for reading, understanding and writing scientific names.

Example:

Common name: Housefly
Scientific name: *Musca domestica* Linnaeus

1 *Musca* — This is the name of the genus to which this fly belongs. The generic name always begins with a capital letter.
2 *domestica* — This is the name of the species to which this fly belongs. The specific name always begins with a lower case letter. It should be noted that the specific name has no meaning when used on its own. For example, the specific name *norvegicus* may refer to *Calocoris norvegicus* (the potato bug) or *Rattus norvegicus* (the Norway rat).
3 Linnaeus — This is the name of the scientist who originally described and named the animal. If the name appears in brackets, a change in the name of the species has occurred subsequent to its original description. This may be useful for people studying classification and naming but is not normally included in texts and inspection reports.
4 A scientific name should appear in *italics* or underlined.
5 Within a given text, after the name has been written in full, the shorter form (eg *M. domestica*) can be used, but only where no confusion with the name of another genus can arise.
6 *Musca* sp. — This refers to a species of the genus *Musca* and may refer to any member in that genus.
7 *Musca* spp. — This is the plural of '*Musca* sp.' and as such refers to more than one member of the genus.

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CHAPTER 6

TYPES OF INSECTS— THE MAJOR INSECT ORDERS

While all insects share in common some basic structural characteristics, there is, beyond this commonality, an enormous amount of structural, functional and behavioural diversity.

Insects are generally divided into about thirty different groups or insect orders. In this chapter, an overview of each of the more important insect orders is presented.

ORDER THYSANURA

Silverfish

Approximate number of species: world 370, Australia 28.
Type of metamorphosis: primitive (no metamorphosis).
This relatively small order includes some of the most ancient insects and is the only order of true insects that are primitively wingless; that is to say, in the evolutionary sense, they have never possessed wings.

Appearance

Silverfish have flattened bodies and most species are clothed in tiny scales. They are wingless and have chewing-type mouthparts and medium to long thread-like antennae. Compound eyes may be present, reduced or absent. Three long abdominal appendages, cerci and an appendix dorsalis, are obvious.

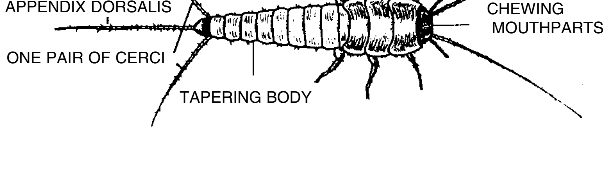


Figure 6.1 Adult silverfish

Biology and habits

In their natural habitat, silverfish live under bark and in soil, leaf litter and rotting logs. Being nocturnal, they mostly hide during the day, becoming more active at night when they seek food. They seem to be mostly omnivorous, although some have a preference for materials of vegetable origin. They are fast-running and agile, and their easily detached scales probably serve as a means of escaping the clutches of predators.

Reproduction in silverfish is a little unusual, for, although it is mostly sexual, copulation as such does not take place. Rather, during courtship, the male deposits a sperm capsule (spermatophore) on the ground and this is duly picked up by the female and transferred to the appropriate part of her anatomy. Eggs are laid singly or in batches, usually in cracks and crevices. Because silverfish have a primitive metamorphosis, the young are almost exact miniature replicas of the adults. The young grow slowly, undergoing a number of moults and maturing in about 3 to 24 months. After reaching maturity, the adult silverfish continues to moult throughout its life, which may be as long as four years.

Pest status

In Australia, about five species of silverfish have, with varying degrees of success, exploited built environments, feeding on, and often damaging, books, paper and clothing — in particular, the starchy glues and sizing on these articles. No disease transmission is known. Pest control operators are sometimes called to control silverfish in domestic and commercial premises.

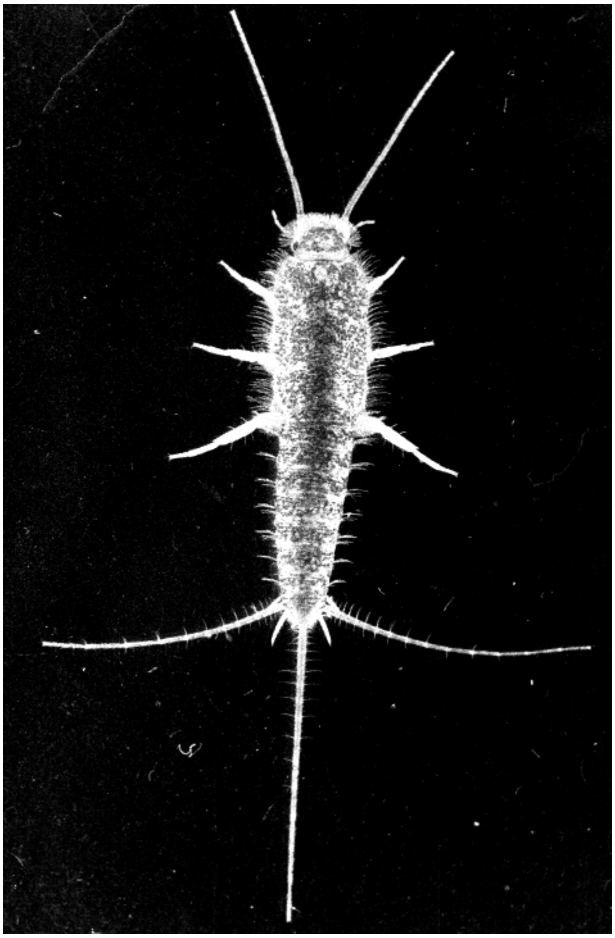


Figure 6.2 Silverfish (*Ctenolepisma longicaudata*) — 15 mm (Family Lepismatidae)

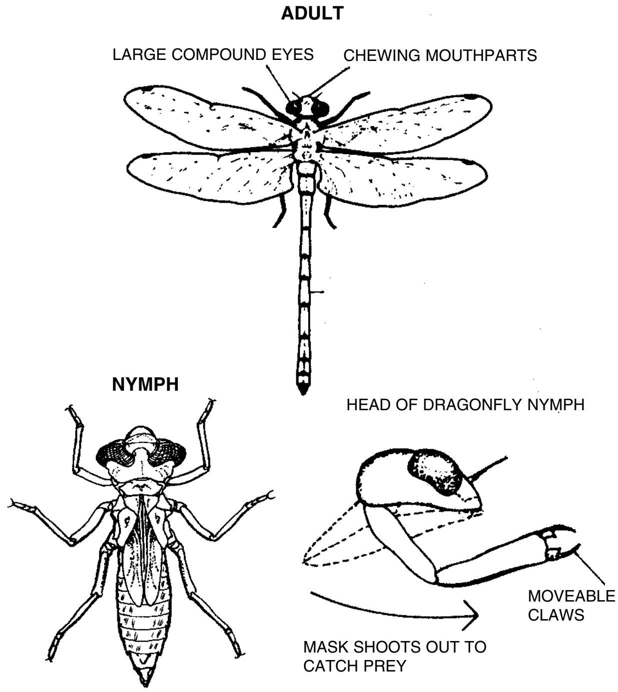


Figure 6.3 Adult dragonfly, dragonfly nymph and head of dragonfly nymph

ORDER ODONATA

Dragonflies and damselflies

Approximate number of species: world 5,000, Australia 300.
Type of metamorphosis: gradual (modified).
The adults of this ancient order of predacious insects, regarded by many as having astounding speed and manoeuvrability in flight, are often observed flying close to water (eg streams and ponds), catching their prey on the wing. The immature forms are also predacious, but not as conspicuous owing to their aquatic habit.

Appearance

Adults are medium to large in size and have well-developed compound eyes (in some cases giving almost 360° of vision), three ocelli and minute antennae. Mouthparts are of the chewing type, adapted for predation. The thorax is thickset and very muscular, with short legs adapted for seizing and holding prey. The two pairs of wings are large and of near-equal length. The abdomen is elongate and cylindrical.

Nymphs are shorter and stouter than adults and often have relatively smaller eyes and longer antennae. Mouthparts are of the chewing type, with a modified lower lip that can be projected forward to seize prey and carry it to the stronger chewing jaws.

Figure 6.4 Dragonfly nymph — 25 mm

Biology and habits

The adults are mostly day-active predators, seen most commonly during the spring and summer in temperate regions. They catch, on the wing, flying insects such as mosquitoes, flies and beetles. The aquatic nymphs are found underwater, seizing mosquito larvae, tadpoles or fish fry with their extensible lower lip; they breathe through gills.

Reproduction is sexual, and the method of copulation is most peculiar. The male bends his long abdomen, so that sperm from its tip is transferred to a 'holding device' at the front end of his abdomen. He then seizes the female just behind the head, using claspers on the tip of his abdomen. Then, by flexing their abdomens, the female's genitalia may come into contact with the sperm. This may occur during flight or at rest. Eggs may be inserted into aquatic plants or dispersed on the water. After hatching, the nymph undergoes a number of moults during its development. At the completion of the nymphal stage, it crawls away from the water, undergoes its final moult and then takes to the air as an adult.

Pest status

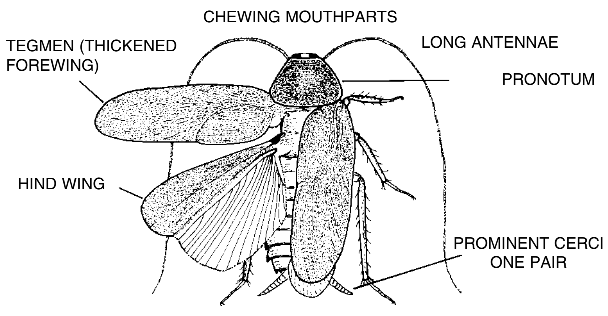
Dragonflies and damselflies are in no way pests to humans. Indeed, their activities may be beneficial, as they aid in the biological control of mosquitoes and other pests.

ORDER BLATTODEA

Cockroaches

Approximate number of species: world 3500, Australia 428.
Type of metamorphosis: gradual.
This widely known group of ancient insects are much despised, largely owing to the success with which a small handful of species have exploited environments in which humans live and work. Those few species are supreme scavengers.

Figure 6.5 Adult cockroach



Appearance

Adults are generally medium to large in size, flattened and, viewed from above, mostly oval shaped, with the head shielded beneath the pronotum. They have long and slender thread-like antennae, legs well suited to running, well-developed compound eyes and chewing mouthparts. Wings may be well developed, reduced or absent. In fully winged species, the forewings are narrower and thicker (called tegmina), covering and protecting the more membranous hindwings. The abdomen is large and carries a pair of usually prominent cerci.

Nymphs are mostly similar to adults except in the development of wings, genitalia and sometimes the colour and texture of the cuticle.

Biology and habits

Adults and nymphs alike frequent mostly dark, humid places and are, for the most part, nocturnal, resting during the daytime under bark or between boards in a building. Some native species eat mostly decaying wood, but the group is generally regarded as being quite omnivorous. Some species are capable of flight, but very warm conditions are usually required.

Reproduction in most species is sexual, often involving attractant pheromones, courtship procedures and what is often a rather prolonged end-to-end copulatory session. The egg-laying habit is unusual. A number of eggs (12–40) are glued together in a capsule (or ootheca), which is usually identifiable by shape. This may be dropped or glued to a surface by the female just prior to, or a long time before, hatching. At hatching the egg case splits and thereafter the nymphs often coexist with the adults all in a somewhat gregarious fashion. Nymphal development involves a number of moults and may take 2–4 months in some of the smaller species or up to a year or more in others.

Pest status

Cockroaches are predominantly tropical and subtropical. A number of species have, with the aid of commerce, dispersed worldwide, exploiting built environments for food and shelter. Many such environments (eg commercial kitchens) can provide year-round warmth, food and shelter, which may support literally thousands of cockroaches.

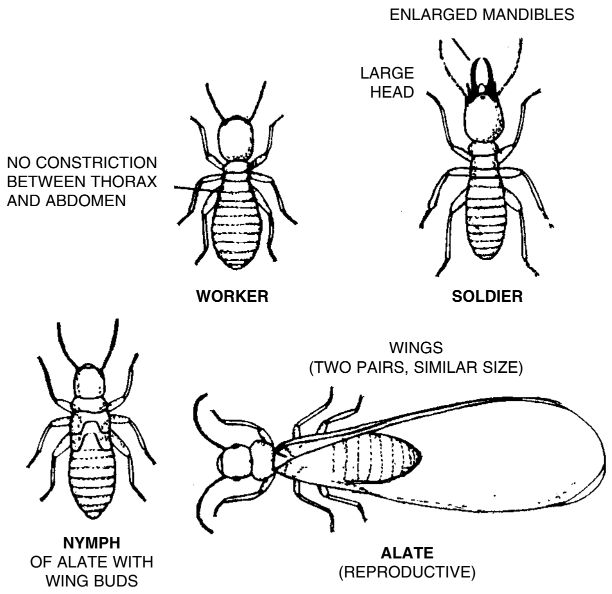
Cockroaches eat stored foods and other materials. Also, they contaminate foods and food handling areas with droppings, cast skins, regurgitation marks and odours caused by abdominal secretions. As well, disease organisms of various kinds (bacterial, viral and protozoan) have been isolated from cockroach bodies and droppings. Infestations of cockroaches are generally regarded as a threat to human health.

ORDER ISOPTERA

Termites

Approximate number of species: world 2300, Australia 260.
Type of metamorphosis: gradual.
Termites are one of the few groups of insects that have exploited a 'social' or 'colony' type of existence. So successful have they been that, philosophically, the colony has often been referred to as a kind of 'super-organism' and, economically, the annual cost of coping with their destructive powers is enormous.

Figure 6.6 Appearance of common termite castes



Appearance

Termites are mostly small and soft-bodied, with chewing mouthparts and beadlike antennae. Colonies comprise a number of different castes — that is, a number of structurally and functionally specialised individuals:

1 *Primary reproductives*, prior to establishing a new colony, have two pairs of equal membranous wings, compound eyes and are more sclerotised than the other castes. They drop their wings when establishing a new colony and become king and queen termites.
2 *Supplementary reproductives (neoteinics)* often develop but only if the primary reproductives become non-functional. They have reduced compound eyes, are less sclerotised, and their wings are undeveloped, often being present only as wing buds.
3 *Workers*, usually the most numerous caste, are mostly sterile, blind and soft-bodied. They procure food, feed other castes, and build and repair the nest and workings.
4 *Soldiers* are sterile, blind and often highly specialised in structure. The head is usually very sclerotised and important in defence.

Close examination, then, of a mature termite colony may reveal primary or supplementary reproductives, numerous workers, soldiers, developing primary reproductives (alates) and nymphs, which may develop into any of the above-mentioned castes.

Biology and habits

Living in social colonies that may number from less than 100 to well over a million individuals, most termites live in the darkness and moisture of underground nests and tunnels and inside sound and rotting wood. They seldom venture out into the open, drying atmosphere; but when this is necessary, they usually build mud tunnels that retain their concealed, protected existence. Nest types vary, some being merely hollowed-out sections of the sustaining food source, such as a decaying log or tree limb. More sophisticated nests may be built underground, as mounds on the ground, or as nests in or on trees. Most termite species can closely control the conditions of temperature and humidity within the nest.

The basic food of termites is the sugar present in plant materials as cellulose. This may be obtained from sound or decaying wood, grass, paper, leaf litter and other materials. Protein requirements are often met by consumption of the fungus that grows in the warm moist environment of the nest or rotting wood. In nature, few organisms can break down and digest cellulose. Termites are one of the few organisms that are very important in the natural recycling of nutrients.

Reproduction may involve a colonising flight of fully developed alates. This usually occurs once or twice a year when weather conditions are suitable. The future kings and queens (alates) take flight, disperse and, on landing, undergo courtship behaviour. This, if successful, leads to the construction of a 'nest' for the new couple and to subsequent intermittent mating and egg production. This form of reproduction may be very slow, requiring perhaps a few years before the colony becomes populous. Another method of reproduction, which some species utilise, is referred to as 'budding-off'. It involves the production of many supplementary reproductives, which break away from the parent colony.

Pest status

Termites are, economically, a very important group of insects. Considerable damage is caused to railway sleepers, poles, posts, bridges, all kinds of buildings, forest trees and even a variety of crops in the drier inland. Even in well-settled urban areas, termites, particularly the subterranean species, continue to damage buildings and fences — sometimes even the few timber fittings in the upper storeys of an otherwise entirely concrete structure. Pest control operators are engaged in inspecting for termite activity, controlling active infestations and in preventative measures that will protect buildings from attack by subterranean termites in the future.

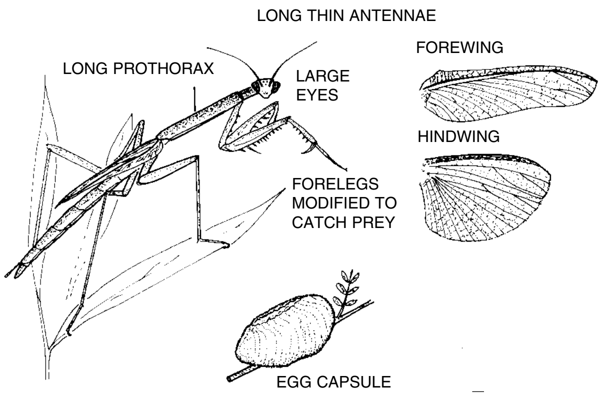
ORDER MANTODEA

Praying mantids

Approximate number of species: world 1800, Australia 162.
Type of metamorphosis: gradual.
Many people recognise mantids by the very characteristic 'praying' posture that they adopt in their 'sit and wait' type

of predatory habit. The precision with which the victim is seized is often quite remarkable, and this, together with the female mantid's reputation of eating her male partner during copulation, certainly qualifies these insects for the 'supreme predator' stakes in the insect world.

Figure 6.7 Adult praying mantid and egg capsule



Appearance

Adults are mostly medium to large in size and clearly adapted for predation. Mouthparts are of the chewing type and the head is almost triangular in shape and freely mobile on a slender 'neck'. Compound eyes are well developed, ocelli (usually 3) may or may not be present, and antennae are slender. The prothorax is long, narrow and hardened and supports the forelegs, which are specialised for seizing and holding prey. The hindlegs, used for walking, are long and slender and set back from the forelegs. In winged species the forewings (tegmina) are somewhat thickened and cover the more membranous hindwings. In most Australian species the wings are fully functional in males but reduced or absent in females.

Nymphs are similar to adults except for wing and genital development.

Biology and habits

These insects lead a largely solitary existence and are often found in vegetation awaiting prey such as insects and spiders. Being a 'sit and wait' type of predator, they are often well camouflaged.

Sometimes a courtship ritual precedes mating. The female often eats or partly eats the male during or after copulation. Before laying her eggs in batches of 10 to several hundreds, the female secretes a frothy material into which the eggs are laid. This material hardens to form a protective egg capsule. Soon after hatching, the nymphs, which will undergo a number of moults, adopt habits similar to those of the adults.

Pest status

Praying mantids have no pest status. Many would regard them as beneficial insects.

ORDER DERMAPTERA

Earwigs

Approximate number of species: world 1800, Australia 60.
Type of metamorphosis: gradual.
Despite their misleading and indeed curious common name, the most characteristic feature of earwigs is the 'pair of forceps' terminating the abdomen. Seemingly, this structure is used in courtship, defence (as any careless insect collector will complain) and carrying prey or other food.

Figure 6.8 Praying mantid — 65 mm (Family Mantidae)

Figure 6.9 Earwig — 30 mm

Appearance

Adults are small to medium in size, with an elongate, somewhat flattened body that is usually covered with tough cuticle. Mouthparts are of the chewing type. Compound eyes are usually moderate or absent, ocelli absent and antennae thread-like. Legs are quite short and developed for walking and running; and although many species are wingless, those that are winged usually have fan-shaped membranous hindwings which, when at rest, are folded underneath and protected by short thick forewings (tegmina). The cerci are modified into conspicuous terminal forceps.

Nymphs are similar to adults except for wing and genital development.

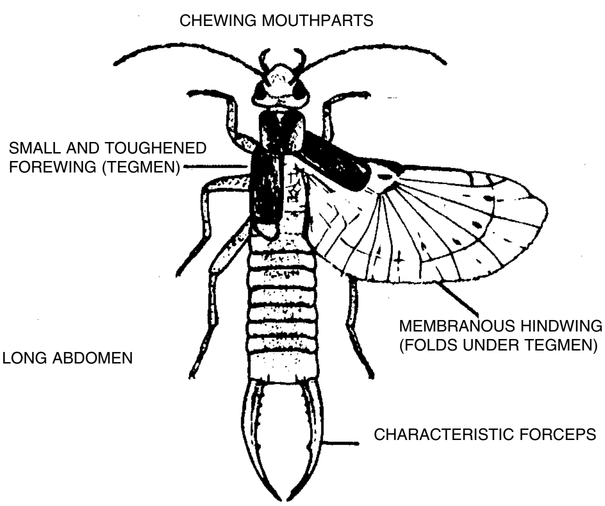


Figure 6.10 Adult earwig

Biology and habits

Earwigs are mostly nocturnal and favour damp, confined spaces (eg under logs and rocks). They are mostly omnivorous, eating living and dead plant and animal matter. The abdominal forceps seem to be used in courtship, defence and food handling.

Reproduction is sexual. The female lays batches of 20–50 eggs in a burrow and tends the eggs and young nymphs for some time. Developing nymphs undergo a number of moults and behaviourally are quite similar to adults.

Pest status

Earwigs occasionally cause annoyance by invading houses or flower and vegetable gardens. They are seldom regarded as important pests.

ORDER ORTHOPTERA

Grasshoppers, crickets and locusts

Approximate number of species: world 20,000, Australia 2827.
Type of metamorphosis: gradual.
This is a very large and prominent group of insects, perhaps best known for their 'singing' on warm summer nights and for their jumping ability, which no doubt frequently facilitates their escape from danger. Locusts, a particular kind of short-horned grasshopper, have since ancient times been responsible for many major crop losses when swarming.

Appearance

Adults are medium to large and have an almost cylindrical body and large prothorax, which often resembles a protective collar. They have chewing mouthparts, often well-developed compound eyes and thread-like antennae, either long or short. Wings may be well developed (in which case the leathery forewings, the tegmina, cover the more fan-shaped membranous hindwings), reduced or absent. Hindlegs are usually enlarged for jumping, cerci are present, and females often carry a rather conspicuous ovipositor.

Although not easily visible, structures for producing and hearing sounds are present.

Nymphs are similar to adults except for wing and genital development.

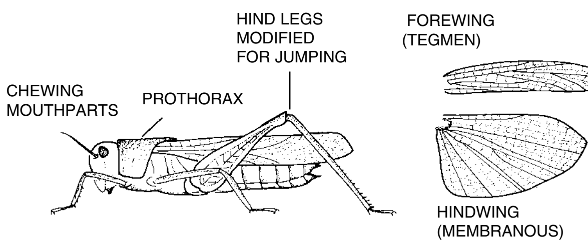


Figure 6.11 Adult grasshopper

Biology and habits

Most orthopterans feed on exposed vegetation (eg in grasslands and open forests), moving by running, jumping and flying. Less common habits include predation, living in burrows, living in caves and a subaquatic habit. Activity patterns vary; many species are night active, while others are most active during daylight. They are mostly solitary insects, but because of population fluctuations, some species of short-horned grasshoppers (the locusts) become transformed into an often very destructive, migrating, gregarious swarm.

Reproduction often involves elaborate courtship procedures, which may incorporate species-specific 'songs', produced by rubbing together specialised sections of wings or legs and wings. Copulation may, within the group as a whole, employ quite diverse positioning and last several hours. Eggs are generally inserted singly or in bunches into plant tissue or the soil substrate, covered with a plug of protective material secreted by the female. Nymphs undergo a number of moults and otherwise share very similar habits to the adults.

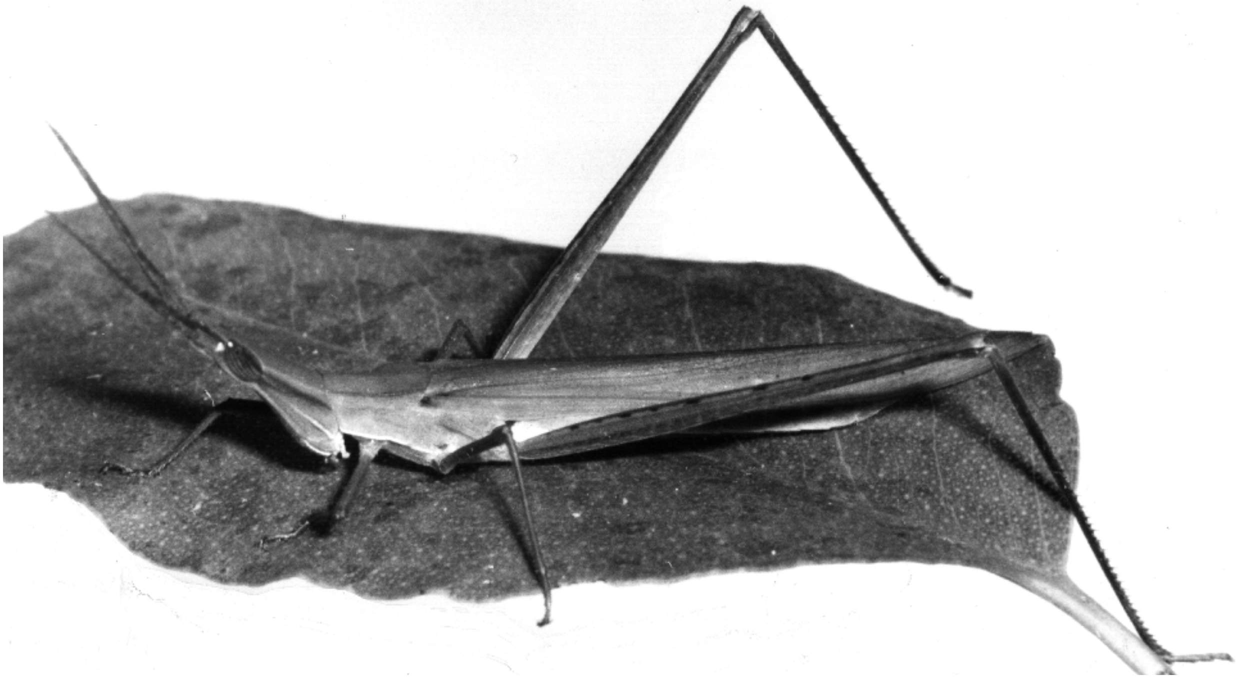


Figure 6.12 Short-horned grasshopper — 40 mm (Family Acrididae)

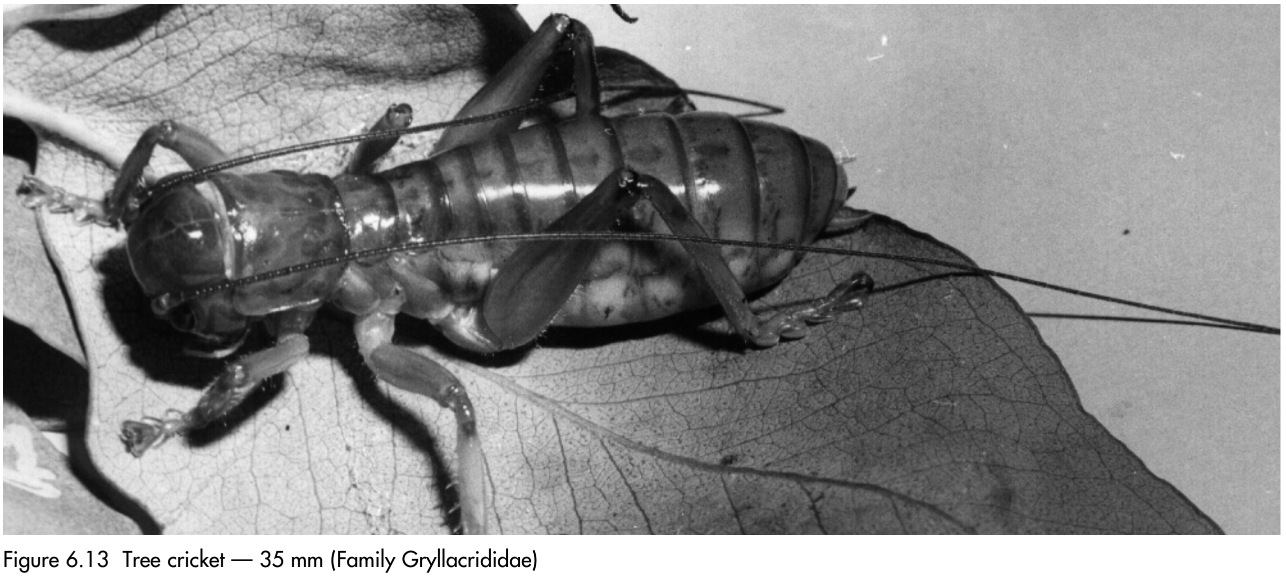


Figure 6.13 Tree cricket — 35 mm (Family Gryllacrididae)

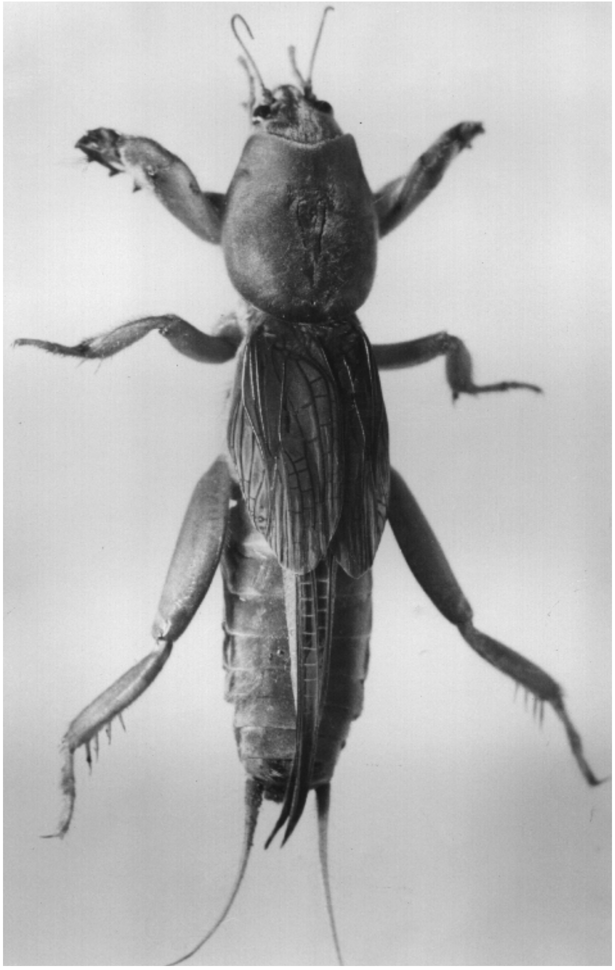


Figure 6.14 Mole cricket — 45 mm (Family Gryllotalpidae)

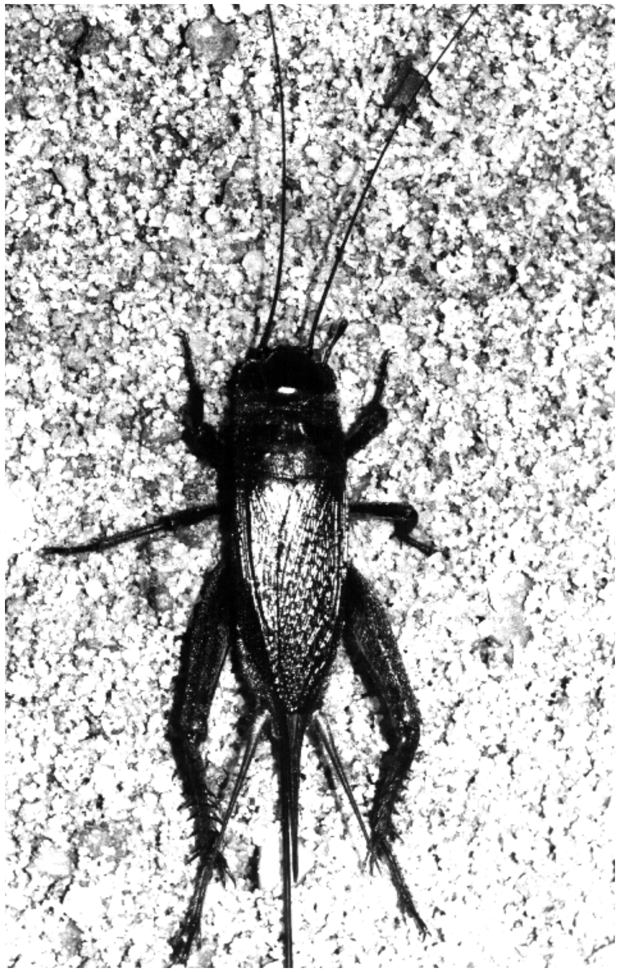


Figure 6.15 Black field cricket (*Teleogryllus commodus*) — 20 mm (Family Gryllidae)

Pest status

The orthopterans are of great economic importance horticulturally and agriculturally. Locust outbreaks have caused extensive famines and in many countries continue to be expensive in terms of crop losses and/or control measures. Less significantly, field crickets and mole crickets sometimes cause annoyance in and around buildings.

ORDER PHASMATODEA

Stick insects

Approximate number of species: world 2500, Australia 150.
Type of metamorphosis: gradual.
Aptly named stick insects and sometimes leaf insects, these slow-moving foliage-eating creatures are masters in the art of camouflage.

Appearance

Adults are medium to very large. Mostly they have rather cylindrically shaped, elongate bodies or are depressed and leaf-like. They are modified structurally to mimic vegetation. Antennae are short to long and slender, compound eyes are relatively small, and ocelli (normally three) are present in some winged species. Most Australian species are without wings, but when present, wings are often fully functional in the male and reduced in the female. A fully winged specimen usually has short thickened forewings (tegmina) and larger fan-shaped membranous hindwings.

Nymphs are similar to adults except in the development of wings and genitalia.

Biology and habits

Stick insects and leaf insects are mostly solitary animals that feed on the foliage of a variety of trees and shrubs at night, often resting motionless during daylight. When disturbed, many fall to the ground and remain entirely motionless for some time. Their movement is slow and at times seems clumsy.

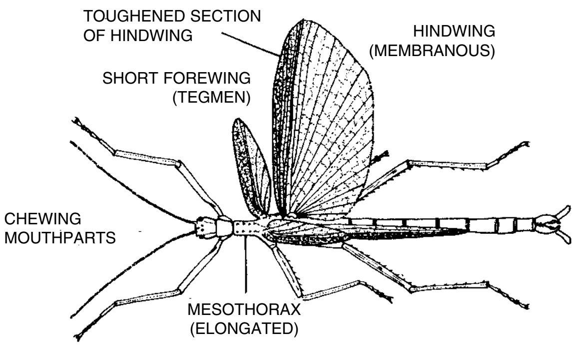


Figure 6.16 Adult stick insect

Some species reproduce parthenogenetically but reproduction is mostly sexual. The female may produce from 100 to more than 1000 oval or barrel shaped eggs, which are glued to vegetation or dropped to the ground. After hatching, the nymphs undergo a number of moults. Nymphal habits and behaviour are similar to those of the adult.

Pest status

A few species of stick insect occasionally reach plague proportions, causing serious loss and damage to forests.

Figure 6.17 Ringbarker phasmatid (*Podocanthus wilkinsoni*) — 100 mm (Family Phasmatidae)

ORDER PSOCOPTERA

Booklice

Approximate number of species: world 3000, Australia 300.
Type of metamorphosis: gradual.
Sometimes scavengers in places of human habitation, booklice

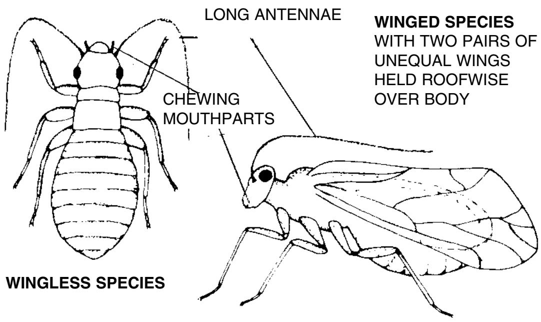
Figure 6.18 Spiny leaf insect (*Extatosoma tiaratum*) — 100 mm (Family Phasmatidae)

are not a widely known insect, probably owing to their small size and retiring habits. Books seldom used are often attractive to them.

Appearance
Adults are mostly small and soft bodied, with a large head. They have slender antennae and chewing-type mouthparts. Usually they have large compound eyes and winged species have three ocelli. Wings may be absent, reduced or present as two pairs of membranous wings.

Nymphs resemble adults except for wing and genital development.

Figure 6.19 Wingless and winged adult booklice



Biology and habits
Booklice are scavengers found in leaf litter, grass, under bark, in bird and rodent nests, mouldy stored foods, among books and in insect collections. The diet usually comprises fungi, lichen, dead plant and animal tissue and starchy sizing of books.

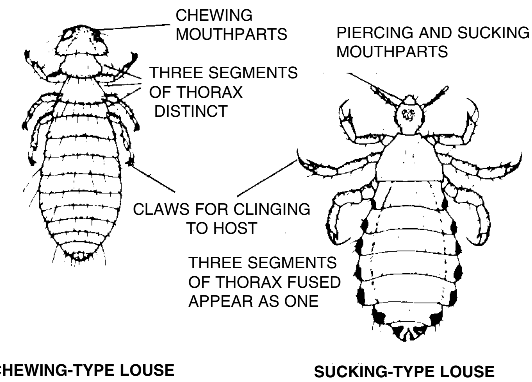
Reproduction is mostly sexual but parthenogenesis is known. Eggs are usually laid singly or in batches, and the habits of nymphs, which undergo a number of moults, are similar to those of adults.

Pest status
Booklice are not generally regarded as being of great economic importance. Although some species associated with stored products may develop enormous populations, they are usually present only if storage conditions are poor. Some damage to books and insect collections may result from their activities.

ORDER PHTHIRAPTERA

Lice
Approximate number of species: world 3000, Australia 255.
Type of metamorphosis: gradual.
Lice, although abhorrent to many, and perhaps justifiably so, exhibit an amazing degree of adaptation and specialisation to the parasitic lifestyle. They rely entirely on their host's survival, for, should the host die, a drop in temperature stimulates movement to the outer parts of the fur or feathers, where death will follow unless by some fortune another appropriate host happens to be close by.

Figure 6.20 Adult lice



Appearance
Adults are mostly very small, with flattened bodies and short antennae. Compound eyes are reduced or absent. Cuticle is often tough yet elastic and covered with rows of bristles. Legs are short, terminating in single or paired claws, and cerci are absent.

Nymphs resemble adults.

There are broadly two types of lice:

1 Those that infest mainly birds and mammals and have chewing-type mouthparts.
2 Those that infest mainly mammals and have highly modified piercing and sucking mouthparts, which are retractable into the head.

Biology and habits
Lice are entirely dependent on the live host for their existence. They tend to be rather host-specific and, furthermore, are often restricted to a particular part of the host's anatomy.

Reproduction is mostly sexual (although parthenogenesis is known), and the female usually glues the eggs to the host's fur, hair or feathers. Lice with chewing mouthparts feed on fragments of feather, hair, skin scales, clotted blood and so on, while those with piercing and sucking mouthparts are blood suckers.

Pest status
Many lice are pests of humans or livestock. As well as debilitation that may arise from irritation, several human and livestock diseases are known to be transmitted by lice. Problems related to louse infestation usually fall into the domain of the medical and veterinarian professions. Serious human disease outbreaks (eg typhus epidemics) associated with lice have been largely related to circumstances of poor body hygiene (eg trench warfare).

ORDER HEMIPTERA

Bugs, including aphids, scales, cicadas and bedbugs

Approximate number of species: world 57,000, Australia 5650.
Type of metamorphosis: gradual.
In insect evolution, the development from chewing mouthparts to a beak-like arrangement of stylets that can pierce tissue, inject saliva and suck up nutrients opened the doorway to a vast array of exploitable food sources. The huge numbers and great diversity of bugs bears testimony to the success of this development.

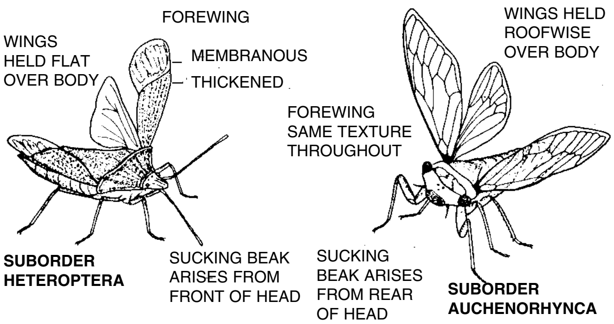


Figure 6.21 Two types of adult bug

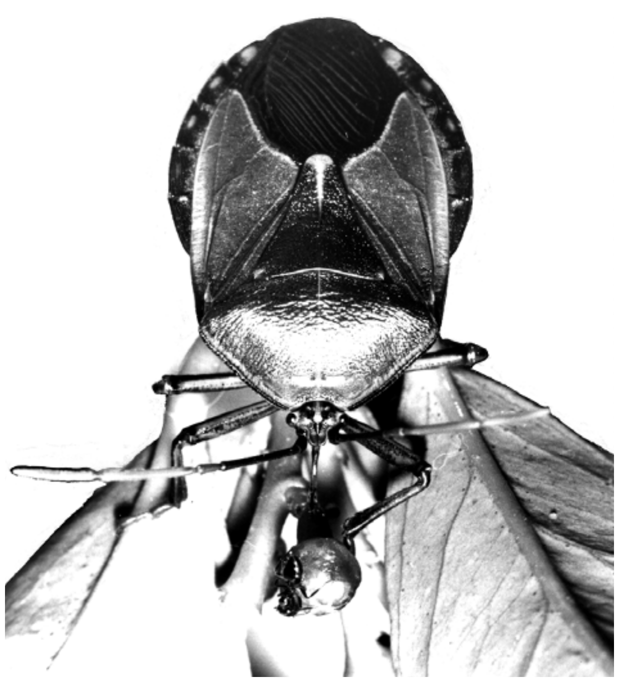


Figure 6.22 Bronze orange bug (*Musgraveia sulciventris*) feeding — 25 mm (Family Tessaratomidae)

Appearance

This order includes a large number of very diverse forms. Adults are very small to large, and their most characteristic feature is the beak-like piercing and sucking mouthparts. These arise from the underside of the head and comprise two pairs of bristle-like stylets in a sheath. The structure allows for two channels: one for the injection of saliva into the plant or animal host, the other for sucking up nutrients. Compound eyes are usually large, and ocelli may be present or absent. Antennae are thread-like or bristle-like and short to long. They usually have two pairs of wings, and the forewings are often wholly or partly more thickened than the hindwings. Legs are usually adapted for walking, except in some predatory species. Cerci are absent.

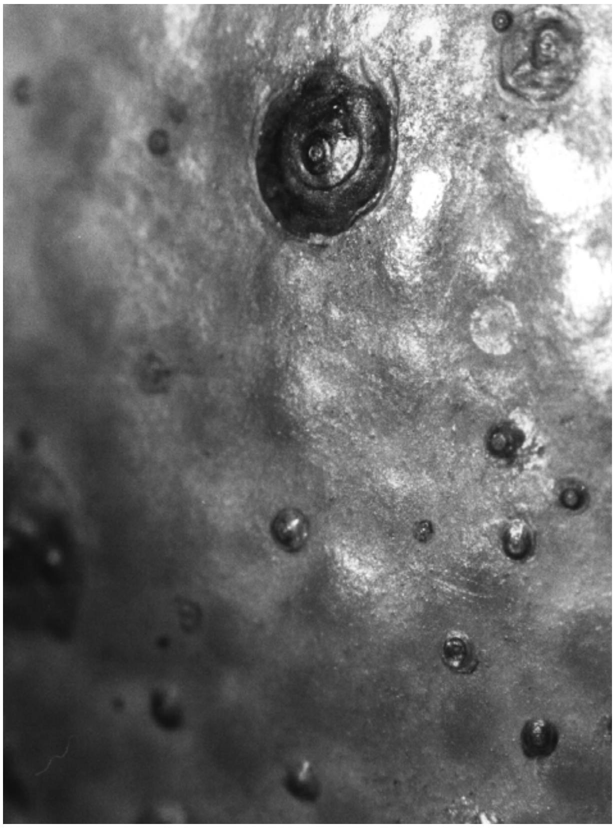
Nymphs are mostly similar to adults.

Biology and habits

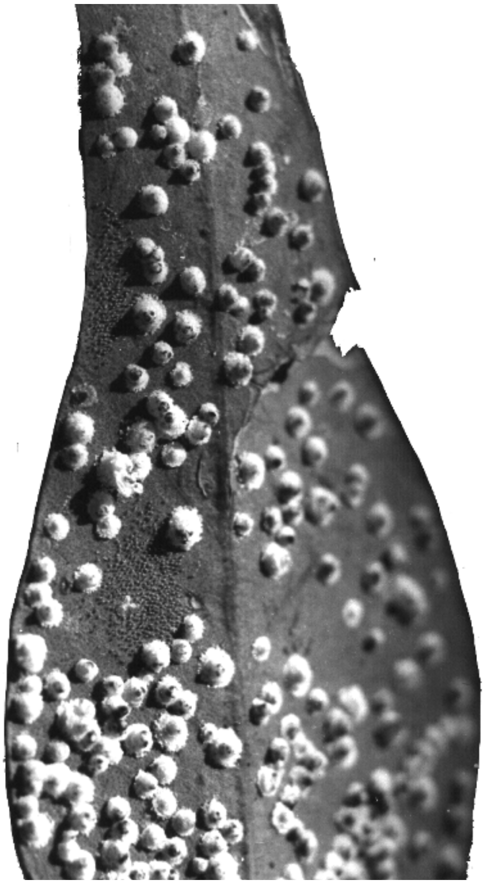
The vast majority of hemipterans are plant feeders, sucking sap from virtually every accessible part of plants. Some are predators, attacking insects and allied forms while others are external parasites of birds or mammals, living from the blood meals they obtain. The majority of bugs are terrestrial but some species have exploited the aquatic environment. Of the many plant-feeding hemipterans, some are sedentary or slow moving, while others are agile.

Figure 6.23 Giant fish killer (*Lethocerus* sp.) — 55 mm (Family Belostomatidae)

6.24 Leafhopper (*Eurymela* sp.) — 14 mm (Family Eurymelidae)



6.25 Californian red scale (*Aonidiella aurantii*) — 2 mm (Family Diaspididae)



6.26 Psyllids (lerp insects) (*Creiis* sp.) — 2.5 mm (Family Psyllidae)

Reproduction is mostly sexual, involving copulation followed by egg-laying in or on the host plant. However, parthenogenesis and production of live young occur in some species of this very diverse order.

Pest status

Many hemipterans are pests of plants grown by humans. Damage may be direct, causing wilting and debilitation, or indirect, by the conveyance of viral or other diseases. Of interest to urban pest control operators is the bedbug, which is an obligate blood sucker that visits people while they sleep.

ORDER THYSANOPTERA

Thrips

Approximate number of species: world 4500, Australia 422.
Type of metamorphosis: intermediate between gradual and complete.
Despite their minute proportions, thrips can be most troublesome creatures. Extensive crop damage, particularly to flowers and fruit, can result when climatic factors favour their development. Furthermore, under favourable weather

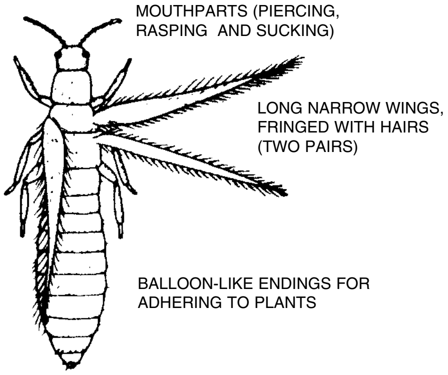


Figure 6.27 Adult thrip

conditions, plagues of these tiny insects can invade homes and gardens in nearby towns, often causing much concern and perhaps annoyance and irritation.

Appearance

Adults are mostly very small to small and have a slender elongate body, large compound eyes, three ocelli in winged adults and short, thread-like antennae. Legs are short and stout, with special structures for adhesion; cerci are absent; and in winged species, two pairs of long wings are characteristically fringed (at least on the hind margins). The mouthparts are also relatively characteristic, being in the form of a cone, from the end of which project stylets, which can pierce and rasp plant tissue. Plant juices are sucked up into the mouth cone.

Nymphs, when young, resemble adults.

Biology and habits

The majority of thrips are plant juice feeders, mostly attacking flowers and leaves. Some species are found in leaf litter, feeding on fungi. A few are predacious, and some species form galls. They can be competent fliers but their movements over long distances usually rely on wind conditions.

Reproduction is largely sexual, but parthenogenesis is quite common. Eggs are generally laid in or on plant material, and although young nymphs resemble adults, there are 2 or 3 later, non-feeding, resting, pupa-like stages with wing pads.

Pest status

Thrips often cause serious damage to fruit, vegetable and ornamental crops, damaging mainly floral parts and fruit. Some species are vectors of plant diseases. Plagues of thrips are occasionally carried to cities, causing concern in homes and gardens.

ORDER NEUROPTERA

Lacewings

Approximate number of species: world 5000, Australia 623.
Type of metamorphosis: complete.
Many people would not associate the often delicate beauty of an adult lacewing with the almost vicious appearance of the young larval form that it once was. Both are predators of insects such as aphids and scales, and the order has a reputation of being one of the most beneficial to humans.

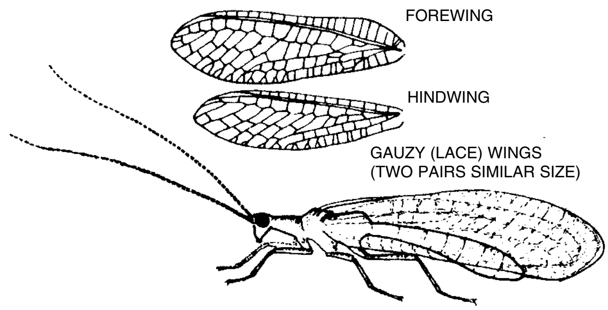


Figure 6.28 Adult lacewing

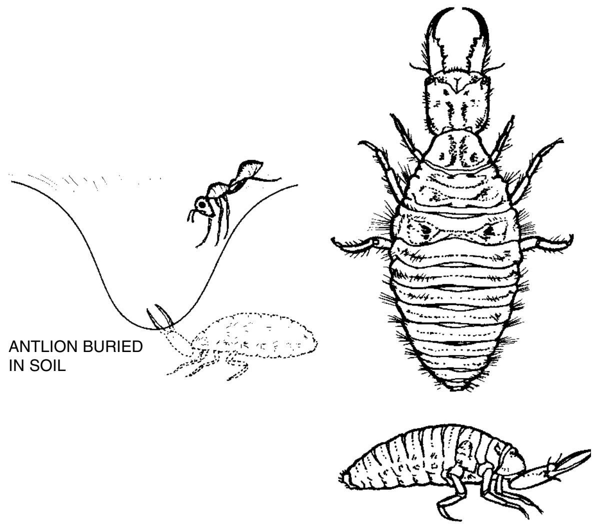


Figure 6.29 Antlion-type lacewing larva

Appearance

Adults are very small to large, soft bodied, and usually have two pairs of membranous, heavily cross-veined wings which are lace-like in appearance. Antennae are usually slender, compound eyes are prominent, and mouthparts are of the chewing type. Cerci are absent.

Larvae are so diverse in structure that a short generalised description would be inadequate. Mostly, they have a clearly defined head capsule bearing chewing mouthparts that are sometimes modified for sucking. The body is often covered with tubercles or hairs.

Figure 6.30 Lacewing eggs — 0.5 mm (Family Myrmeleontidae)

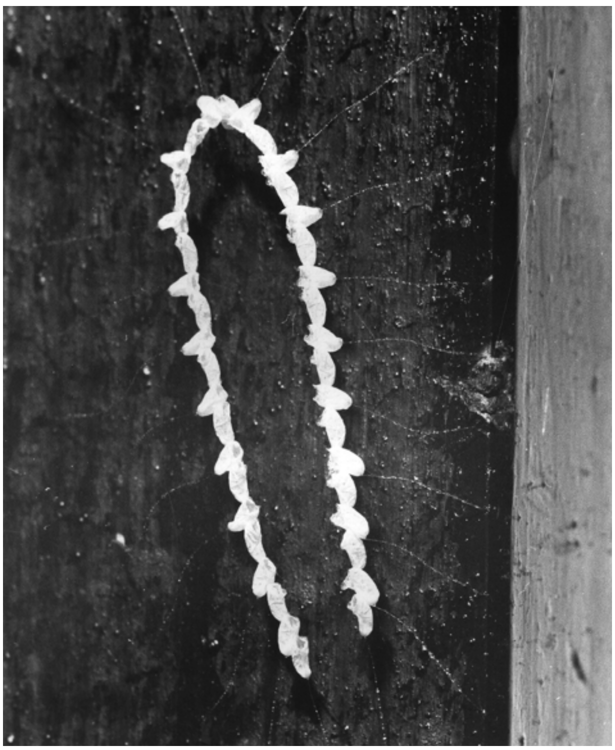


Figure 6.31 Lacewing (*Nymphes myrmeleonides*) eggs — (Family Nymphidae)

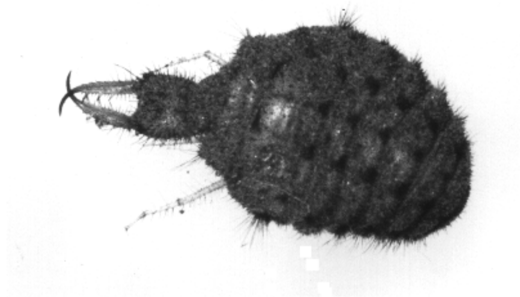


Figure 6.32 Larva of a lacewing (antlion) — 7 mm (Family Myrmeleontidae)

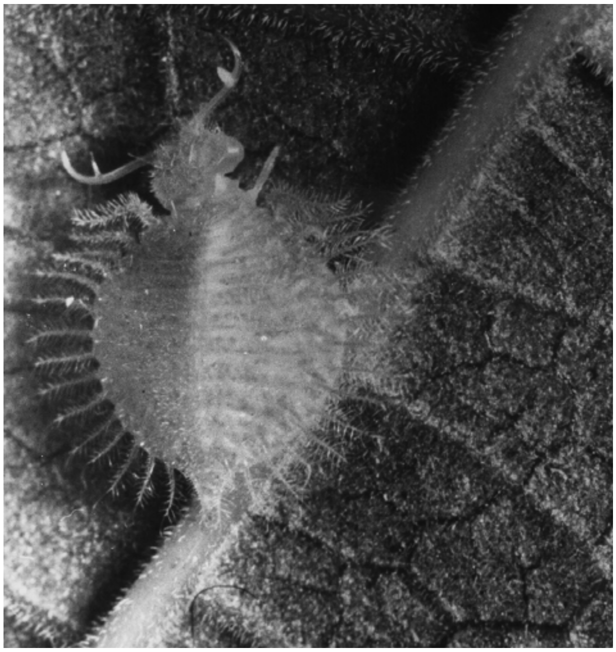


Figure 6.33 Lacewing larva — 6 mm (Family Nymphidae)

Biology and habits

Adult lacewings are largely nocturnal and are generally weak fliers. They are predatory on small insects and allied forms, but also feed on pollen, nectar or honeydew. Larvae have a diverse range of predatory habits, perhaps the most documented being that of the antlion larva, which makes a pit trap and impales the unfortunate insect that stumbles into it.

Reproduction is sexual. Eggs may be laid in soil or cemented to surfaces either directly or on stalks made by the female. After a number of moults, the larva often spins a protective silken cocoon in which it pupates. The winged adult later emerges.

Pest status

Order Neuroptera has no pest status. It is widely regarded as an entirely beneficial group.

ORDER COLEOPTERA

Beetles and weevils

Approximate number of species: world: more than 300,000, Australia 28,200.
Type of metamorphosis: complete.
The largest insect order in relation to number of species, beetles represent about a third of all known animal species. The order includes some of the smallest and largest known insects. The success of the group is best gauged by the enormous diversity of habitats exploited, but even so, particularly in the larval stage, they mostly lead rather concealed private lives.

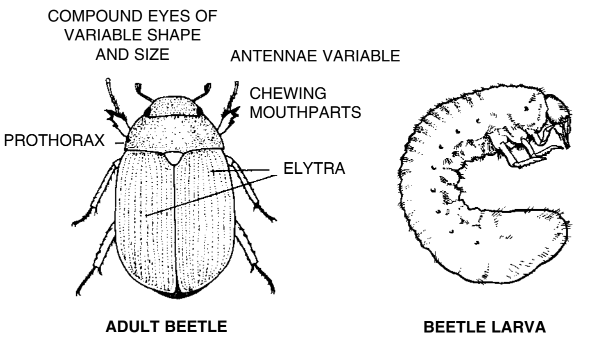


Figure 6.34 Adult beetle and beetle larva

Appearance

Adults mostly have a hard compact body form. Their characteristic feature is the hardened shield-like modified forewings called elytra. Inactive for flight, these rigid structures are lifted forward to enable the membranous hindwings to unfold and sustain flight. Compound eyes are conspicuous and variable. Antennae are extremely variable. Legs are mostly heavily sclerotised. Mouthparts are mandibulate.

Figure 6.35 Ground beetle — 28 mm (Family Carabidae)

Larvae, often referred to as grub-like in appearance, vary greatly in structure. Usually the head capsule, with chewing mouthparts, is much sclerotised and well defined. Ocelli and legs may or may not be present, and they usually have short antennae.

Figure 6.36 Whirligig beetles (*Macrogyrus* sp.) — 15 mm (Family Gyrinidae)

Biology and habits

In some beetle species, adult and larval habitat and food are similar. In broad terms, beetles may be plant feeders, predators, parasites or scavengers. They are mostly terrestrial, but some are aquatic. Habitats exploited include under bark and in caves, sand, mud, freshwater, dung, carrion, stored foods, fungi, galls, wood, plants, moss, leaf litter, soil, flowers and animal nests.

Reproduction is mostly sexual and the female usually lays eggs, singly or in batches, in or on or close to the food. The grub or larval stage usually feeds voraciously and undergoes a number of moults. Pupation usually occurs in a protected cell constructed by the larva within the feeding medium or nearby.

Pest status

Given the size and diversity of the order it is not at all surprising that the activities of many beetle species are of concern to humans. Although they are not important carriers of disease, their voracious feeding, particularly larval feeding, often results in damage to materials valued by humans. Many beetles are pests of plants grown for food, timber or ornament. Many stored materials are attacked, including foods, clothing, leather, hides, tobacco, drugs, timber and so on. Many pest control operations, in both the agricultural and urban contexts, are aimed at protecting goods from the ravages of beetles.

ORDER SIPHONAPTERA

Fleas

Approximate number of species: world 2380, Australia 88.
Type of metamorphosis: complete.
As a domestic nuisance and carrier of diseases, fleas feature well on most people's list of abhorrent and repulsive insects. From a different standpoint, few insect groups can boast such a refined adaptation to the ectoparasitic lifestyle.

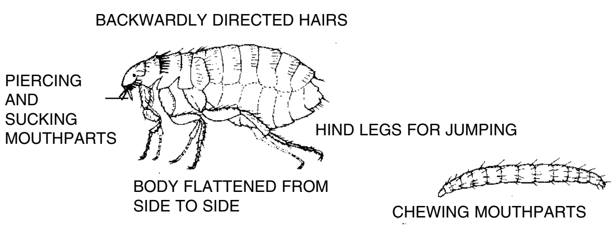


Figure 6.37 Adult flea and typical flea larva

Appearance

Adults are very small, flattened from side to side, and have a body covered with stout, backwardly projecting spines. Legs are stout and spiny, and the hindlegs are enlarged for jumping. They are wingless and have no compound eyes; only lateral ocelli sometimes are present. Antennae are small, and mouthparts are developed for piercing and sucking.

Larvae are very small, legless, worm-like creatures with short antennae, chewing mouthparts and rigid hairs along the body.

Biology and habits

Fleas are external parasites of mammals, in the main, and birds. Some species have only one type of host, while others can survive on a variety of hosts. Adults are quite active, crawling among hair or fur and often moving by jumping. They may spend little time on the host, perhaps visiting only briefly for a blood meal when required.

Reproduction is sexual, and eggs usually fall into the host's nest or immediate environment. Larvae feed on organic material, such as skin scales or food scraps in carpet or floorboard cracks. When fully fed, the larva pupates in a protective cocoon, and the adult later emerges, the stimulus for emergence often being vibrations.

Figure 6.38 Dog flea (*Ctenocephalides canis*) — 2 mm (Family Pulicidae)

Pest status

Fleas are annoying and irritating in the home where, particularly when climatic conditions are favourable, they can create huge populations. More importantly, some fleas are carriers of serious diseases, such as bubonic plague, murine typhus and a number of tapeworm infections.

ORDER DIPTERA

Flies, mosquitoes, gnats, midges, and house flies

Approximate number of species: world 150,000, Australia 7786.
Type of metamorphosis: complete.
Many would hold that, when it comes to flying, dipterans, the true flies, are the masters. Whether it be hovering, barrel-roll ceiling landing or indulging in aerial copulation, it seems their speciality; and oddly enough, they have achieved their expertise, at least partly, by losing a pair of wings.

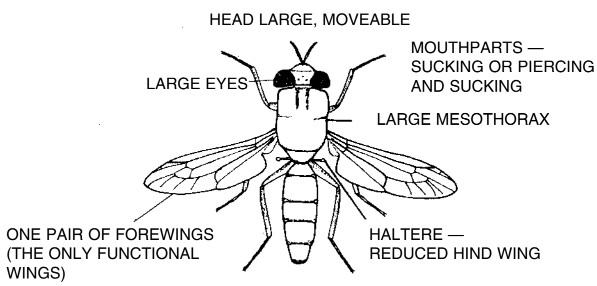


Figure 6.39 Adult fly

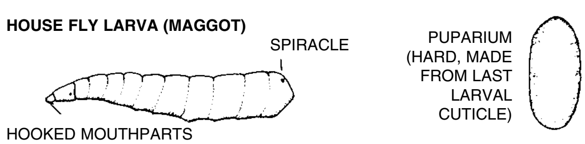


Figure 6.40 Maggot-type fly larva and pupa

Figure 6.41 Flesh fly (*Sarcophaga* sp.) — 9 mm (Family Sarcophagidae)

Appearance

Adults are very small to medium in size, and their most characteristic feature is their wing structure. Except for a few wingless forms, adult dipterans have only a single (front) pair of membranous wings, the hindwings being represented only by a pair of clubbed balancing organs called halteres. They usually have large compound eyes, three ocelli and mostly small bristle-like antennae. Body forms are diverse and often covered with hairs or bristles. Mouthparts are basically sucking type, modified for rasping, piercing or sponging.

Larvae are mostly maggot-like, cylindrically shaped, soft bodied and legless and have chewing or modified chewing mouthparts.

Figure 6.42 March fly — 18 mm (Family Tabanidae)

Figure 6.43 *Aedes* mosquito (*Aedes* sp.) — 5 mm (Family Culicidae)

Biology and habits

In most dipterans, the adult and larval habitats are quite separate. Adults mostly have a short life span, perhaps weeks, and feed on nectar, sap, free liquids in rotting organic matter and some solid foods made liquid by dissolving with saliva. Some forms with piercing and sucking mouthparts feed on animal blood (often only the female indulges in this diet, requiring the protein for egg development), and some adult dipterans do not feed at all.

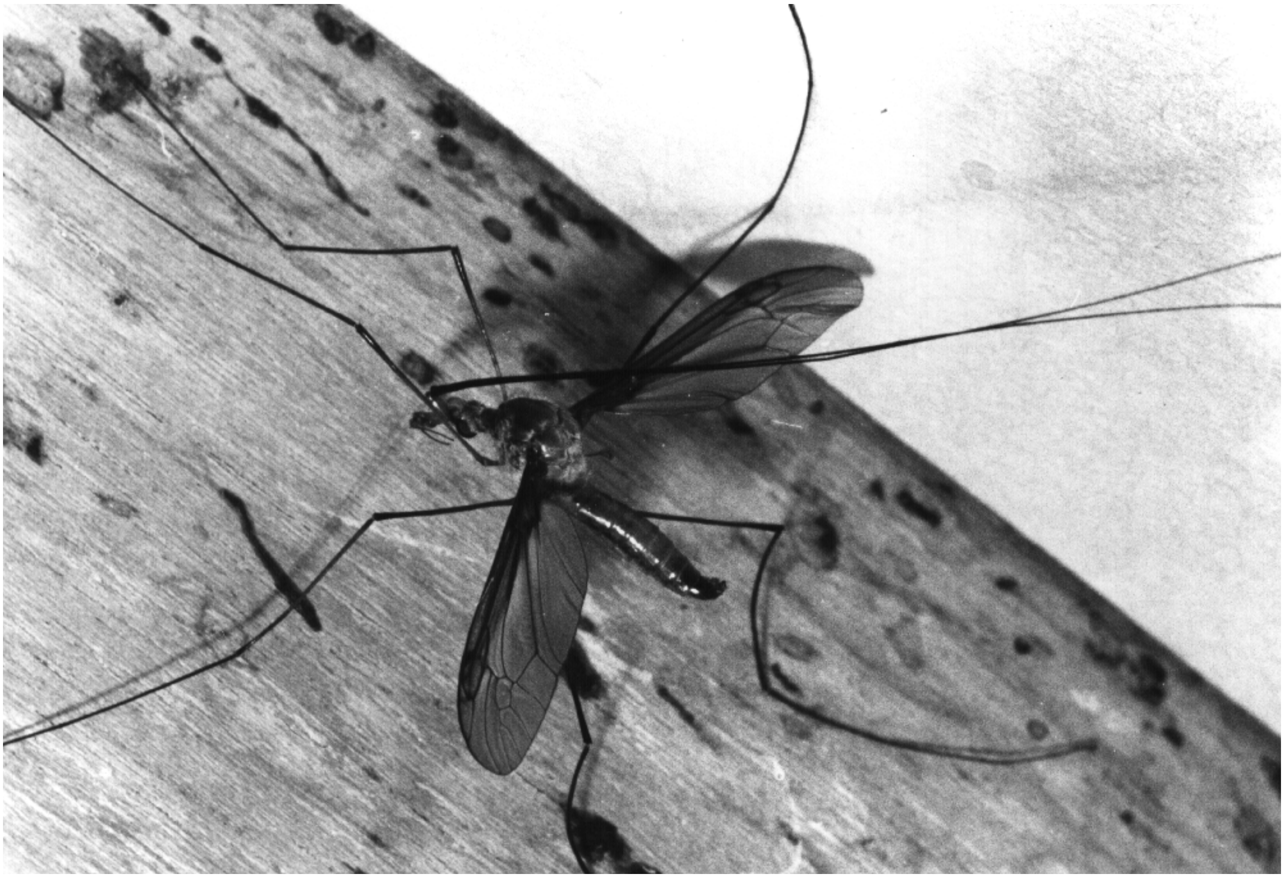


Figure 6.44 Crane fly — 25 mm (Family Tipulidae)

Reproduction is mostly sexual, with courtship and mating procedures often taking place in flight. Eggs (and sometimes live young) are laid in or on the larval food, which is often a medium high in moisture, ranging from stagnant water to rotting flesh or vegetable matter or even the inside of live animals or plants. The larvae undergo a number of moults during feeding and mostly leave the feeding site to pupate in drier conditions (eg adjacent soil). Most pupae are enclosed in a hardened case or puparium. Adults emerge often within weeks of pupation.

Pest status

Although the order contains some insects beneficial to humans by way of pollinating, killing or parasitising other insects or decomposing organic matter, dipterans are of profound veterinary and public health importance. House flies, bush flies, mosquitoes and the like not only can annoy people but also, particularly when in large numbers, have an enormous potential for disease transmission. Some blood feeders are vectors of important human diseases (eg malaria) and a variety of diseases of livestock. Scavenging flies (eg house flies, blowflies) can carry many types of human diseases. As well, some flies are pests of fruit and vegetable production, and others are internal parasites of livestock.

ORDER LEPIDOPTERA

Moths and butterflies

Approximate number of species: world 113,000, Australia 20,816.
Type of metamorphosis: complete.
This is perhaps the most widely celebrated group of insects for beauty and grace. However, the often voracious appetites of their young make them loathsome in the eyes of many a farmer.

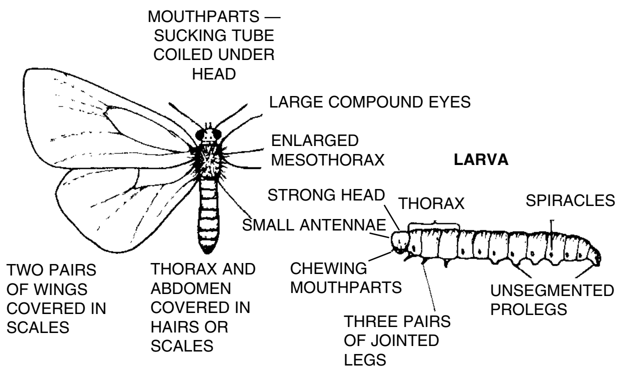


Figure 6.45 Adult butterfly and caterpillar-type larva

Figure 6.46 Male emperor gum moth (*Opodiphthera eucalypti*) — 100 mm wingspan (Family Saturniidae)

Appearance

Adults are small to very large. Although a few are wingless, characteristically they have two pairs of wings covered with overlapping scales, often beautifully coloured. The forewings are usually larger, and there is usually a coupling mechanism. Compound eyes are mostly well developed, and ocelli may be present. Antennae are relatively large and variable. Legs are developed for walking. The mouthparts, in the form of a coiled tube, are quite distinct; when uncoiled, the tube is used simply as a drinking straw to suck available liquids.

Figure 6.47 Larva of fruit-tree borer (*Cryptophasa* sp.) — 35 mm (Family Oecophoridae)

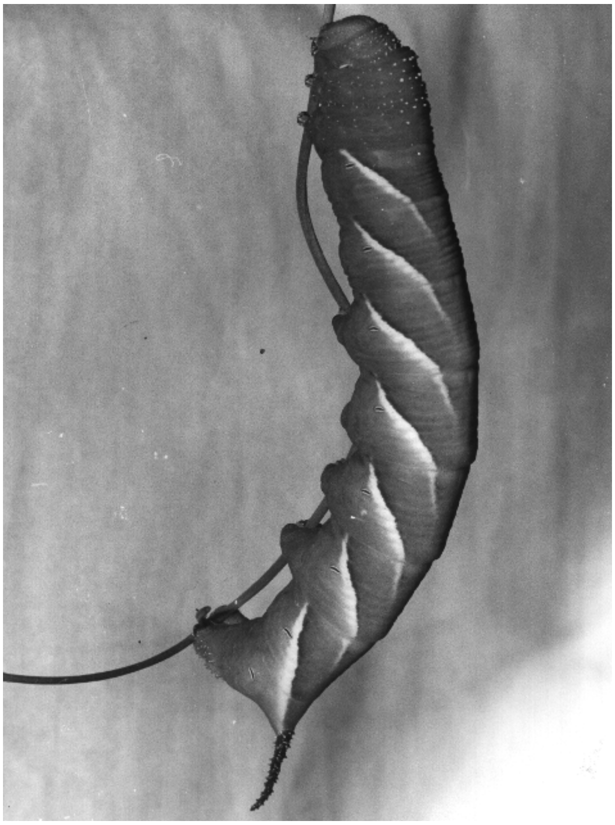


Figure 6.48 Larva of Australian privet hawk moth (*Psilogramma menephron menephron*) — 75 mm (Family Sphingidae)

Larvae are mostly cylindrical caterpillars, with sclerotised head capsules, chewing mouthparts, thoracic legs and often 5 pairs of abdominal prolegs. The caterpillar may be smooth skinned or hairy or have fleshy spines or tubercles.

Biology and habits

Moth and butterfly adults are mostly short lived and ingest only available liquids, such as nectar.

Reproduction is mostly sexual, with flight pattern and scent often playing a role in attraction. Copulation usually occurs on a surface and eggs are laid in or on the larval feeding medium. The vast majority of lepidopterous larvae feed on plants as leaf eaters, leaf miners, or borers in stems, roots and trunks. Some are general scavengers and a few species feed on stored products. Silk production for larval or pupal protection is common. Most larvae are solitary, but some are gregarious. After feeding and undergoing a number of moults, the larvae pupate in or on the soil, host plant or other food source. Pupae may be naked or protected in a cocoon.

Pest status

Owing largely to the plant-feeding habit of many of the larvae, many lepidopterans are serious and costly pests of agriculture and horticulture. In urban situations, stored products such as grains, cereals, dried fruits and fabrics may be attacked by various moth species.

ORDER HYMENOPTERA

Ants, bees and wasps

Approximate number of species: world 108,000, Australia 14,780.
Type of metamorphosis: complete.
Given the massive degree of natural control of plant pests afforded by parasitic and predatory wasps, and the extensive pollination programs seen to by bees and others, we often underestimate the benefits of this abundant and highly successful group of insects.

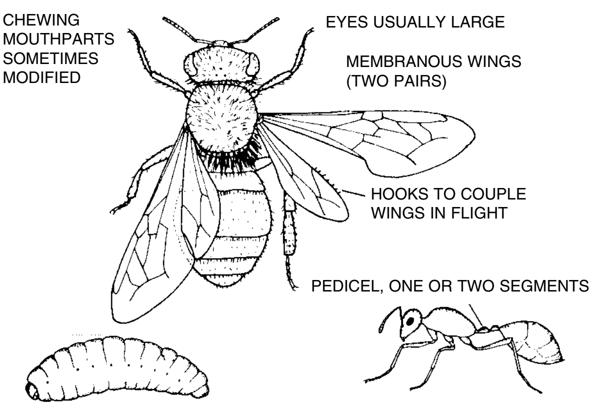


Figure 6.49 Adult and larval Fly, and adult ant

Appearance

Adults are very small to large and of diverse form. Wings may be present, reduced or absent. When present, wings are membranous; the forewings are usually larger than the hindwings, and there is a coupling mechanism. Mouthparts are of the chewing type, with some modifications for lapping or sucking. The cuticle is often highly sclerotised. Compound eyes are usually large, 3 ocelli are often present, and antennae are variable. Females often have an ovipositor developed for sawing, piercing or stinging.

Larvae are highly variable in form; some are caterpillar-like, others more grub-like. Some have thoracic or abdominal legs or both; others are entirely legless. Their chewing mouthparts and head capsule are often distinctive.

Biology and habits

Habits vary enormously within the group. Some are solitary insects while others are social, forming sometimes very complex societies that involve different castes and a high degree of communication. Although many adult hymenopterans feed on nectar or pollen, larvae may be foliage eaters, wood borers, internal or external parasites of insects and allied forms, or feeders of prey or prepared diets provided by adults.

Reproduction may be sexual or by parthenogenesis. Eggs of parasitic species are usually laid in or on the host animal. Eggs of foliage eaters are usually laid in or on the host plant. In social insects, eggs are tended by workers. Larvae undergo a number of moults before pupating.

Figure 6.50 Papernest wasp (*Polistes* sp.) — 25 mm (Family Vespidae)

Pest status

Some sawfly species are pests as foliage eaters, some wood wasps are pests of forest trees, some wasp species are troublesome to humans and some ants may be regarded as household pests; but by and large, the group is very beneficial.

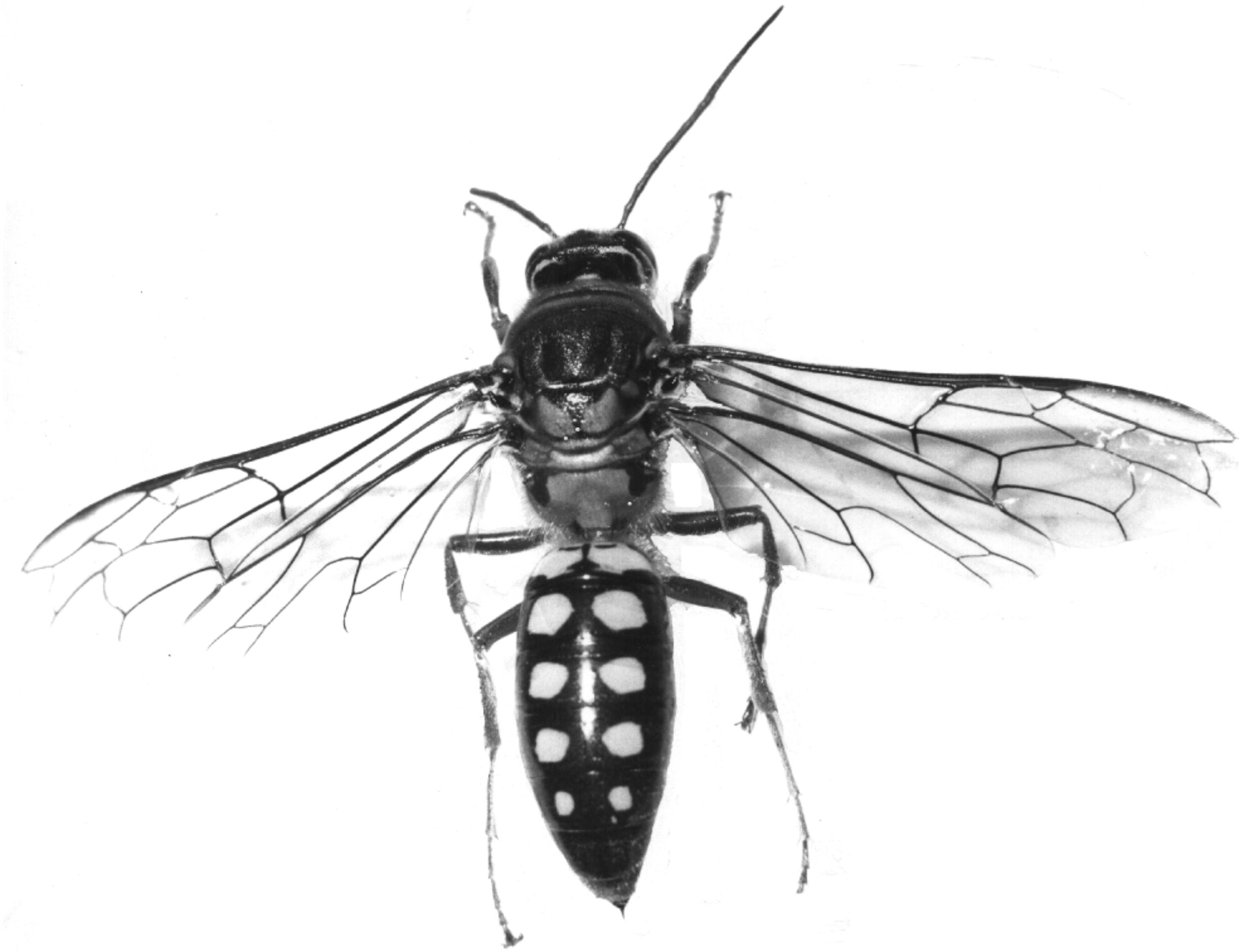


Figure 6.51 Flower wasp — 25 mm (Family Tiphiidae)

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CHAPTER 7

PESTICIDES — AN INTRODUCTION

Pesticides play a vital role in the control of a huge variety of organisms that are pests of humans. To introduce the next three chapters, about the types of pesticides and insecticides and their use, this chapter looks at:

1. the history of the use of chemicals in pest control;
2. the definition of a pesticide and the main types of pesticides in current use;
3. government legislation, which plays an important role in the regulation and control of pesticide usage; and
4. pesticide labelling, which is critically important in the systems of regulation and control that aim at safe and effective use of pesticides.

HISTORY OF THE USE OF CHEMICALS IN PEST CONTROL

Ever since humans first began to grow foods and store them, they have been faced with the formidable task of protecting them from the ravages of a variety of live organisms, including bacteria, fungi, mites, insects, birds and many others.

Perhaps the earliest records of this battle come from the writings of the ancient Greeks and Romans, who used a variety of control methods. Mechanical methods were widespread. For instance, legislation for locust control required citizens to fight locusts physically three times a year: by crushing the eggs, then the hoppers and finally the adults. Cultural methods suggest some 'scientific' understanding of the problem. For example, the harvesting of wheat during a dry west wind seemed to reduce pest problems in storage, and the storage of grain in airtight pits (creating an environment low in oxygen and high in poisonous carbon dioxide, as a result of the respiration of the grain itself) was widely known for its prevention of pest problems in stored grain. As invasion by pests was often seen as a manifestation of the discontentment of the gods, ritual and magic also played an important role in pest control procedures. Millet crops, for instance, could be 'protected' from birds by burying a plant (name unknown) at the four corners of the field. Seed was protected from mice by being dressed with the ashes of a cat or weasel, and if this proved distasteful in the final product, the seed was steeped in ox gall. Clearly, many of the 'magical' or ritualistic procedures used involved what some might regard as crude chemical methods.

For many centuries, mechanical, cultural and ritualistic methods prevailed in attempts at pest control. Close examination of pest problems from a scientific viewpoint was lacking until the nineteenth century. For instance, the Black Death, a disease epidemic that swept through Europe in the fourteenth century, claimed about 25 million lives, but how the disease spread was not understood until the late 1800s, when scientists identified the role of fleas in transmitting the bacterial disease from rodents to humans. Perhaps the first successful large-scale defeat of 'pests' by chemical means was the control of a vine mildew in Europe in the 1840s, by spraying with lime sulphur and sulphur dusting. The following year saw some exploitation of chemicals for control. Mostly, these evolved from inorganic materials (eg arsenic) and from plant extracts (eg nicotine from the tobacco plant).

A significant step in the evolution of chemicals in pest control was taken in 1939, when the insecticidal properties of DDT were discovered. DDT proved to be more persistent and effective than any other insecticide then known. The discovery may have effectively saved millions of lives during the Second World War by checking louse-carried typhus epidemics. Further investigations, stimulated by the war, led to the discovery of other types of very potent chemicals that had insecticidal properties. Since that time, the pesticide industry has developed into a very sophisticated system of finding or contriving chemicals that can be used in the war against pests.

With the development in more recent years of technology that can measure pesticide residues and their effects, there has been a growing awareness of hazards to non-target life forms and to the environment. At present the development of a new pesticide can take several years and cost more than $20 million. Much of this enormous cost in time and money is spent in investigations to elucidate the potential hazards to various life forms and the environment.

Accompanying the growing concern about the harmful effects of pesticide use, very recent approaches to pest control are becoming more and more involved in examining non-chemical approaches. Even though many non-chemical methods of pest control have a long history, they are currently being used in pest management programs, which often incorporate also a judicious use of chemical pesticides. The concept of Integrated Pest Management (IPM) is becoming very important in various sectors of pest control. At the same time, many would argue that our dependence on chemical pesticides cannot be overstated.

DEFINITION OF PESTICIDE AND TYPES OF PESTICIDES

The word pesticide usually refers to a substance used to kill undesirable animals or plants. However, it may also refer to substances that may repel, sterilise or in some other way mitigate the growth of pest populations. Most 'pesticides' effect the death of the pest species by interfering with normal life processes.

The word 'pesticide' comes from the Latin *pestis* (a plague, pestilence or contagious disease) and *cidere* (to kill). The term 'pesticide' is a broad one that embraces many specific and particular types. Particular pesticides are usually named by preceding '-icide' with the name of the target organism. The term 'biopesticide' usually refers to a live organism (eg bacteria) that is used as a biological control agent against a pest species. The following is a list of different types of pesticides and the target organisms they control:

Insecticides	Insects
Rodenticides	Rodents (rats and mice)
Miticides (acaricides)	Mites
Herbicides (weedicides)	Weeds
Bactericides	Bacteria
Algicides	Algae
Fungicides	Fungi
Molluscicides	Molluscs (snails and slugs)
Avicides	Birds (from Latin *avis*)
Ovicides	Eggs (from Latin *ovum*)
Piscicides	Fish (from Latin *piscis*)
Termiticides	Termites
Adulticide	Adult stage of life cycle
Larvicide	Larval stage of life cycle

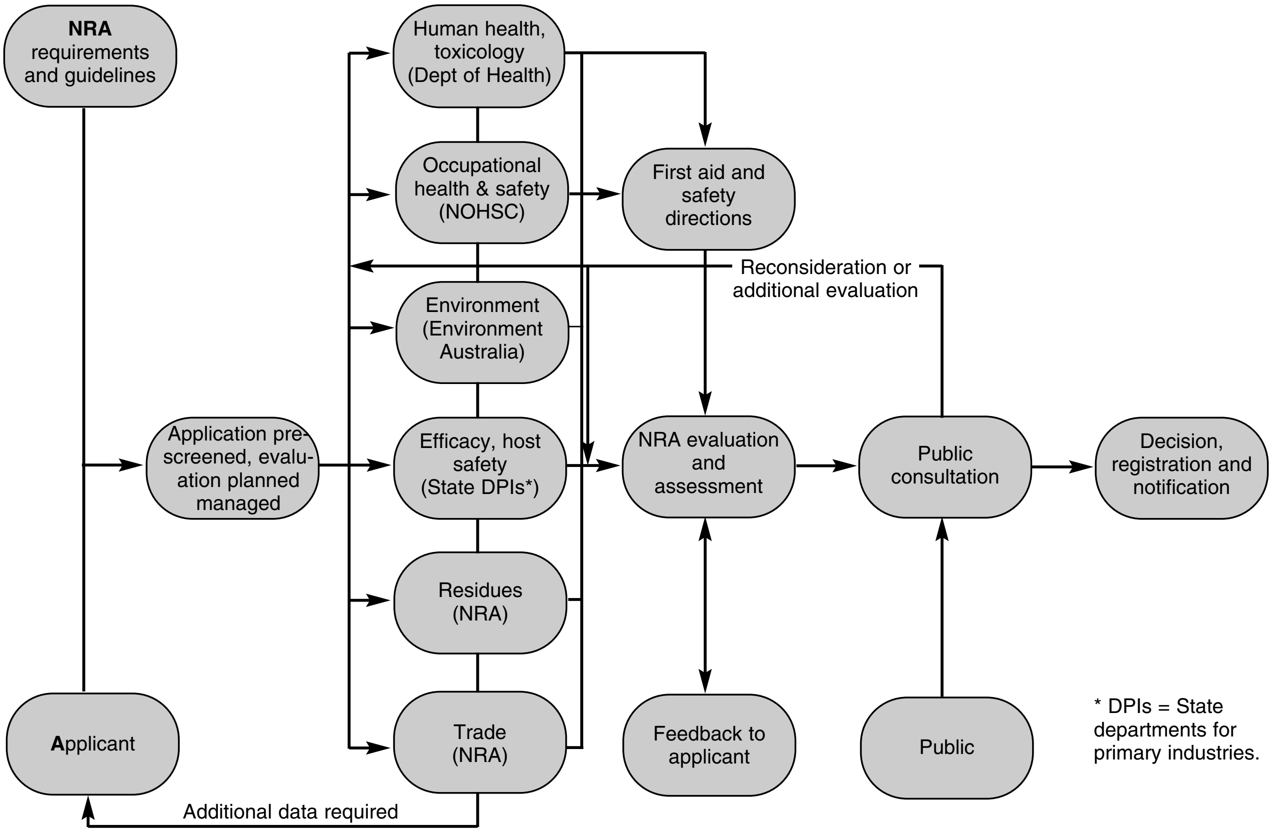
Pesticides act in a variety of ways to kill or regulate pest populations. Often, however, the means of poisoning is such that the pesticide is toxic to a range of non-target organisms, which may include the operator applying the pesticide, the wildlife close by, or the consumers of foods treated with the pesticide. The threat posed warrants some control over the use of potentially hazardous chemicals. Such control is usually implemented by the appropriate government legislation.

GOVERNMENT LEGISLATION AND PESTICIDES*

The increasing use of a variety of pesticides since the Second World War has led to the need for controls over their handling and use in order to avoid harmful effects. In Australia, a system of product registration operates for this purpose and is administered by the National Registration Authority for Agricultural and Veterinary (Agvet) Chemicals. The National Registration Scheme evaluates, registers and regulates all agricultural and veterinary chemicals so as to ensure high standards of safety and effectiveness.

* The information on 'Government Legislation and Pesticides' and 'Pesticide Labelling' has been largely sourced and extracted from National Registration Authority (NRA) publications, viz: *Annual Report 1997-98* and *AG Labelling Code — Code of Practice for Labelling Agricultural Chemical Products* (March 1997). The authors gratefully acknowledge the assistance and co-operation of the NRA.

FIGURE 7.1
Registration process for Agricultural and Veterinary Chemicals*



* Extract from the National Registration Authority Annual Report 1997–98

The National Registration Scheme

Before a pesticide (or other agricultural or veterinary chemical product) can be sold in Australia, it must be assessed and registered by the National Registration Authority (NRA).

Chemical companies are required to provide extensive data to demonstrate that a product will be effective for the uses described on the label, will be safe for humans and non-target species, and will not pose unacceptable risks to the environment or to trade with other nations.

When products are evaluated, the NRA takes full account of the nature of the product, the amount and completeness of the data for review, and the extent of consultation required between the NRA, manufacturers, advisory agencies and the States or Territories.

Residue studies on crops and animals are evaluated to establish an MRL (Maximum Residue Limit) and a withholding period. Recommendations for using the product are checked to ensure that they are consistent with the data provided and labelling is examined to ensure it is accurate and meets Commonwealth and State legislative requirements.

Specialist advice from agencies

For specialist advice during the assessment process, the NRA receives input from three Commonwealth agencies:

- The Department of Health and Family Services evaluates toxicology data submitted by applicants to determine if any health risk may be posed to the community.
- Environment Australia evaluates the environmental implications of the products submitted for registration and recommends measures to avoid or minimise adverse environmental effects.
- The National Occupational Health and Safety Commission (NOHSC) conducts occupational health and safety assessments to ensure that any risks arising out of workers' exposure to agricultural and veterinary chemical products are minimised.

Evaluations may take several months to complete in the case of new products, whereas evaluations of variations to products already on the market may be completed more quickly.

At some stage during the evaluation process, consultation may occur with the States and Territories, other Commonwealth agencies and a range of expert panels or committees that provide advice to the NRA. This process ensures that appropriate knowledge and experience is incorporated into the assessment process. Figure 7.1 (page 55) summarises the registration process. Applicants are consulted frequently during the evaluation process, particularly on technical issues and areas of concern.

Before registering a product containing a new active constituent, or amending a registration to allow a major change of use, the NRA publishes a summary of an evaluation as a basis for public comment. These public release summaries are advertised in the NRA Gazette to notify the community that the product is under assessment, to offer further information and to invite comment that is taken into account before the final decisions are made.

When an assessment is complete, the product is either registered or rejected. In many cases, the NRA proposes amendments to the draft label as a requirement of approval.

Regulation and monitoring

Pesticides (and other Agvet chemical products) are not registered forever.

The NRA operates four programs that monitor Agvet chemicals after registration. These programs have the capacity to bring about regulatory action if registration standards are not maintained or if new information dictates the need to reconsider the conditions of registration.

Chemical Review

Two review programs revisit the registration of Agvet chemicals to ensure that they continue to meet contemporary efficacy, health, safety, environmental and trade standards.

The Existing Chemical Review Program (ECRP) is a systematic review that focuses on chemicals that have been prioritised from public nominations.

The Special Review Program allows the NRA to review chemicals immediately if issues arise that may alter the terms of their registration.

Compliance and surveillance

The NRA manages the national Compliance Program under which it funds inspection and surveillance activities that are undertaken on its behalf by State and Territory agencies.

Compliance involves testing of product samples to ensure that formulations are true to the standards of registration. Surveillance involves inspecting premises that store or supply pesticides and other Agvet chemicals to check that products and labels are registered; that their containers are approved; that correct information appears on product labels and associated literature; that products are stored correctly; and when necessary, that products carry a visible expiry date, batch number and date of manufacture.

Consultation

The NRA places a high priority on communication with the various stakeholders involved in the National Registration Scheme. It operates or participates in a number of consultative forums on issues relating to Agvet chemicals and products. These consultative mechanisms have been instrumental in developing key programs and priorities.

Improving the system

The NRA is committed to the continuous improvement of the systems used to register Agvet chemicals and to the harmonisation of regulatory processes with key agencies in the field.

It is important to note that the use of pesticides may differ from state to state because of environmental conditions, pest conditions and agronomic practices. As a result, the recommended uses for a particular pesticide may vary in each state, so it is essential to read the label before purchase and use. By approving information contained on the label of a pesticide, the registration authority can ensure that pesticides are used effectively, efficiently and safely — when used according to label directions.

Users of pesticides must use the product precisely as the label directions indicate, and they must not use the product for any purpose(s) other than those indicated on the label.

Various kinds of legislative control, ancillary to pesticide registration, operate in various states and territories. Such legislation mostly incorporates a licensing scheme for pest control operators and may outline regulations pertaining to the use of certain more hazardous pesticides. Pest control operators in a given state must be entirely familiar with the pesticide legislation that operates in that state.

A first, most important step in the direction of safe and effective use of pesticides is:

READ THE LABEL and HEED THE LABEL.

PESTICIDE LABELLING

A great deal of information is gathered from the work of entomologists, chemists, toxicologists and many other specialists before pesticide labels are prepared. The NRA provides a 'Code of Practice for Labelling Agricultural Chemical Products' so that label submissions conform to relevant national legislation. The assessment and approval of labels submitted to the NRA is a key aspect of the procedure for registration of agricultural chemical products.

The following is a generalised summary of the basic components that make up a pesticide label:

Signal heading

The signal heading appears at the top of the main panel of a label. The wording is determined by the poison scheduling according to the *Standard for the Uniform Scheduling of Drugs and Poisons* (SUSDP) published by the Australian Health Ministers' Advisory Council. A summary of the typical signal headings and required wording is shown in Table 7.1.

TABLE 7.1

Poisons Schedule	Signal Headings
Unscheduled	READ SAFETY DIRECTIONS BEFORE OPENING OR USING
Schedule 5	CAUTION
	KEEP OUT OF REACH OF CHILDREN
	READ SAFETY DIRECTIONS BEFORE OPENING OR USING
Schedule 6	POISON
	KEEP OUT OF REACH OF CHILDREN
	READ SAFETY DIRECTIONS BEFORE OPENING OR USING
Schedule 7	DANGEROUS POISON
	KEEP OUT OF REACH OF CHILDREN
	READ SAFETY DIRECTIONS BEFORE OPENING OR USING

Distinguishing name of the product

The distinguishing name of the product is the name given to the product which many refer to as its 'trade name'. It usually appears below the signal heading and above the active constituent statement. A distinguishing name must be unique and it must describe the intended end use (eg insecticide, termiticide, insect repellent).

Active Constituent statement

Active constituents are those components of pesticide formulations that are primarily responsible for the biological activity of the product. The active constituent statement is usually located below the distinguishing name and has the heading:

Active Constituent(s): followed by the concentration(s) and common name(s) of the active constituent(s) present in the product:

For example:

ACTIVE CONSTITUENT:500 g/kg CYPERMETHRIN

Correct symbols for units of mass and volume include: 'g' (grams); 'kg' (kilograms); 'mL' (millilitres) and 'L' (litres).

Products containing solvents that are listed in the schedules of the SUSDP must include a Solvent Statement that includes the solvent concentration:

For example:

ACTIVE CONSTITUENT:100 g/L BIFENTHRIN
SOLVENT:763 g/L HYDROCARBON LIQUID

Products containing certain Organophosphorus or Carbamate compounds must carry an appropriate statement:

For example:

ACTIVE CONSTITUENT:450g/L CHLORPYRIFOS*
SOLVENT:327 g/L HYDROCARBON LIQUID

(*an anticholinesterase compound)

Statement of claims for use

This statement is usually located below the Active Constituent statement and is a concise statement of the purpose for which the product is to be used:

For example:

For Pre-Construction Control of Subterranean Termites

If a product has many uses, a more general statement may apply:

For example:

For the control of domestic insect pests as specified in the Directions for Use Table

In cases where a product is prescribed as a 'restricted chemical product', the following statement must follow the statement of claim for use:

RESTRICTED CHEMICAL PRODUCT — ONLY TO BE SUPPLIED TO OR USED BY AN AUTHORISED PERSON

Contents/Net Contents

In the case of products sold by weight, the term 'net contents' is used:

For example: NET CONTENTS: 300 g

For products sold by volume, the term 'contents' is used:

For example: CONTENTS: 20 L

Name and address of registrant, formulator or distributor

In order to facilitate contact with the company responsible for a particular product, the label must include the name and street address of the registrant, formulator or distributor. An emergency telephone number is included.

Directions for Use

The directions for use provide instructions on how, when and where the product is to be used. Limitations on use, such as those aimed at minimising hazards to human health and the environment, may also be included. This part of the label usually contains a number of subsections:

Restraints

A restraint is a limitation that is placed on the use of pesticide product:

For example:

DO NOT apply to soils if excessively wet or immediately after heavy rain to avoid run off of chemical

Use-Table or Directions for Use

The use-table or directions for use provides essential information about the proper use of the product. It will provide information pertaining to:

- the approved target pest(s) of the product
- the rate(s) of application (including product dilution and amount applied per unit area)
- critical comments (for example: crawling insects: apply as a coarse low pressure spray to areas where pests hide)
- State differences ie differences in Directions for Use between various States

'Not to be Used ...' statement

All pesticide labels must include the following statement:

**NOT TO BE USED FOR ANY PURPOSE,
OR IN A MANNER, CONTRARY TO
THIS LABEL UNLESS AUTHORISED**

Other limitations or prohibitions

In cases where further limitations on use are deemed necessary, for example in relation to human safety or protection of the environment, these will be indicated after the above statement.

General Instructions

The general instructions section of the label outlines any information about product use that has not been included under 'Directions for Use'. This may include information such as:

- the mode of action of the product
- equipment guidelines (eg appropriate type, calibration, use, maintenance, cleaning)
- compatibility with other products
- mixing instructions
- use patterns.

Precaution statements

Under the heading 'Precautions', these statements attempt to minimise the health risks to humans and animals that may arise from the use of the product.

For example:

Avoid contact with food, food utensils, or places where food is prepared or stored.

Some more toxic pesticides may need to carry specific requirements relating to the entry of treated areas. Such instructions are usually found in the 'Precautions' section under the heading 'Re-entry period'.

Protection statements

Protection statements serve to minimise the hazard to non-target plants and animals and the environment. These statements usually follow headings such as:

Protection of wildlife, fish, crustaceans and the environment

Examples of protection statements include:

Toxic to fish

Remove or cover fish tanks before use

Storage and Disposal statements

These statements provide instructions about the proper methods of storage, disposal of excess spray mix and empty containers and dealing with spillage.

Safety Directions

This section of the pesticide label outlines those directions that relate to the safe handling, safe use and safe storage of the product.

First Aid

This section outlines the steps that should be taken immediately in the event of a poisoning.

Other information

Further information that may be found on a pesticide label includes:

- Material Safety Data Sheet (MSDS) — Some labels are required (under State/Territory legislation) to include an MSDS and in those cases, a statement referring to the additional information is required.
- Emergency Information — Products classified under the 'Australian Code for the Transport of Dangerous Goods by Rail and Road' are required, under State legislation, to include emergency information on the label
- Batch Number
- Date of Manufacture and/or Expiry Date
- NRA Approval Number.

Note: The information above, pertaining to the process of pesticide registration and the contents of pesticide labels, is meant only to be broadly descriptive. The guidelines for such matters change with time and with specific circumstances. Authoritative advice regarding such matters should be sought directly from the National Registration Authority.

Again, it should be stressed:

READ THE LABEL and HEED THE LABEL.

A pesticide label should be read:

1. *before purchasing the pesticide* — to ensure that it is appropriate for the particular pest that is to be controlled;
2. *before mixing and applying the pesticide* — to ensure that these procedures are carried out safely according to the directions set out on the label; and
3. *before storing or disposing of the pesticide* — to ensure that these procedures are carried out in a safe and appropriate manner.

FURTHER READING

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CHAPTER 8

INSECTICIDES — MAIN TYPES, PROPERTIES & USES

Insecticides, as just one kind of pesticide, play an important role in the control of insect pests that are in various ways harmful to humans. Those who are intimately involved in insect control may gain a broader perspective by knowing something about the history of insecticides, and should be familiar with both the action of insecticides (i.e. how they gain entry into the body, and how and where they may act) and the various properties of insecticides (eg persistence, volatility). An important aspect of insecticide usage that can determine its effectiveness is the development of insecticide resistance in some strains of insects. Most insecticides presently used in urban pest control can be categorised into one of several types of insecticides (Table 8.1, page 63), and each insecticide is usually available in several products. The choice of insecticide product will depend on several factors. Information relating to a range of insecticide products that are used in urban pest control is outlined in Appendix V.

BRIEF HISTORY OF INSECTICIDES

During the Second World War the discovery of DDT marked a significant step in the development and use of insecticides. Before that time, urban pest control relied largely on the use of:

1 *inorganics* — substances of mineral origin that are often highly toxic (eg arsenic);
2 *botanicals* — substances extracted from plants (eg pyrethrins); and
3 *fumigants* — substances that behave as (often highly toxic) gases (eg hydrogen cyanide).

Inorganic and botanical substances were employed mainly as dusts and baits, giving, no doubt, only limited control.

The development of DDT in 1939 marked the beginning of a more widespread effort to investigate, develop and manufacture new synthetic insecticides. *Organochlorine* insecticides (eg DDT, dieldrin, chlordane), which contain carbon, hydrogen and chlorine in their make-up, were developed in the 1940s and early 1950s. The late 1940s and following decades saw the significant development of *organophosphorus* insecticides, substances derived from phosphoric acid (eg dichlorvos, diazinon). *Carbamate* insecticides, derivatives of carbamic acid (eg propoxur, bendiocarb), were introduced in the early 1950s.

The more 'modern' group of insecticides known as *synthetic pyrethroids* contain molecules that are largely based on the molecules of the natural (botanical) insecticide pyrethrins. In relation to safety and effectiveness considerations, some of the synthetic pyrethroids are showing much promise.

In the search for safer and more effective insecticides, another very significant development is that of Insect Growth Regulators (IGRs) (eg hydroprene, methoprene). Most of the more traditional insecticides act as nerve poisons; however, IGRs target other physiological processes such as general development or cuticle formation. With generally low mammalian toxicities, they represent a very important direction in insecticide technology.

Biological control (ie the use of live organisms such as bacteria or fungi to control certain pest species), also offers a range of advantages over the more traditional use of 'poisonous' pesticides. Biological control agents are often referred to as *biopesticides*.

The continuing need to develop new pesticides stems from:

1 the harmful effects of some pesticides presently in use (particularly pesticides that do not readily break down in the environment and/or are highly toxic to non-target animals); and
2 the development, in insect pests, of resistance to certain insecticides.

THE ACTION OF INSECTICIDES

Insecticides kill insects by disrupting important life processes. This toxic (poisonous) action relies on:

1 the route of entry of the insecticide into the insect body; and
2 the mode of action of the insecticide inside the insect body.

Routes of entry of insecticides

Insecticides may enter the insect body via the cuticle (dermal entry), via the mouth (oral entry) or via the breathing system (respiratory entry). A given insecticide may enter primarily by one, by two or by all three of these methods.

Dermal entry

The penetration of insect cuticle by an insecticide is often referred to as 'contact' action; hence, insecticides that rely heavily on this method of entry are referred to as *contact poisons.* Most of the synthetic insecticides used in urban pest control practices are contact poisons. The contact of the insecticide with the insect is shown in Figures 8.1 and 8.2.

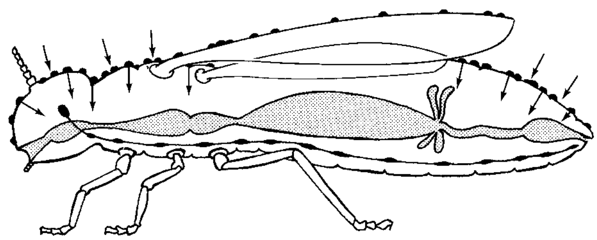

Figure 8.1 Direct and immediate contact occurs when insects are 'wetted' by aerosol (mist or fog) droplets

The precise details of cuticle penetration have not as yet been clearly determined, but solubility factors clearly play an important role. It is likely that much penetration of the cuticle occurs where it is thinner (i.e. where sensory structures are present, and where body segments are joined by thinner, more flexible cuticle). Once inside the body cavity it is likely that contact poisons are to some extent transported in the haemolymph to the target tissue, which in most cases is the nervous system. It is likely that some insecticides applied as liquids act more quickly than when applied as solids (eg dusts).

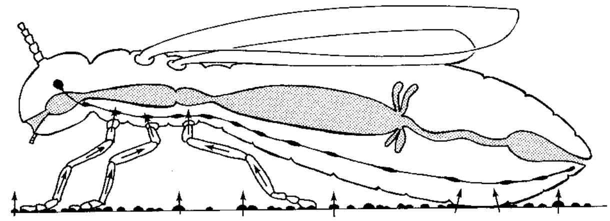

Figure 8.2 Contact occurs when crawling insects walk on surfaces that have been treated so as to leave an insecticidal deposit

Oral entry

The oral entry of insecticides relies on ingestion of the poison into the digestive system of the insect. Insecticides that rely heavily on this means of entry are called *stomach poisons.* They may effect their entry as shown in Figures 8.3 and 8.4.

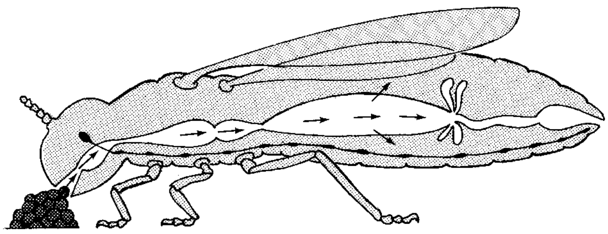

Figure 8.3 Pesticide may be incorporated in a poisonous bait that is ingested by the pest

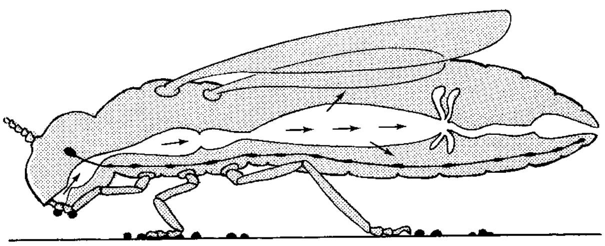

Figure 8.4 Pesticide may be ingested during grooming, when the insect's body may be contaminated by the insecticide (eg when the places where cockroaches hide are dusted)

Most contact poisons act as stomach poisons when ingested. Some stomach poisons (eg arsenic and boracic acid) have little or no contact action on insects.

Certain insecticides, called *systemic insecticides,* are designed so that, when administered to the host plant or animal, they are translocated throughout the host, effectively making poisonous the sap or blood within. When parasitic pests such as aphids (on plants) or fleas (on animals) feed on the host, the poison is ingested. Only a few insecticides (mostly organophosphates) can act as systemic insecticides. Clearly, systemic insecticides must not harm the host plant or animal and should break down reasonably rapidly.

Respiratory entry

Insecticides that rely largely on being 'breathed in' by the insect to cause death are often referred to as *respiratory* or *inhalation poisons.* All fumigants are, by definition, inhalation poisons. They act by being present as toxic molecules in the atmosphere. Fumigants are described as 'volatile' (i.e. capable of easy and rapid evaporation). Fumigation techniques, such as the treatment of grain or timber, rely on containing the toxic vapours for a period of time in a silo or chamber, as relatively airtight conditions are required.

All insecticides have some degree of volatility, but for most this is a very low level. The unusually high volatility of some insecticides (eg dichlorvos) can be an important consideration in use. Dichlorvos is incorporated in resin strips to give a slow release of toxic vapours. Placed in an enclosed environment such as a closet, the resin strips can release sufficient dichlorvos vapours to kill insects that are somewhere inside the closet, breathing the toxic atmosphere. As well, it is likely that dichlorvos sprayed onto surfaces, or as an aerosol, evaporates to create toxic vapours that move around in the treated area, killing insects that inhale the toxic vapours. Dichlorvos is an oral, dermal and inhalation poison that requires a great deal of care in its use.

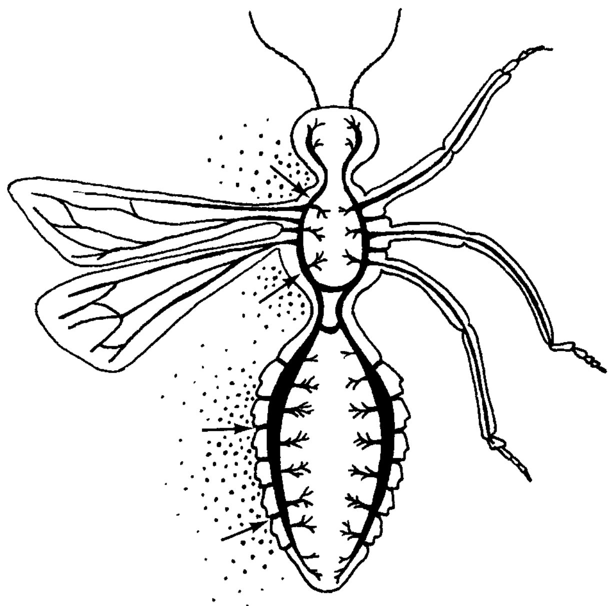

Figure 8.5 Respiratory entry of insecticides

Modes of action of insecticides

The mode of action of an insecticide is the method by which it causes death. While the precise detail of the toxic action of many insecticides is unclear, most of the synthetic insecticides appear to act as nerve poisons (ie substances which interfere with the normal functioning of the nervous system).

Synthetic pyrethroids, for example, appear to exert their effect on the functioning of the nerve fibre (or axon) resulting in a period of intense electrical activity and blockage of nerve impulses.

The organophosphorus and carbamate insecticides, on the other hand, are referred to as *cholinesterase inhibitors* and exert their effect at the nerve synapses (see figure p 20). Normally, transmitter substances are secreted in nerve synapses to convey messages across the 'gap'. These substances are usually broken down by the important enzyme cholinesterase. When cholinesterase-inhibiting insecticides reduce the amount of this enzyme, transmitter substances accumulate in nerve synapses, leading to severe disruption of the nervous system and, eventually, of the organs and tissues that rely on its proper functioning.

Some poisons act by means other than disruption of the nervous system. IGRs disrupt normal development or cuticle formation. Abrasive dust (eg silica aerogel) acts by abrading the waxy layers of the cuticle, so allowing water to escape and causing death by dehydration. Mineral oils can wet so as to exclude air, causing the insect to die of suffocation. Inorganics (eg arsenic) can kill by precipitating proteins in the gut lining.

PROPERTIES OF INSECTICIDES

Before examining the main types of insecticides in common use, it is worth considering the various properties of insecticides that, in many instances, can influence the end use and effectiveness of the product.

Toxicity The toxicity of an insecticide is its capacity to poison. For the control of certain pests, extensive tests are carried out on new insecticides to determine their toxicity to those pests.

Hazard This is the risk of harm that may result from the handling and use of pesticides. A highly toxic pesticide may be used in a relatively low hazard (low risk) manner (eg subsoil injection) whereas a less toxic pesticide may be used in a high hazard manner (eg spraying eaves on a windy day with children playing downwind). The relative hazard of a particular pest control operation can be influenced by many different factors including choice of pesticide, type and condition of application equipment and weather conditions.

Spectrum of activity The spectrum of activity of an insecticide refers to the range of pests against which the product is active. Insecticides that kill many types of insects (eg pyrethrins and dichlorvos) are said to have a broad spectrum of activity. Insecticides that are active against only a few types of insects are said to have a narrow spectrum of activity.

Mammalian toxicity The mammalian toxicity of an insecticide is usually determined by testing with test animals (usually rats). The relative measures of the mammalian toxicity of an insecticide are usually given as: Oral LD50 (mg/kg; that is, in milligrams of poison per kilogram of body weight); Dermal LD50 (mg/kg); and Inhalation LC50 (usually in mg/m^3 for 4 hours).

Persistence The biological activity of most insecticides begins to decline after application. When the loss of activity is slow, the insecticide is said to be persistent, stable or residual. Dieldrin in soil remains active for more than 40 years, so dieldrin can be referred to as a stable, persistent insecticide. Other insecticides have an extremely short residual life. Dichlorvos is often rapidly broken down, perhaps within some hours after application. By their chemical nature, insecticides may have stabilities ranging from hours to many years. As well, environmental factors can shorten the residual life of an insecticide; and the nature of the surface to which the insecticide is applied can affect its stability, as can the presence of sunlight, moisture and heat.

Volatility The volatility of an insecticide refers to the ease with which it converts into a gaseous state (usually from the liquid state). Volatile insecticides (eg dichlorvos) can act as inhalation poisons.

Repellency The repellency of an insecticide is its ability to keep insects away from a treated area. Pyrethrins has a repellent action and is sometimes used as a space spray in low concentrations to repel flying insects.

Flushing action The flushing action of an insecticide is its tendency to excite the insects in a treated area, causing them to leave their harbourages. Dichlorvos and pyrethrins are said to have a flushing action. Flushing agents are sometimes mixed with surface spray chemicals (where label directions permit) to encourage contact with treated surfaces, or they may be used independently to indicate insect activity that is otherwise hidden. Operators often use a small aerosol of pyrethrins, which, sprayed into cracks and crevices, can reveal information about a cockroach infestation.

Knockdown action The knockdown action of an insecticide refers to the rapid incapacitation of insects by a quick-acting insecticide. Pyrethrins and certain synthetic pyrethroid insecticides are regarded as knockdown agents, and may be incorporated in products specifically for the purposes of quick knockdown.

Compatibility The compatability of chemicals refers to whether or not two chemicals (eg pesticides) can be mixed without an undesirable outcome. Pesticides should only be mixed when label directions indicate the compatibility of one product with the other.

Phytotoxicity The phytotoxicity of an insecticide refers to the degree to which it is poisonous to plant life. Insecticides that are declared phytotoxic should not be applied to plant life.

Withholding period This is the period of time which must elapse between the treatment of a crop with a pesticide and the harvesting of the crop.

Insecticide resistance

Resistance to insecticides may broadly be regarded as the development, in a strain of insects, of the ability to tolerate doses of insecticide that would be lethal to the majority of individuals in a normal population of the same species. The factors that facilitate the fast development of insecticide resistance in all insect pest populations are:

1 rapid life cycle (i.e. short period between generations); and
2 constant exposure to the same type of insecticide.

Insecticide resistance in a population of insects usually arises by way of a kind of sieving process. A few individuals in a given population may have the biochemical means to detoxify a given insecticide as it enters the body. If the population of insects is constantly exposed to this insecticide, a constant selection process operates whereby susceptible individuals die but those with the chemical armoury to deal with it survive, breed and genetically pass on the resistance characteristic. If the population of insects breeds rapidly, and if the same selecting factor (insecticide) is constantly applied to their environment, the selection process will occur rapidly.

After only a few years of the use of DDT, a number of insects once controlled by it (eg house flies, mosquitoes, lice and fleas) were found to be very resistant. The prolonged residual action of the organochlorine chemicals is likely to be a factor in aiding the development of resistance to them. Residues on surfaces eventually start to break down, and in so doing they select out (and kill) the more susceptible individuals, leaving those insects that have the inherent ability to detoxify the insecticide. These resistant individuals then contribute these genetic factors to the next generation.

Soon after the Second World War and the development of the organochlorine chemicals (eg chlordane, dieldrin), a great deal of 'household pest' control was carried out with these materials. Generally speaking, at that time there was not the awareness of the full safety implications that now govern and restrict our use of these materials. In most places where such control has operated, it is likely that organochlorine resistance occurs in house flies, mosquitoes, German cockroaches, fleas and some others. Given the more recent use of organophosphorus insecticides, it is possible that strains with organophosphorus resistance are also present.

Cross-resistance occurs when the resistance of a pest to a given insecticide of a particular group (eg chlordane, an organochlorine) confers resistance to other insecticides of that group (eg dieldrin). Even cross-resistance between different groups has been observed, but not so frequently.

The control of stored product insect pests is an area that is closely studied for problems relating to insecticide resistance. As it involves mostly fast-breeding insects that may be constantly exposed to insecticides, selection progresses rapidly.

One way to slow down the development of resistance is to alternate the types of insecticides used (ie to alternate between different categories or types of insecticides eg from organophosphate to synthetic pyrethroid to Insect growth regulator). As well, non-chemical methods of pest control (eg hygiene and sanitation programs for German cockroach control) can, and will in the long term, be an invaluable aid in the problem of insecticide resistance. While new insecticides are constantly being screened, tested and sometimes developed for use, the longer term future of pest control practices may rely largely on the development of 'biological' control and chemical methods which involve the use of synthetic biologically important substances that target physiological processes beyond the nervous system. The use of synthetic hormones, pheromones and the like, along with a more applied, Integrated Pest Management approach (with a strong commitment to non-chemical methods), may well prove to be the answer to the insecticide resistance problem.

TABLE 8.1
Main types of insecticides used in urban pest control: examples and some general characteristics.

Type of insecticide	Examples	Characteristics
Inorganic	arsenic trioxide boric acid	Used for diverse purposes. Mammalian toxicities vary (some are very toxic). Typically they are very stable.
Botanical	pyrethrins	Usually applied as a non-residual space spray for flushing and fast knock down. Natural pyrethrins is extracted from certain daisies. Mammalian toxicity is relatively low.
Organochlorine	aldrin dieldrin chlordane heptachlor	Historically, have been used for a wide variety of pests. Use areas have been restricted over time. Have played an important role in chemical-soil-barrier treatments against subterranean termites. Banned from use in Australia since 1995 owing mainly to concerns about persistance and the potential for harmful environmental and health effects. Mammalian toxicities range from relatively moderate to high.
Organophosphorus	azamethiphos chlorpyrifos diazinon dichlorvos fenthion pirimiphos-methyl temephos	Used mostly as surface sprays for short to medium term (usually up to a few months) residual control against a variety of household pests. Dichlorvos is a volatile contact and inhalation poison that is sometimes used as a non-residual space spray for control of various household pests. Mammalian toxicities range from relatively low/moderate to high.
Carbamates	bendiocarb methomyl propoxur	Used mostly as surface sprays for short to medium term residual control against a variety of household pests. Mammalian toxicities are mostly relatively moderate.
Synthetic pyrethroids	allethrin alpha-cypermethrin beta-cyfluthrin bifenthrin bioresmethrin cyfluthrin cypermethrin deltamethrin lambda-cyhalothrin permethrin phenothrin	Mostly based on the molecular structure of natural pyrethrins. Exhibit a range of stabilities from non-residual to medium-term stability. Several are used as surface sprays for medium-term control of a wide range of household insect pests. Many synthetic pyrethroids are used in 'supermarket'-type aerosols. Mammalian toxicities are generally low; however, there are exceptions.
Insect Growth Regulators	diflubenzuron fenoxycarb hexaflumuron hydroprene methoprene pyriproxifen triflumuron	These compounds disrupt physiological processes such as development and cuticle formation. Some are juvenile hormone analogues that are largely insect specific and disrupt normal growth and development of immature stages. Others act as chitin synthesis inhibitors disrupting the normal formation of cuticle. Mammalian toxicities are generally low.
Miscellaneous	fipronil hydramethylnon imidacloprid	— a phenyl pyrazole compound — a pyrimidin-2-one hydrazone compound — a chloronicotinyl compound These compounds exert a range of insecticidal actions.

TYPES OF INSECTICIDES

The majority of insecticides currently used in urban pest control procedures belong to a number of chemical types or groups. The groups considered here are inorganics, botanicals, organochlorines, organophosphates, carbamates, synthetic pyrethroids, IGRs, miscellaneous insecticides (and fumigants). A summary of characteristics and examples of each of the main types of insecticides is given in Table 8.1.

Appendix V outlines some of the insecticide products that are used in urban pest control procedures (providing product trade names, manufacturer, active ingredient, type of formulation, main uses and poisons scheduling).

Appendix VI lists a range of insecticide active ingredients according to types of application and target pests.

Appendix VII outlines the main fumigants and their characteristics.

Inorganic insecticides

Inorganic insecticides are of mineral origin and contain no carbon in their make-up. Such materials were probably the first chemicals used against insects, so the group has a very long history of use. Being mostly crystalline solids, they have been used mostly as baits or dusts. The use of some inorganics as insecticides has declined over the last few decades, probably because of:

1 the high mammalian toxicity that many have;
2 their great stability, which can lead to accumulation of toxic compounds; and
3 the recent development of safer synthetic insecticides that can replace them.

Only a few inorganics are used at present. **Arsenic trioxide** is used as a dust in the control of termites. It acts as a stomach poison. **Boric acid**, a non-repellent inorganic of relatively low mammalian toxicity is used mainly as a dust for cockroach and silverfish control and in baits for the control of ants and cockroaches. Boric acid kills insects by disrupting the conversion of energy within their cells. **Silica aerogels**, very finely ground silica formulations, are sometimes used in cockroach and stored product pest control; they act as physical abrasives that cause death by dehydration owing to their highly sorptive nature.

Botanical insecticides

Botanical insecticides, sometimes referred to as natural or plant-derived insecticides, are extracted from specific parts of certain plants and have a long history of use. **Nicotine** extracts from tobacco were used as insecticides as early as the late 1600s. The most widely used botanical insecticide is **pyrethrins** which is obtained as an oil extract (pyrethrum) from the daisy-like flowers of certain varieties of *Chrysanthemum.* Kenya has been a significant supplier of pyrethrins for some time and Tasmania has, in more recent years, also become an important grower/supplier. Its main areas of use include the control of various household and industrial insect pests, insect pests of stored products and garden pests. Its very wide range of applications can be attributed to a number of characteristics:

1 broad spectrum of activity;
2 low mammalian toxicity;
3 rapid breakdown after application; and
4 fast knockdown, flushing and repellent properties.

Pyrethrins is a rather expensive insecticide. It is often formulated with piperonyl butoxide, which acts as a synergist to increase the potency of the formulation. It is largely a contact insecticide that acts as a nerve poison. While pyrethrins has a relatively low mammalian toxicity, it is relatively toxic to fish and reptiles.

Rotenone is a botanical insecticide extracted from the roots of certain South American plants. It is used mainly for the control of plant pests and animal ectoparasites. Rotenone is usually formulated as a dust (derris dust) and is often used in the control of certain insect pests of plants.

Organochlorine insecticides

Organochlorine insecticides (also referred to as chlorinated hydrocarbon or OCs) are synthetic insecticides that contain carbon ('organo'), chlorine and hydrogen atoms in their make-up. Within the group, various OCs differ widely in chemical structure, biological activity and mammalian toxicity. Soon after the discovery of the first OC, **DDT** (during the Second World War), the cyclodiene OCs (eg chlordane, aldrin) were developed. While most OCs are very persistent chemicals, the cyclodienes are particularly stable in soil. For this reason the OCs **aldrin**, **dieldrin**, **chlordane** and **heptachlor** have been widely used in the prevention and control of subterranean termites.

However, owing largely to their persistence and to concerns in relation to environmental and health implications, the OCs have been banned from use in urban pest control in Australia.

OCs are largely contact and oral poisons that exert their toxic action on the nervous system.

Organophosphorus insecticides

Organophosphorus insecticides (also referred to as organophosphates or OPs) are synthetic insecticides derived from phosphoric acid. Early work on OPs grew out of wartime research on 'nerve gases', so it is not too surprising that, while some OPs are of a relatively low toxicity to mammals, others are among the most toxic pesticides to higher animals.

OPs are chemically unstable compared with organochlorine compounds. Some have a short life of some hours, but others may remain insecticidal for weeks or even months. It is this lack of stability (persistence) that has led to organochlorine insecticides being replaced by OPs in many quarters. As well, OPs have shown some value in the control of organochlorine-resistant strains of insects.

While an enormous range of OPs have been developed for use in agricultural and horticultural pest control, a number have been used extensively in urban pest control practices. This use has mostly been for the control of 'household pests' (eg flies, mosquitoes, cockroaches, silverfish) and relies largely on the relative instability of these insecticides. OPs used in urban pest control include: **azamethiphos**, **chlorpyrifos**, **diazinon**, **dichlorvos**, **fenthion**, **pirimiphos-methyl** and **temephos**. With the decline in use of organochlorine insecticides in control and prevention of subterranean termites, the OP chlorpyrifos is now used in chemical barrier treatments against termites.

The majority of OPs are contact and oral poisons. A few of the more volatile OPs (eg dichlorvos) exert an inhalation toxicity as well. A few OPs, those with particular solubility and toxicity characteristics, are used as systemic insecticides to control insect pests of plants or animals. The OPs are classed as nerve poisons that exert an anti-cholinesterase action at nerve synapses. Their toxic action interferes with the enzyme cholinesterase, which normally removes nerve transmitter substances after the 'message' has been passed on. The build-up of transmitter substances leads to convulsions, paralysis and death.

Carbamate insecticides

Investigations of chemicals that exert an anti-cholinesterase action on the nervous system (as occurs with the organophosphorus insecticides) led in the 1950s to the development of carbamate insecticides. These compounds, derivatives of carbamic acid, vary in their spectrum of activity, mammalian toxicity and persistence.

The carbamates used in urban pest control include **bendiocarb**, **propoxur** and **methomyl**. They are relatively unstable compounds that break down in the environment within weeks or months, and tend to be used in the control of 'household pests' as surface sprays, dusts or baits.

The carbamates act largely as contact and oral poisons. They are nerve poisons that have an anti-cholinesterase action.

Synthetic pyrethroids

Following the insecticide developments that occurred during and soon after the Second World War, there was a need to widen the gap between an insecticide's toxicity to the target insect and its toxicity to higher animals, including humans. One area of research and development that has achieved much in this regard involves the synthetic pyrethroid insecticides. Very broadly, the development of synthetic pyrethroids arose out of close examination of the biologically active, natural pyrethrins molecules, followed by the development of ways to produce copies or approximations of these molecules synthetically. Since the early 1950s, a wide range of synthetic pyrethroids have been developed and marketed. Tailoring and refining of the pyrethroids has, over years, led to improvements such as quicker knockdown, greater toxicity to target insects, increased safety to humans and, in some cases, greater residual action. Many of these insecticides are among the safest insecticides available.

As well as in crop protection and stored-product pest applications, pyrethroids are very widely used in supermarket-type household aerosol sprays, where the safety factor is clearly very important. The insecticides **allethrin**, **alpha-cypermethrin**, **beta-cyfluthrin**, **bifenthrin**, **bioresmethrin**, **cyfluthrin**, **cypermethrin**, **d-phenothrin**, **lambda-cyhalothrin**, **deltamethrin**, **permethrin** and **tetramethrin** are pyrethroids that, owing to their broad spectrum of activity against a range of household pests (and in most cases safety to humans) are finding considerable application in urban pest control operations.

Synthetic pyrethroids appear to exert their toxic action at the nerve fibres (axons), causing intense electrical activity that results in blockage of nerve impulses.

This type of insecticide technology is likely to play a very important role in the future of many pest control applications.

Insect Growth Regulators

The term Insect Growth Regulator (or IGR) usually refers to a chemical substance which controls insect pests by interfering with their development and reproduction. This may be accomplished by:

Juvenile Hormone Analogues (JHAs), chemicals which are chemically similar to the insect's natural juvenile hormone and which disrupt normal glandular function, resulting in death or the inability to reproduce successfully (Note: A *juvenoid* is an IGR-type substance that is not chemically similar to insect juvenile hormone but that interferes with its function).

Chitin Synthesis Inhibitors (CSIs), chemicals that interfere with the formation of chitin which is an important part of insect cuticle, giving it its strength.

While the IGRs are slower-acting than many of the more traditional nerve-poison type insecticides, they nevertheless show considerable promise as important tools in the future of urban pest management.

Juvenile Hormone Analogues

Hydroprene For cockroach control. When immature cockroaches come into contact with this juvenile hormone analogue, abnormalities of development occur, resulting for example in adults with deformed wings or darker body colour and, most importantly, sterile adults, that is, adults that cannot reproduce. It may take 3–5 months after treatment before high levels of control are achieved and, as the hydroprene does not affect adult cockroaches, it is usually advised that it be used together with a 'traditional' insecticide which will kill the adults. Application of hydroprene each 4 months is sometimes advised (but refer to label directions).

Methoprene For control of a variety of insects which undergo a complete metamorphosis, such as mosquitoes, certain ants, flies, grain pests and fleas. In flea control, when immature stages contact the methoprene, it disrupts their moulting and either prevents pupal formation or inhibits adult emergence from the pupa, thereby causing a break in the progression of generations. In flea control it is best used early in the season (spring) before many adults are present. As adults are not affected by methoprene, it is usually applied in conjunction with a 'traditional' insecticide (adulticide) to reduce adult numbers initially. Application of methoprene indoors is sometimes recommended at 9 month intervals (but consult label directions).

Pyriproxifen also mimics the structure of natural juvenile hormone and has application in the control of fleas and cockroaches.

Fenoxycarb, while chemically a carbamate compound, exerts an IGR effect by disrupting normal degradation of juvenile hormone in immature insects.

Chitin Synthesis Inhibitors

These compounds disrupt normal cuticle formation in developing insects by blocking the synthesis of chitin. Chitin is the component of insect cuticle that gives it its structural strength. Immature insects exposed to CSIs often die within one or two moults after exposure because of a failure to produce a new cuticle to replace the one that is shed. As adults are not affected by CSIs, these compounds are often used with an adulticide (eg a synthetic pyrethroid).

Examples of CSIs include:

Triflumuron used in the control of insects including cockroaches and fleas.

Hexaflumuron used as a bait for the control of subterranean termites.

Diflubenzuron used in the control of a range of insect pests including cockroaches, fleas and ants.

Advantages of IGRs include:

- The pest population continues to decline with time.
- The chemicals mostly have low mammalian toxicities.
- They are quite persistent indoors and are mostly non-repellent to the insect pest, odourless and relatively insect specific.

Disadvantages of IGRs include

- They can take a long time to work (relative to 'conventional' insecticides) and are often relatively expensive.

Miscellaneous insecticides

Fipronil (a phenyl pyrazole compound) This compound is non-repellent and highly insecticidal at low concentrations. Its primary application is as a bait for cockroach control. The mode of action involves a very specific effect (the blocking of the gamma-aminobutyric acid receptor) on the central nervous system of insects.

Hydramethylnon (a pyrimidin-2-one hydrazone compound) This non-repellent insecticide is used mainly in bait formulations for the control of ants and cockroaches. Its mode of action involves the disruption of energy metabolism within the cells of the insect, resulting in a depletion of the energy that normally facilitates movement and normal life processes. It is often referred to as a 'slow-acting' or 'delayed-action' insecticide because it may take up to several days to cause death. This can be advantageous in ant control allowing greater distribution of the active compound throughout the colony.

Imidacloprid (a chloronicotinyl) Originally developed as a systemic insecticide for the control of sap-sucking plant pests such as aphids, it is now used as a soil treatment for the control of subterranean termites. Imidacloprid is non-repellent, so termites are more likely to come into contact with the treated soil. It is also used as the active ingredient in a gel bait for cockroach control. Imidacloprid acts on the central nervous system, causing irreversible blockage of postsynaptic nicotinergic acetylcholine receptors.

Fumigants

Fumigants are pesticides that are volatile and exert their toxic action as poisonous gases in an enclosed space. A number of widely used insecticides exert a 'fumigant action' when, in an enclosed space, the vapours are breathed in by insects; for example dichlorvos strips or mothballs (naphthalene), used in a wardrobe. This discussion, however, is concerned with a particular group of pesticides that are often referred to as fumigants and which include a number of very toxic, very hazardous compounds (eg hydrogen cyanide and methyl bromide).

Fumigants are usually stored as liquids under pressure in industrial cylinders (note: phosphine is also available in pellet, tablet and a range of other forms). When they are dispensed from the container, the drop in pressure causes the stored liquid to gasify. (Sometimes, particularly in cold conditions, a vaporiser is required.) The sorts of materials that may be fumigated are usually those where some penetration of the insecticidal action is required, as in treating timber or grain to kill the pests within. The enclosed space that must contain the poisonous fumes for a given time may be created by: placing the articles in a pressure chamber (in which a vacuum may be created before treatment with the fumigant); covering the articles with appropriate plastic sheeting; or carrying out fumigation in relatively airtight conditions (eg a cargo container or a ship's hold).

Insects controlled by fumigation practices are killed by breathing in toxic vapours. Dosage rates of fumigants are thus a function of concentration (ie the amount of fumigant in the atmosphere) and time (ie the period of exposure to the toxic atmosphere). As temperature affects the rate of respiration of insects and the rate of diffusion of the fumigant, it also must be considered in fumigant applications. Fumigations at temperatures below 15°C are often avoided.

So hazardous are some of the chemicals involved in fumigations that a specific licence is often required of those handling the fumigants. Licensed fumigators have undergone special training that will equip them with the knowledge required for handling fumigations. Such operations usually require: pre-warnings to appropriate bodies; continuous guarding of the area; the use of special detecting equipment and proper safety equipment; logging of information; knowledge of the dosage rate requirements of particular fumigants (ie concentration–time–temperature relationships); and correct ventilation procedures for conclusion of the operation.

Regulations on the use of fumigants lack consistency from state to state, and sometimes within states. Certain states may require the user of a particular fumigant to be licensed, while other states may not have such a requirement. Within a particular state some 'types of users' may require a licence, while others may not. (For example, commercial urban operators may require a licence, while agricultural or horticultural operators may not.) Given such inconsistency, it is important that the prospective user of a fumigant should:

1. ensure that he or she is qualified to use the particular fumigant concerned (this can usually be effected by contacting the State Department of Health);
2. ensure that the fumigant is registered in that state for the intended purpose; and
3. ensure that label directions pertaining to that state are strictly adhered to.

Fumigants used widely in the control of insect pests act as inhalation poisons, and their modes of action are complex and diverse. Generally, they have a very broad spectrum of activity, being toxic to many life forms, including the higher animals such as humans.

Some characteristics of the more widely used fumigants are outlined in Appendix VII.

FURTHER READING

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CHAPTER 9

INSECTICIDES — FORMULATIONS & APPLICATION

Insecticides are mostly manufactured as relatively pure materials. Usually, the 'pure' insecticide is processed into a form that will facilitate its safe and efficient application. Different types of insecticide formulations have different characteristics, which are important in their end use. As well, owing to the variety of pest habitats and different types of building construction, the operator must select, within safety constraints, the most appropriate method of insecticide application. This requires an understanding of the types of insecticide application and the kinds of application equipment available. Figure 9.1 summarises the general relationship between these factors.

INSECTICIDE FORMULATIONS

Insecticides are usually manufactured as reasonably 'pure' (90–99%) chemicals, and this reasonably pure form is referred to as 'technical material'. It may be a waxy solid, a crystalline powder or a viscous, oily liquid. Owing to high toxicity, cost, problems associated with dilution, and other factors, technical material is seldom useful to the end user in its pure form. Consequently, most insecticide manufacturers must prepare the technical material for use, and this process is called formulation. The end product may be a 'ready-to-use' formulation, or it may require dilution (eg with water) at the site of application. Formulation of insecticides, then, is the processing of technical material so as to improve aspects of its effectiveness, storage, ease of preparation, ease of application and safety in handling.

The type of formulation chosen for a given pest problem can play an important role in the effectiveness of the insecticide. Some formulations, for example, are absorbed by porous surfaces such as brickwork while others tend not to be and instead remain on the surface. Such differences can be important in the effectiveness of the application. In all attempts at insect control, the operator must use insecticides in such a way as to make likely their contact with the insect. A sound understanding of the important aspects of insecticide formulations is essential for the effective, efficient and safe use of insecticides.

Common components of formulations

Before examining particular types of insecticidal formulations, some of the terminology used to describe various components should be considered:

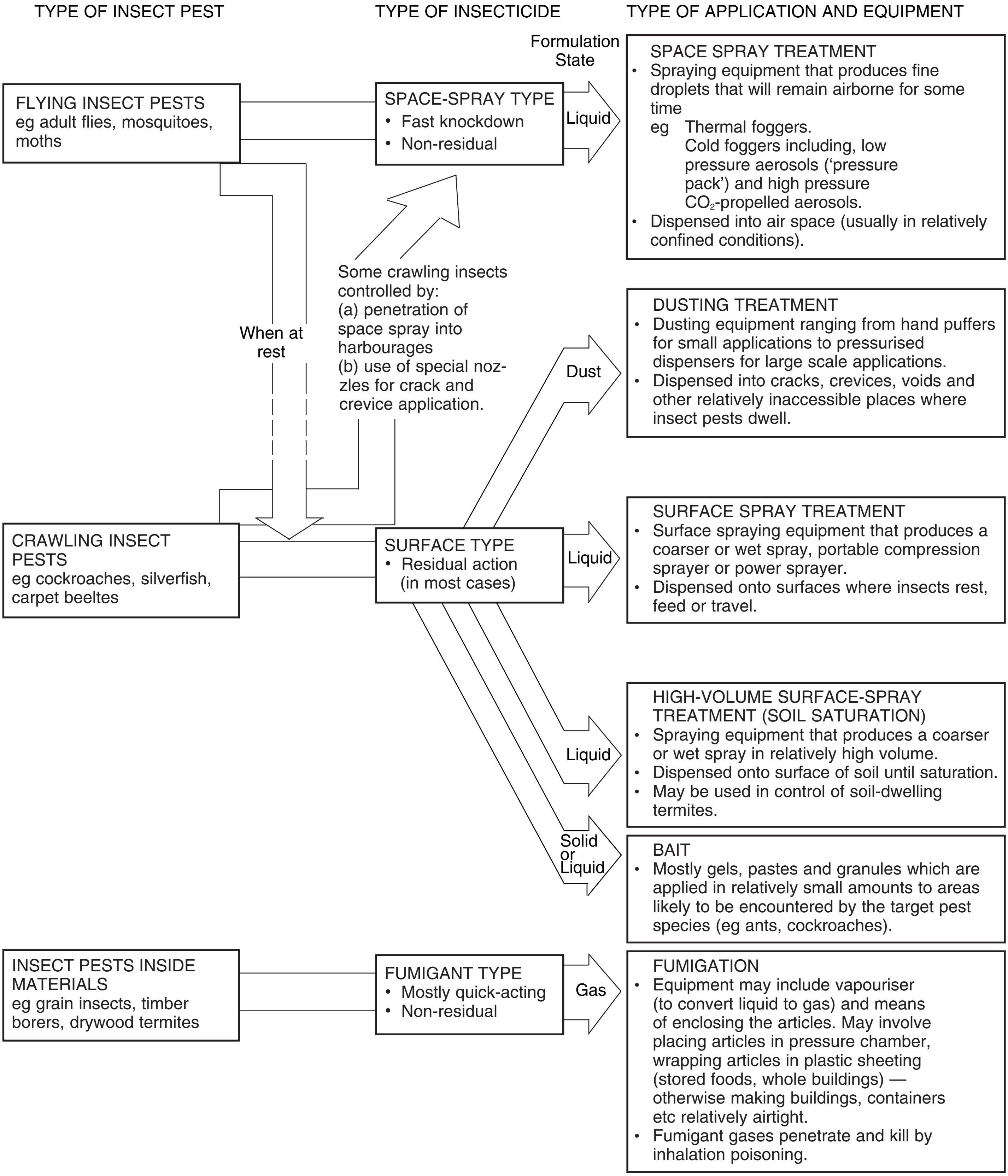
Active constituent The active constituent (sometimes referred to as active ingredient) is the biologically active component. Usually, insecticide labels indicate it by giving the common chemical name and its proportion of the net contents (eg active constituent: 800 g/kg propoxur).

Diluent The diluent in a formulation is any component that is added to reduce the concentration of the insecticide. Commonly used diluents include oil or water in many liquid formulations, and talc or clay in solid formulations (eg dusts).

Solvent A solvent is a liquid in which a chemical may be dissolved. Some chemicals dissolve readily in water; others require special solvents, such as the aromatic hydrocarbons (eg toluene, xylene). In formulations, most solvents act as diluents as well. Solvents in liquid formulations usually evaporate after application, leaving an insecticide residue.

Attractant A component used in baits that attracts the target pest species.

Figure 9.1
Types of insecticides, formulations, application methods and equipment for the control of insect pests



Surfactant Also called surface-active agents, surfactants are chemicals introduced into a liquid to affect its wetting, spreading, dispersibility or emulsifiability properties (ie properties that depend on surface tension). Broadly, they are detergent-like substances. In insecticide formulations, two types of surfactants may be considered:

1. *Emulsifiers* — These facilitate the mixing of oil-based liquids in water. Normally, oil and water will not mix; instead they form two separate phases. With the addition of emulsifiers, the oil (plus insecticide) forms tiny globules that are evenly dispersed throughout the water (often giving the mix a milky appearance, which is caused by the refraction of light).
2. *Wetting agents* — These facilitate the mixing of solid insecticide particles in water. Normally, a dry powder will not mix evenly in water. When a wetting agent is added, its effect is to allow the powder to disperse evenly throughout the water. As well, wetting agents are sometimes added to a water-based spray mix to enhance its wetting ability. This may be appropriate when spraying for webbing spider or foliage pests, for example. Proprietary wetting agents should be used.

Synergist A synergist is a substance that, although it may not have insecticidal properties of its own, increases the potency of the insecticide with which it is formulated. Perhaps the most common synergist is piperonyl butoxide, which is often formulated with natural pyrethrins or synthetic pyrethroids. Synergists probably act by blocking detoxification mechanisms that normally operate in the target insect.

Types of formulations

The main types of insecticide formulations used in urban pest control operations are: emulsifiable concentrates, wettable powders, suspension concentrates, dusts, baits and aerosols/space sprays. Some generalised examples of the components of formulations are given below, but these are broad guides only and do not reflect the exact composition of products presently marketed.

Oil concentrates

Perhaps the simplest of liquid formulations, oil concentrates are not as widely used now as they were in past decades. Oil concentrates comprise the insecticide itself, dissolved in a strong solvent.

Such concentrates may be further diluted by the end user with an oil-based solvent/diluent (eg kerosene, diesel oil). Water, of course, would not mix.

The resultant mixture has been used as a surface spray; for example, in attempts to control borers in timber (though this type of application has declined significantly). Currently such formulations are primarily used for space spraying with fogging equipment.

The more general use of oil concentrates has declined because of a number of limitations. Oil solvent-based mixtures:

- are expensive, owing to the high cost of the solvent;
- are bulky and costly to transport;
- may react with some surfaces (eg lino, wallpaper, rubber);
- present a flammability risk (particularly when used in enclosed spaces);
- may react with gaskets and hose lining in pumping equipment; and
- are readily absorbed into porous surfaces, making the insecticide less active on the surface (where surface action is important, eg in cockroach control, this can be a disadvantage).

Perhaps the one advantage of oil-based mixtures can be appreciated when penetration of a porous surface is desired. In materials such as wood, oil-based mixtures are more penetrative than water-based sprays. For the treatment of timber-boring insects in timber, surface spraying with an oil-based mixture is likely to provide better penetration.

Emulsifiable concentrates (ECs)

The EC formulation is very commonly used in urban pest control practices. Most insecticides dissolve in strong oil-based solvents (eg toluene), but this mixture is not miscible with water. To facilitate mixing of the oil phase (insecticide + solvent) with water, an emulsifier is added. So the constituents of an EC are:

insecticide + solvent + emulsifier = EC

When the product is diluted with water, this results in an ‘oil in water’ emulsion, in which globules of insecticide and solvent are evenly dispersed in the water

ECs are used chiefly for surface-spraying (either high volume, as in soil-saturation for termite control, or low volume, as in surface treatment for cockroach control) or for space spraying, with the use of misting equipment. The advantages of ECs include:

- The concentrate can be diluted with water, which is cheap, usually readily available on site (no need to transport) and non-flammable.
- The spray is often less visible on surfaces than are other types of formulations.

Disadvantages of ECs include:

- Being an all-liquid system, the insecticide emulsion sprayed onto porous surfaces is to some extent absorbed, and this may be undesirable in some cases (eg in cockroach control).
- Water staining of certain surfaces may occur, but this is rarely serious.
- May be phytotoxic.

While most proprietary ECs form quite stable uniform emulsions with water, some agitation will ensure a uniform mixture. Where possible, insecticide emulsions should not be kept in the tank overnight, as some less stable insecticides (eg organophosphorus) may be broken down. Many of the organophosphorus insecticides used in urban pest control are formulated as ECs.

Wettable powders (WPs)

Sometimes called water-dispersable powders, WPs are particularly suited to insecticides whose technical form is insoluble in water and other solvents. They contain finely divided insecticide mixed with a suitable solid diluent (eg talc, diatomaceous earth) and wetting agents (detergent-like substances that enable the powder to mix with water to form a suspension). So the constituents of a WP are:

insecticide + diluent + wetting agent = WP

The diluent (or carrier) may be impregnated or coated with the insecticide. The mixture, often packaged as a dry powder in pre-measured sachets, is mixed with water when applied.

WPs are chiefly used as surface-sprays (eg in cockroach control). Their advantages include:

- They can be diluted with water, which is cheap, usually readily available on site (no need to transport) and non-flammable.
- They are effective on porous surfaces (eg timber, brick-work), because, although the water may be absorbed or may evaporate, the insecticide particles remain on the treated surface and hence are available for pick-up by crawling insects (eg cockroaches).
- They are unlikely to be phytotoxic.

One disadvantage is that they may leave a visible deposit on surfaces, but this is rarely serious and usually can be wiped off.

Comprising, as they do, solid particles (insecticide + diluent) in suspension, WP mixtures are relatively unstable: the solid particles, after some time, tend to drop to the bottom of the tank. To ensure a uniform spray mixture, frequent agitation is necessary. As well, owing to the presence of solid particles in the mixture, more wear on some spraying equipment is likely, and blockages may occur. To avoid blockages, spraying equipment should be rinsed through with clean water after use. Spray mixtures made up with a WP should not be stored in the spray tank. Many lose activity after a day of being mixed with water. A number of organophosphorus and carbamate insecticides are formulated as WPs.

Suspension concentrates (SCs)

The constituents of an SC are:

insecticide + diluent + wetting agent = SC

This make-up appears to be similar to that of WPs, however, WPs are a dry formulation while SCs are supplied as a liquid concentrate. SCs tend to have a finer diluent (ie inert carrier), contain deionised water, may contain a bactericide and may also contain anti-freeze (to reduce mixing problems).

Because SCs rely on a suspension of solid particles in water, it is important to agitate the liquid concentrate before use and agitate the spray mixture frequently during use to ensure the material does not drop out.

Micro-encapsulated concentrate (MEs)

Often referred to as a type of slow-release formulation, these products involve the incorporation of an insecticide in a permeable covering (i.e in micro-capsules resembling tiny spheres). The insecticide is released from the capsules over an extended period of time.

Advantages of MEs include:

- long residual activity
- good pick-up by insects and may be ingested during grooming
- usually no smell
- usually not phytotoxic.

Disadvantages of MEs include:

- require regular agitation during use
- may be more expensive
- some may leave a visible residue on some surfaces.

Dusts

Dusts are commonly used formulations in urban pest control procedures. Some insecticidal dusts consist only of the finely divided insecticide itself (eg some boric acid products and other inorganic insecticides). More commonly, insecticidal dusts contain only 0.5–5.0% of active constituent. They are a dry mixture of finely ground insecticide with a diluent (eg fine talc or clay particles). The mixture may be prepared by coating the diluent with insecticide or by milling the two components in a ball mill.

Insecticidal dusts are chiefly used in the control of household pests and are usually applied to relatively inaccessible areas (eg cracks, crevices, wall voids and roof voids). Advantages of dusts include:

- Fine dusts usually achieve good distribution in inaccessible places (eg complex equipment, wall voids, cracks and crevices).
- They are useful where wet sprays must be excluded for reasons of safety or aesthetics (eg ceiling voids).
- They are not absorbed by porous surfaces and remain on surfaces to be picked up by crawling insects (eg cockroaches).
- They may be picked up on insect bodies and ingested during grooming.

Disadvantages of dust formulations include:

- They may leave hazardous, conspicuous, unsightly deposits if not applied carefully.
- Deposits are not fixed and can easily be blown away or removed physically.
- They should not be used above ground level if there is a chance of them falling to contaminate food, utensils and the like.

Insecticidal dusts should only be applied to locations where they will remain relatively dry. Some carbamate and synthetic pyrethroid insecticides are available as insecticidal dusts.

Aerosols

Aerosols are self-contained systems that, with the operation of the nozzle or gun, emit a space-spray present as droplets in the air, which contain the active insecticide. Broadly, there are two types of aerosol systems:

- the 'pressure pack' aerosol; and
- the high pressure liquid carbon dioxide-propelled aerosol.

Pressure pack aerosols Sometimes referred to as 'pressurised aerosol containers', these formulations essentially contain the insecticide (often relatively safe materials, which may include a synergist), an oil solvent and the propellant, which is usually a hydrocarbon type. The aerosol container usually has a dip tube, which connects to the valve at the top and remains open at the bottom. Normally, pressure in the container forces the propellant to remain liquid, mixing with the other components. When pressure is released by actuating the valve, the liquid mixture escapes up the dip tube and, on exiting from the nozzle, is broken up into fine droplets as the propellant 'boils off'.

Initially, aerosol formulations were used only for the control of flying insects (eg flies and mosquitoes). Following developments in nozzle configurations, droplet sizes and active ingredients, aerosols are now available to serve a range of applications:

- surface treatment with residual insecticides using a larger droplet size;
- crack and crevice treatments using a small plastic extension tube fitted to the standard nozzle on the can;
- crack and crevice treatments using a remote push button nozzle that is connected to the can via a flexible hose/extension tube;
- 'total release' (or one-shot) whereby the can is placed in a room or void and, when activated, empties its contents; and
- automatic dispensers fitted to walls around a building to release small amounts of insecticide at predetermined intervals.

For pest control operators, pressure pack aerosols can offer a very convenient method of insecticide application that avoids the need for mixing on site. The very effective penetration of cracks and crevices afforded by this technology is especially useful for the application of flushing agents as well as for normal control procedures.

High-pressure, liquid carbon dioxide propelled, aerosol system A more recent development in aerosol technology is the use of liquid carbon dioxide as a solvent and propellant for insecticides including pyrethrins, dichlorvos and fenoxycarb (Envirosols®— BOC Gases) In this system, the contents (insecticide and liquid carbon dioxide) are stored in an aluminium industrial gas cylinder at about 5000 kPa. At this pressure the carbon dioxide remains liquid and well mixed with the insecticide. Inside the cylinder, an eductor (dip) tube connects to the valve and extends to the bottom of the cylinder. When in use, a high pressure gun and hose are attached to the valve. Operation of the gun allows the liquid mixture to escape up the eductor tube, along the hose and out via the gun nozzle. At this point the carbon dioxide rapidly boils off, breaking the insecticide up into very small droplets.

The system is used mainly for space-spraying and, with the use of an extended nozzle, for treatment of cracks and crevices in the control of 'household pests' in a variety of situations. Owing to the very high pressure of the system, and the very small droplet size produced, very effective distribution of the insecticide is achieved.

Multi-nozzled automatic systems may be installed in warehouses or other buildings, facilitating regular (eg each night) space-spray treatment of small or large areas.

Other formulations

Insecticidal lacquer The insecticide (1–4%) is incorporated in a resin formulation so that, when it is painted onto surfaces, crystals of insecticide continue to 'bloom' for months. The material is painted or sprayed onto surfaces and may be active for several months.

Smoke generators The insecticide is formulated with a pyrotechnic material (eg sodium chlorate) and a burnable 'fuel' (eg sugar). When the mixture is ignited, the insecticide is vaporised. Smoke generators are suitable only for enclosed spaces.

Baits The insecticide is formulated with an attractant in acceptable proportions. Forms available include gels, pastes and granules. Some are supplied within a bait station ready for placement while others are supplied in a cartridge for use with an applicator gun.

The technology of baits has improved markedly and there is now a range of bait products for use in the control of urban pests such as cockroaches, ants and termites. It is likely that bait formulations will play an increasingly important role in urban pest management.

Granules Insecticide is sprayed onto clay granules, often about the size of sugar granules, which are then distributed appropriately. Granules are used mostly in crop pest control and are useful in the control of a variety of soil-dwelling insect pests.

ULV (ultra low volume) formulations Some insecticides that are oily liquids in their pure form may be supplied neat', or in a small amount of oil solvent, for ULV spraying. ULV-dispersing equipment breaks up the insecticide into such tiny particles that only small amounts of concentrated insecticide are needed.

Impregnated resin strips The very volatile organophosphorus insecticide, dichlorvos, may be impregnated into resin strips that, when kept in an enclosed environment, emit toxic vapours to kill insects by inhalation poisoning.

Choice of formulations

The final decision about which formulation to choose for a given pest control operation will probably be influenced by a number of factors:

Pest to be controlled Many different products and formulations are registered for various uses, and the operator must ensure that the product selected is appropriate for the purpose.

Calculations for spray mixes

Insecticides applied as liquid sprays are usually diluted in the spray tank before they are applied. Insecticide labels usually give clear directions for mixing. However, in any case, pest control operators should be able to calculate the amount of concentrate needed to prepare a given volume of spray of the recommended strength.

To make this calculation the operator must know the strength of the concentrate. The 'active constituents' statement on the label gives the proportions of active constituents as: g/L (grams per litre, ie weight by volume, w/v), or g/kg (grams per kilogram, ie weight by weight, w/w). The amount of concentrate needed to prepare a given volume of spray at recommended strength may be calculated by using the following formula:

$$X = \frac{s}{c} \times V$$

Where: X = quantity of concentrate
S = spray mix concentration desired (in g/L)
C = concentraton of 'active' in the concentrate (in g/L)
V = total volume of spray mix required (in L)

Examples:

1. An operator wishes to make up 360 litres of a 5g/L (0.5%) spray mix of Insecticide A.
The concentrate in the drum contains 600 g/L Insecticide A.

$$X = \frac{s}{c} \times V = \frac{5}{600} \times 360 = 3 \text{ Litres}$$

That is, 3 litres of Insecticide A concentrate mixed with 357 litres of water will yield the required spray mix.

2. An operator wishes to make 10 litres of a 10 g/L (1.0%) spray mix using a 400 g/L Insecticide B concentrate (ie contains 40% Insecticide B).

$$X = \frac{s}{c} \times V = \frac{10}{400} \times 10 = 0.25 \text{ Litres or 250 ml}$$

The operator will mix 0.25 litres of concentrate with 9.75 litres of water to achieve the desired spray mix.

Convenience of use Some operators prefer to use the pre-measured sachets that some wettable powders are packed in or even water soluble bags instead of measuring out amounts of liquid emulsifiable concentrate from a drum or bottle.

Application equipment available An operator who does not have a dust dispenser may mist a roof cavity space, while an operator who has a powerful dust applicator may avoid the inherent risk of misting in the roof space and instead apply a uniform, light film of dust throughout.

Nature of surfaces to be treated Where surface sprays are to be applied for the residual control of crawling insects that will come into contact with the insecticide at some time after application, the type of surface may be an important consideration. The all-liquid system of an emulsion will allow it (the insecticide included) to be absorbed by porous surfaces (eg unpainted timber, brickwork). Wettable powders, suspension concentrates and micro-encapsulated insecticides, on the other hand, deposit the solid on the surface, so that it is available for pick-up by insects.

Pest habits and habitats

- Where the pests are contained and protected (as is the case with timber borers in furniture) the most appropriate treatment may be to have the article fumigated. The fumigant gas penetrates the timber to ensure the pests are killed.
- Where insect pests that spend much time hidden in cracks and crevices (eg cockroaches) are to be controlled, there may be a choice of formulation options:
  - a non-residual flushing chemical (eg pyrethrins);
  - a residual insecticide (eg WP, SC, ME or EC);
  - a residual dust insecticide;
  - a bait in the form of a gel or paste; or
  - a combination of these methods.

Price The cost of formulations of insecticides varies, depending on relative costs of manufacture. Operators considering cost implications when choosing between liquid concentrate products should ensure that they base the calculations on final 'out of the nozzle' costs rather than, for example, the cost per sachet or litre of concentrate. As well, labour costs for application may warrant consideration.

Hazard minimisation

- Where insect harbourages are in close association with electrical switches, wiring, appliances and the like, wet sprays must be excluded for reasons of safety.
- Where animals are bred or kept (eg pet shops, some homes), insecticide sprays and dusts may need to be excluded. Carefully chosen and placed baits and/or traps may be acceptable.
- Where areas to be treated are constantly occupied by humans, space-spray systems are excluded. Viable alternatives may include a low volatility, low mammalian toxicity WP, SC or ME (that is considered safe in such circumstances) or baits.
- Increasingly, the concerns and demands of clients are impacting on the pest control operator's choice of types of insecticides and formulations.
- The risk of non-target contamination (eg due to spray

droplet drift or run-off) must be minimised. The choice of insecticide, formulation and application equipment must always be biased in consideration of the safety of the pest control operator, the people who live or work in and around the areas to be treated, pets and other non-target animals, and the environment at large.

Regulatory obligations

Product labels provide information that pertains both to the efficacy of the product and to its safe use.

A multitude of factors can influence the kinds of insecticide formulations chosen. Users must read product labels to ensure that the chosen product is suitable for the use for which it is intended. Then, whichever product is chosen, users must:

1 read the label before opening; and
2 use the product only according to the directions on the label.

INSECTICIDE APPLICATION

Insecticides in their pure form are, in most cases, very potent materials. Manufacturers convert the pure insecticide into a variety of formulations to enhance the ease, efficiency and safety of use; but even so, the formulations themselves can be potent materials, comprising up to 80% active ingredient. The objective of any insect pest control operation that relies on chemical insecticides is to get the insecticide into contact with the insect pests. However, this should be done in a manner that does not create a risk to people, pets, and so on. Application techniques may require that amounts as small as 5 or 10 g (sometimes less than 1 g) of active insecticide be distributed appropriately in a building the size of an average domestic dwelling. The careful selection and proper use of application equipment facilitates effective distribution and control.

Clearly, the application of insecticides is a very important factor in the efficient and safe chemical control of insects. A sound knowledge and understanding of the habits and biology of the insect pests concerned are essential.

Types of insecticide application

There are a variety of means of dispensing insecticides so that the target pests make contact with it and the desired level of control is achieved. In very broad terms, most urban pest control procedures fall into one of four types of control methods, and these are related to the type of insect pests and their activities:

- baiting treatments;
- space-spray treatments for control of flying insects;
- surface treatments for control of crawling insects; and
- fumigation treatments for control of insect pests inside materials.

Baiting treatments

Baiting is becoming an increasingly widely used technique in urban pest control procedures, especially in relation to the control of cockroaches and ants (and termites). The more common forms are paste and gel baits supplied in ready-to-use, syringe-type cartridges, or cartridges designed for easy loading into applicators (sometimes referred to as 'bait guns' — see Figures 9.18 and 9.19).

Such systems may offer a range of accessories, including different dispensing tips (such as crack and crevice/extension tips) and in some cases an attachable torch and holster for more efficient work.

There is no need for on-site mixing of chemicals, and bait products are becoming increasingly palatable (to the target pests) and effective.

Space-spray treatments for control of flying insects

Flying insect pests (eg flies, mosquitoes, certain moths, beetles) may be effectively controlled by various types of space-spray treatment. Such treatments are taken here to imply those methods of insecticide application whereby a liquid insecticide is broken up into small droplets that will remain airborne for a time. Insecticides most commonly applied as space-sprays are of the quick-knockdown, non-residual type. The means of breaking up the liquid insecticide into small droplets may involve energy in the form of: thermal energy (heat), from thermal foggers (powered by electricity); mechanical energy (ie physical breaking up of the liquid), from cold foggers (powered by electricity); or compressed gas energy, from low-pressure (pressure-pack type) and high-pressure aerosols.

Space-sprays are usually applied to a relatively large space (eg the space inside a house or warehouse) and rely mostly on contact of the droplet with the insect pests. Volatile space-sprays (eg dichlorvos) may readily vaporise, to kill by inhalation poisoning. To maximise the use of the insecticide, premises treated with space-sprays are usually closed up, to avoid loss by drift out of windows or other openings. Such treatments require that the premises be:

- vacated during the treatment; and
- ventilated before being reoccupied.

Some people may be particularly sensitive to space-sprays (eg asthmatics and hay fever sufferers), so other methods of control should be used.

The over-use and/or misuse of dichlorvos as a space spray can cause very serious problems relating to:

- harmful effects on the health of occupants. (When misused, dichlorvos may be absorbed by certain materials eg plastics and then released slowly, over a period of time, as vapours toxic to occupants of the building.)
- damage to material goods such as plastics (owing to the strong solvent properties of dichlorvos).

Dichlorvos should be used as a space-spray only in appropriate circumstances (eg warehouses) and then only by competent operators who are fully aware of the potential hazards.

Formulations that incorporate relatively high levels of oil-based solvents (eg kerosene, as used in some fogging equipment) may:

- require certain precautions related to the highly flammable atmosphere created (eg turning off pilot lights); and/or
- contaminate and stain surfaces in the treated area.

Space-sprays may also serve in the control of 'crawling insect pests' in two ways:

- some insecticide may penetrate the harbourages of such insects.
- some types of space-spray/aerosol equipment have specially designed, extended nozzles that may be used to treat cracks, crevices, voids and other hidden harbourage areas.

Space-sprays, then, are a means of applying a small amount of a liquid non-residual insecticide to a relatively large space as droplets that, suspended in air, will contact mainly flying insect pests. The young stages of flying insects (which do not fly), and flying insects at rest, may be controlled using methods for 'crawling insect pests'.

Surface treatments for control of crawling insects

Crawling insect pests (eg cockroaches, silverfish, ants, bedbugs) may be effectively controlled by various types of surface treatments, that is, methods of insecticide application whereby a liquid or solid (dust) insecticide is applied to a surface. Insecticides most commonly applied in this way are of the residual type and may remain active for days, weeks, months or years, depending on the insecticide and pest situation. Insecticides used in surface treatment rely on the insects coming into contact with the insecticide, and the route of entry of the insecticide may be either dermal (through the cuticle) or oral (ingested during grooming).

Broadly, there are three methods of application:

Dusting treatment Dust is dispensed from equipment that may range from a small hand puffer that will serve to treat a small void behind a cupboard, to pressurised equipment that will effectively treat an entire roof void. Dusts are applied to treat surfaces in relatively inaccessible places where insects like cockroaches may dwell, such as cracks, crevices, wall voids and roof cavities. Fine insecticidal dusts can have excellent distributing qualities.

Surface-spray treatment A liquid insecticide is dispensed as a relatively coarse, wet spray onto a surface (usually to just short of run-off). When diluents (eg water, solvents) have evaporated, insecticidal deposits remain. Surfaces treated in this way are usually those where the insect is likely to rest, feed or travel; so in the case of cockroach control, treatment of cracks and crevices may be appropriate. Surface-spray treatments may be executed with equipment ranging from hand pumped, portable, compression sprayers to power sprayers fed by a large tank. A range of nozzle configurations allows a choice of spray patterns. The choice of insecticide formulation may be influenced by staining properties (this may be a problem in the treatment of carpets for fleas, for example).

Higher-volume, surface-spray treatment A liquid insecticide is dispensed as a somewhat coarse, wet spray, in relatively high volume, to a soil surface in order to saturate the soil. Such a treatment may be appropriate for the control of soil-dwelling insects such as subterranean termites for which saturation of the soil with a relatively stable insecticide can create a barrier or 'toxic zone' that may be effective for months or years.

Fumigation treatments for control of insect pests inside materials

Insects that feed inside materials (eg certain timber borers, grain insects, drywood termites) often cannot be effectively controlled with surface treatments. Instead, in order to achieve contact of the insecticide with the insect, fumigant gases can be used to penetrate materials and, by respiratory contact, kill the insects within. This operation requires a reasonably high concentration of toxic vapour, which may be achieved by:

1. the use of a pressure chamber (eg for timber borers in furniture); or
2. making buildings, containers and the like relatively airtight (eg when whole buildings are wrapped in plastic sheeting to kill drywood termites within).

Many of the materials used as fumigant insecticides are highly toxic and dangerous substances. Usually, pest controllers practising fumigation are specially trained and licensed.

Application equipment

Application equipment plays a critically important role in pest control operations. The range of insecticide application equipment presently available is vast. The factors that are likely to influence equipment selection include:

- safety implications (for the operator, clients/occupants, pets and the environment);
- type of environment treated (eg domestic versus industrial);
- ease of use and speed of application (including labour cost implications);
- durability of the equipment;
- purchase and operating costs; and
- after-sales service offered.

Suppliers are usually familiar with their range of equipment in relation to its capabilities, its appropriateness for different kinds of control operations, its limitations and its maintenance requirements. Discussion with the equipment supplier about the kind of pest control involved should help in evaluating and selecting appropriate equipment for insecticide applications.

The following is a very brief outline of some of the basic equipment that may be useful for most control jobs encountered in urban pest control. Where particular products are cited, no specific endorsement is implied.

Equipment for surface treatments

Sprayers Most pest-control operators have two primary means for dispersing insecticides onto surfaces:

- the power sprayer, usually fixed to the vehicle; and
- the hand-pumped, portable, compressed-air sprayer.

Power sprayer The power sprayer is usually truck mounted and may serve for larger volume spraying, as may be required when treating soil for subterranean termites (prevention or control), lawn pests or various pests in large industrial plants. The basic components of a power sprayer unit are as follows:

Power source and pump — Motors may be electric or petrol driven. Various types of displacement pumps are used and selection will be influenced by the output required. Operators who exclusively do termite-spraying need to move relatively large volumes of liquid and may be justified in selecting a more powerful pumping unit than is required for more general work. The pumping unit should have a bypass facility that enables liquid to be recirculated from the pump back into the tank and a pressure gauge. As well, there should be a filter/strainer between the tank and pump, at the tank opening and at the spray gun.

Tank — The tanks that are available vary in capacity from 120 litres up to more than 1000 litres. Again, operators specialising in large-volume termite work may be justified in using a large tank, while operators performing more general work prefer to use 120 litre or 240 litre tanks. Tanks should be constructed of material that will not corrode. Tanks in common use are generally of PVC or fibreglass construction and they should have a gauge to show the level of the contents.

Hose and reel —The hose used should be chemical-resistant. Operators performing general work commonly have two reels, each with about 100 m of 12 mm chemical-resistant, braided hose on a conveniently located and fixed hose reel.

Spray gun — The spray gun is usually of alloy construction and fitted with a standard nozzle, which adjusts from hollow-cone to pin-stream spray pattern. A temporary trigger-locking device is useful for long spraying sessions.

Nozzle accessories — A variety of nozzles are available to satisfy different requirements. Nozzles may offer various spray patterns or may facilitate different kinds of injection, as is often required in termite control (eg concrete slab injection, vent or cavity injection, soil injection). Figures 9.2 and 9.3 show soil, cavity/ventilator and sill type injectors (above), and a range of slab injectors (below). The slab injector pictured in Figure 9.4 (the B+G 486 adjustable sub-slab injector — with foaming unit) has a tip shut-off mechanism, an indexing wheel (used to lock shaft and tip in desired direction for dispersion), a locking foot seal (to seal slab surface) and a range of tips to match soil absorption rates or other application needs. A flowmeter fitted near the nozzle (and regularly calibrated) can very useful for monitoring the amount of insecticide that has been applied (for example, in each hole in a sub-slab termite barrier treatment).

Foaming unit for slab injections — Sub-slab injection of termiticides has always presented the problem of uncertainty about whether or not lateral spread of the chemical has been sufficient to create a continuous barrier. Sandy soils below slabs may result in insecticide emulsions moving downwards only and clay soils may severely limit penetration. The development of equipment that allows a foaming agent to carry the insecticide (see Figure 9.4) means that lateral movement of the formulation (between the soil and the

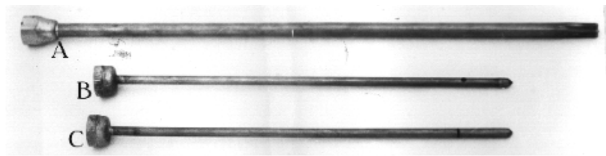


Figure 9.2 Injection nozzles: soil injector (top); cavity/ ventilator injector (middle); sill injector (bottom)

Figure 9.3 Various types of slab injectors

Figure 9.4 B+G Trouble-Shooter Portable Foaming Unit

underneath of the slab) is more likely, and, by using an appropriate surfactant, penetration of the termiticide into the soil is more likely. This approach to slab injection can be particularly useful in cases where conventional methods have failed.

The components of a power sprayer unit should be selected on the basis of the type of work envisaged. When in use, the amount of spray mixture made up should correspond to the amount needed for a given job, so that the hazards of driving the vehicle with chemicals in the tank can be avoided. The entire system should be flushed with water at the completion of the job, and a more thorough cleaning (using an ammonia-based detergent) should be carried out at regular intervals.

Compressed air sprayer The hand-pumped, portable, compressed-air sprayer is basic equipment for pest control operators, as it is widely used for surface-spraying for the control of household pests such as cockroaches, ants and fleas. The sprayer tank should preferably be of stainless steel construction, with a capacity ranging from 2 to 10 litres. Basically, the tank houses a plunger assembly for pressurising and a dip tube, outlet, hose and gun for delivering the liquid. When the plunger is operated, air is forced through a check valve and into the tank, where it rises to the top. At sufficient pressure, operation of the gun allows liquid to travel up the dip tube, along the hose and through the gun, where the nozzle produces a given spray pattern.

Many different kinds of compressed air sprayers and accessories are available. Some sprayers are fitted with a pressure gauge, which indicates tank pressure. Some are fitted with a pressure relief valve, which facilitates reduction of pressure in the tank. Hose length is usually 1–2 m. The gun chosen should accept a variety of nozzle types and wand extensions. Nozzles available produce fan, hollow cone, solid cone, pin stream and other spray patterns. Some have a

Figure 9.5 Compressed air sprayer: Rega, stainless steel 9.1 litre type fitted with extension wand and No. 6 nozzle

Figure 9.6 Compressed air sprayer: B+G 1 gallon sprayer with dripless extenda-ban

piece of fine tubing for crack and crevice treatment. Some are adjustable from hollow cone down to pin stream. Some offer a choice of three nozzle types on the one nozzle head. Wand extensions that may be fitted between gun and nozzle are very useful in work that requires treatment of eaves and other elevated structures. Some gun types cut off liquid at the nozzle, while others cut off at the gun. Where cut-off is at the nozzle, the dripping that may normally follow the shutting off of a liquid supply is avoided. In some sprayers a specially designed, small-diameter torch is attached to the wand, so that areas being treated are illuminated without the need to hold a torch.

The B+G Multi-jector is one of the more advanced compression sprayers which, as well as offering a choice of three conventional spray pattern options (coarse and fine fan and pin stream patterns), also has a 'pressure-enhanced spraying tip' which generates an aerosol-type spray. When treating voids, a straw-like crack and crevice attachment can be fitted to facilitate access to small gaps or openings. The sprayer's pressure regulator and gauge are of brass construction (operating in the range of 5–40 psi), hoses are coiled heavy duty solvent resistant and the stainless steel tank has a capacity of 5 litres.

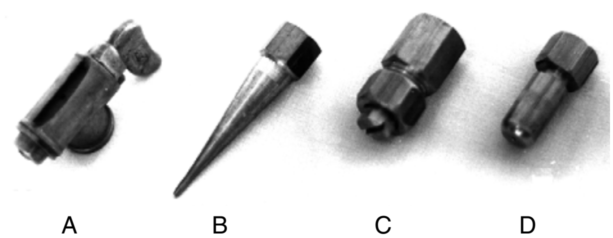


Figure 9.7 Nozzles suitable for use with compressed air sprayers: A. Bordeaux type nozzle; B. 'Borer' nozzle; C. Fantailnozzle; D. No. 6 adjustable cyclone (hollow cone to pin stream)

Some aspects to bear in mind about compressed air sprayers:

- The use of sprayers at high pressures should be avoided as this can be both hazardous and wasteful.
- All sprayers should have a pressure gauge fitted so as to allow the operator to control and monitor the pressure at all times. Normal operating pressure for a fan nozzle may be about 20 psi (ie approximately 140 kPa) while the use of a crack and crevice nozzle should benefit from a lower pressure of about 10 psi (ie approximately 70 kPa) depending on company policy, label instructions, equipment manufacturer's recommendations and other relevant factors.
- Always check pesticide label instructions in case there are instructions relating to sprayer use.
- Always carry a sprayer repair kit.
- Undertake a regular maintenance regime on sprayers so as to minimise the need for on-site repairs and so that on-site repairs are swift and successful should they be necessary.
- Avoid using hard metal objects (such as wire and pins) to unclog a blocked nozzle (nozzles are usual made of brass which is a relatively soft metal that damages easily). Instead, back flush with water or use a soft bristle brush.

In use, a compressed air sprayer should be carefully shaken to ensure proper mixture of the contents. This is particularly important when wettable powders, suspension concentrates or micro-encapsulated products are used, as these may settle out from the water. At the completion of spraying, the sprayer should be rinsed and flushed with water. Spray mixtures should not be stored in the sprayer. A more thorough cleaning, using a brush and an ammonia-based detergent, should be carried out at regular intervals. As well, the plunger assembly should be disassembled, checked and lubricated regularly (always check maintenance requirements with information from the manufacturer or supplier).

Dusters

Equipment used for the application of dust formulations can be simple and relatively inexpensive, depending on the scale of application. Some dusters serve to treat small, localised areas (eg gaps between factory equipment), while others may be used to treat larger areas (eg the entire roof void of a building). Broadly, the types of dusters available include:

Bulb (hand-puffer) type — This comprises a rubber bulb with a length of metal tubing. Dusters with a small bulb (about 50 mm) and relatively fine orifice are suitable for the more delicate applications of poisonous dust to termite workings, while dusters with a larger bulb (about 75 mm) and larger orifice are more suitable in cockroach and silverfish control, where relatively localised application is required.

Figure 9.8 Hand-puffer type dusters: Cockroach duster (top); Termite duster (bottom)

Mechanical rotary type — Hand-cranked rotary dusters rely on a geared worm-fed assembly and are suitable for the treatment of areas such as roof voids, storerooms and warehouses.

Mechanical plunger type — These hand-operated dusters are of lightweight plastic construction and come in a range of sizes. They may be fitted with a variety of nozzle tips and extension fittings to suit different kinds of application, ranging from small, localised areas and cracks and crevices, to more extensive areas (eg wall and roof voids).

Figure 9.9 Mechanical plunger-type duster: B+G Dust-R

Electrical Dusters — The B+G Electrical R is a 240V dust dispenser that is useful for situations such as wall and roof voids. The tank is seamless moulded copolymer, it has hoses for high output, and tip reduction for treatment of voids. An extension tube helps to add a static charge to the dust making it more likely to cling to surfaces.

Compressed gas type — Dusters that rely on compressed gas to distribute the dust are suitable for larger scale application (eg roof voids, warehouses, storerooms). Some depend on 'on site' compressed gas. These usually comprise a spray gun with a pot to hold dust, connected to a small, portable electrical compressor or to a portable cylinder of a compressed gas (eg carbon dioxide). Others rely on a pressurised tank principle. Here, the tank in which the dust is held may be pressurised (either on site or remotely). Some dusters of this type are adapted from modified fire extinguishers.

Figure 9.10 B+G Electric Dust-R

Dust application equipment should be chosen and used very carefully, as drift of fine dust particles to non-target areas must be avoided. As well, equipment should be checked and cleaned regularly, as dust particles may build up between fittings so as to reduce the safety and efficiency of the equipment.

Equipment for space-spray treatments

The technique of space-spraying facilitates the rapid treatment of large areas with relatively small amounts of insecticide. The equipment used to break up liquid insecticide into small, airborne droplets may involve heating up the insecticide in oil, or other cold aerosol generator methods (eg compressed gas and electrically driven mechanical generators).

Thermal aerosol generators Typically, a small thermal aerosol generator is a portable (hand-held) device driven by an electric pump. Usually, the tank (capacity 2–4 litres) is filled with an oil-based insecticide. The electric pump pushes the insecticide-in-oil liquid through an atomising nozzle, and from there the atomised insecticide passes into a thermostatically controlled heating chamber in the barrel. Here the insecticide in oil is vaporised and expelled. The 'wetness' of the droplets is sometimes variable (by altering the rate of flow through the heating chamber), and care should be taken to avoid the dispensing of very oily wet aerosols in sensitive environments (eg the interior of domestic dwellings).

In larger scale applications, where a portable system not reliant on electricity supply is preferred, a pulse-jet 'swinging' type of thermal aerosol generator is sometimes used.

Thermal aerosol generators rely on the presence of a relatively high proportion of 'oil' in the insecticides dispensed. As they are usually dispensed in enclosed situations, the flammability hazard created must be borne in mind, and precautions such as the switching off of pilot lights and the prevention of any other potential sources of ignition should be taken.

Cold aerosol generators Aerosol generators that do not rely on heating the insecticide may operate by mechanically breaking up the liquid (as in some electrical misters) or by using the pressure of compressed gases.

Electrical, mister-type, cold aerosol generators — An electrically powered pump moves the liquid insecticide by venturi action to a mechanical means of break-up (eg spinning discs). Tank capacity is usually about 4 litres.

Figure 9.11 Thermal aerosol generator: Acme Burgess BV1 Thermo-Fogger, 240V

Figure 9.12 Cold aerosol generator: DC-3 Curtis Dyna-Fog, 240V

Compressed gas, cold aerosol generators — These range from small, 'pressure pack' type aerosols to larger, high-pressure aerosol systems.

In 'pressure pack' type aerosol generators the insecticide, mixed with the liquefied propellant gas (usually the hydrocarbon type), is contained in a can that withstands the relatively low pressures developed. Operation of the valve pushes the liquid mixture up the dip tube, to be broken up at the nozzle to form an aerosol. Small pressure packs containing flushing-type insecticides (eg pyrethrins) can be used by pest controllers in inspecting for cockroaches and their harbourages.

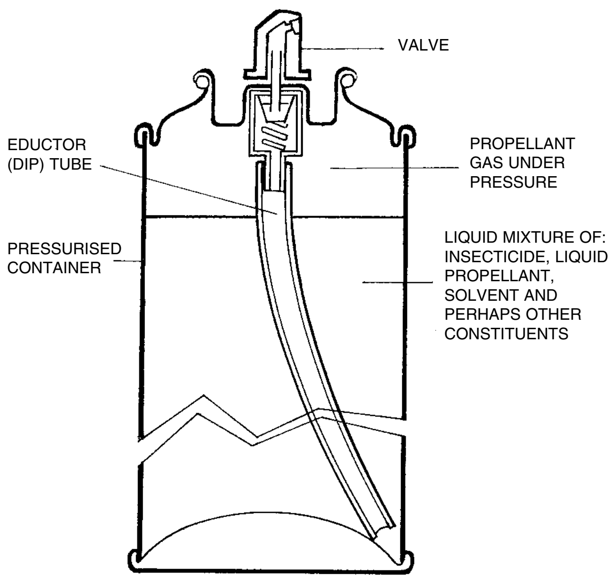


Figure 9.13 Section diagram of typical low-pressure aerosol container

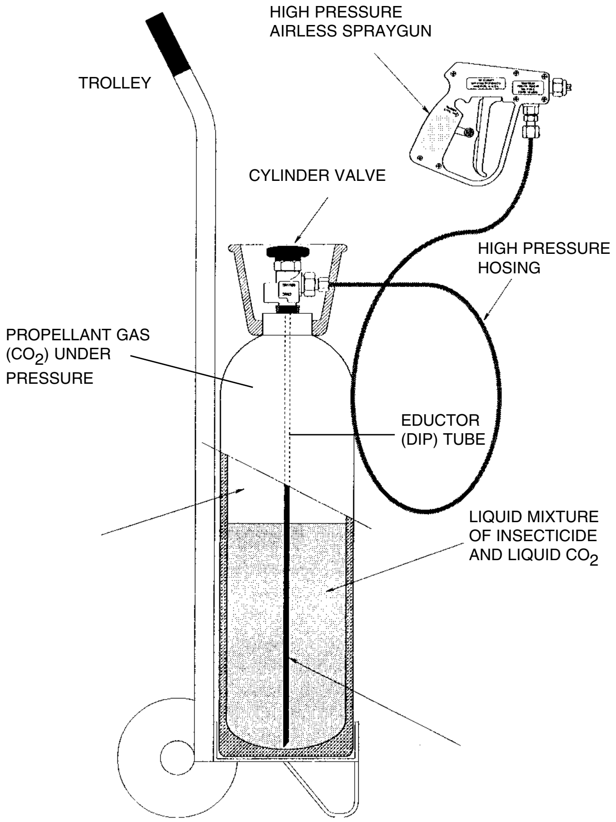


Figure 9.14 Section diagram of high-pressure aerosol system which utilises a liquid carbon dioxide propellant and solvent system

A similar principle is evident in the high-pressure Envirosol® aerosol systems (BOC Gases) that rely on liquid carbon dioxide propellant. Here, the insecticide is mixed with liquid carbon dioxide in cylinders capable of containing the high pressures involved. On operation of the hand-gun trigger, the liquid mixture travels up the dip tube and along the high-pressure hosing to the gun nozzle, where the carbon dioxide boils off, breaking up the insecticide into very small aerosol droplets. Gun, hose and cylinder are entirely transportable and may be used for space-spraying or, with the fitting of a special, extended nozzle, for treating cracks and crevices.

Figure 9.15 High-pressure aerosol: Insectigas-D® Insecticide ('D' size cylinder in trolley)

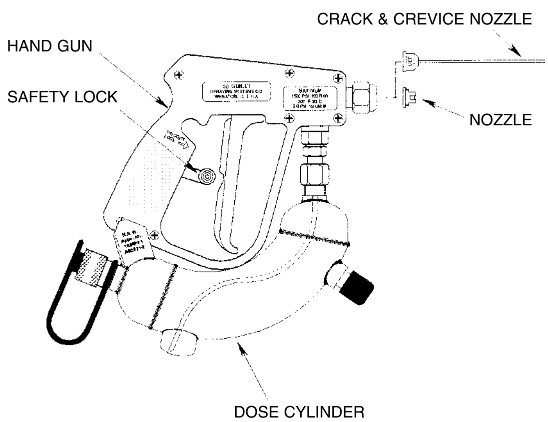


Figure 9.16 The Envirosol® Dose Gun

For situations in which it is not convenient to use a gun that is connected to the cylinder, the hand gun can be modified into an Envirosol Dose Gun which carries its own small dose cylinder (holding approximately 120 g of product) and this can be refilled from the cylinder using a dose fill adaptor. Once filled, the Dose Gun is self-contained (ie can be used without connection to the main cylinder) and can be used with a normal nozzle (for space spraying) or with a crack and crevice nozzle (to which an insert can be fitted if the operator wishes to reduce the flow rate).

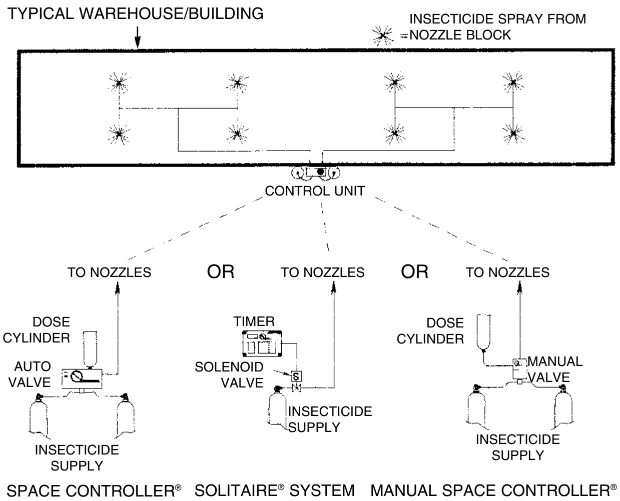


Figure 9.17 Diagrammatic representation of Envirosol® automatic dispensing systems

With the appropriate installation of piping and numerous nozzle heads throughout a building, the high-pressure carbon dioxide aerosol system can be installed as an automatic insecticide-dispensing system in warehouses, factories, stores and the like.

Automatic installations for dispensing high-pressure aerosols fall broadly into two types:

1 The Solitaire® system, for situations requiring frequent application of relatively small doses of insecticide (eg for fly control), is controlled by a micro-processor timer that allows manual override; and
2 The Space Controller®, which is designed for fail-safe application of larger doses of insecticide (eg pest control in large warehouses), uses a three-way ball valve and includes a 'dosing cylinder' (of appropriate capacity for the volume of space to be treated). Only the contents of the dosing cylinder can be released at any one time and direct connection between output nozzles and supply cylinders is not possible. The system has a 1000 hour battery back-up and can be used as a simple manual operation whereby, when a treatment is required (eg once a week), the operator fills the dosing cylinder and releases its contents.

Other cold aerosol-generators rely on pressure from cylinders containing liquid carbon dioxide. Here, a regulator connected to the cylinder valve reduces pressure, and operation of the trigger releases a flow of carbon dioxide gas along the hose to the gun, where insecticide contained in a pot is moved by venturi action to the nozzle, where the liquid is broken into aerosol droplets.

Figure 9.18 Bait gun: Bayer Premise cockroach gel applicator

The above is only a broad outline of some of the kinds of application equipment in common use. Pest control operators should take pride in the proficiency with which they disperse insecticides, treating only appropriate areas and avoiding any undue mess or hazard that may eventuate from leaky or unsuitable equipment. Some operators devise their own equipment or make modifications to standard equipment to suit particular jobs.

Figure 9.19 B+G Multi-Dose 3000 (for application of gels, pastes, dusts and granular formulations)

Where equipment is purchased from a supplier, the responsibilities relating to proper use and maintenance should be clearly understood and implemented. Regular inspection and maintenance of equipment should avoid any messy and potentially hazardous events, such as the bursting of a hose line inside a dwelling.

Equipment maintenance

All equipment used by pest control operators should be kept in good order so that the need for on-site repairs is kept to a minimum. This means that all equipment must be subjected to a regular maintenance regime. A few examples of the need for maintenance include:

- petrol driven motors will need oil level checked
- spray rigs will need filters/strainers cleaned
- dusting equipment will need cleaning to remove caked dust
- fogging equipment will need cleaning to remove carbon build-up.

As a general rule, equipment that is used only occasionally should be cleaned after each use. Equipment that is used frequently, as may be the case with most hand sprayers, should be cleaned and checked regularly (eg at least once a week).

Manufacturers usually provide use and maintenance guidelines with the purchase of equipment. Such information should not only be read and the advice followed, but it should be filed (preferably with other equipment manuals), so that it is easily retrieved when necessary.

Such information usually outlines the recommended maintenance regime for the particular item of equipment and this often comprises two aspects of recommended maintenance procedures:

1. those to be undertaken by the owner; and
2. those to be undertaken by a qualified, authorised service/repair centre.

In order to minimise the incidence of costly and unwelcome equipment problems during jobs, all maintenance recommendations should be followed.

Other equipment and useful items

In addition to the basic application equipment and protective clothing and equipment, pest control operators need to carry with them the following items and equipment:

- tools that will facilitate any 'on-site' adjustments or repairs to application equipment;
- tools for improving access;
- aids for inspection;
- the means to record findings; and
- items for cleanliness.

Tools for application equipment

Operators should carry with them a selection of tools that will enable them to make adjustments and basic repairs to application equipment. Best kept in a tidy toolbox, items may include a set of spanners, a set of screwdrivers, pliers, multigrips, a brush for nozzle cleaning and any other tools that may be necessary for changing nozzles, cleaning nozzles, adjusting equipment and making basic repairs. Operators using hand sprayers should always carry a repair kit for each type of sprayer used. These usually contain all the gaskets, O-rings and other parts that may wear and need replacement (operators should be adept at stripping down their sprayer and carrying out basic repairs and maintenance). Some operators carry spare spray guns to quickly replace the faulty one, which can then be repaired later in the workshop.

In addition, items for measuring and filling may be needed. Often, a funnel, measuring jugs (100 ml and 1 litre) and a pourer (for drums) will facilitate the filling of application equipment.

Tools for improving access Pest control operators sometimes need to gain access to particular parts of buildings either for the purposes of inspection or in order to carry out control procedures. Some of the items often carried for this purpose include:

Basic tools — A basic tool kit should always be carried in the operator's vehicle. This may include a set of screwdrivers (that may be used to open hatches, inspection panels in equipment and the like), a set of spanners (including small and larger shifters), pliers, multigrips, pincers, small crowbar and claw hammer. In cases where a ceiling manhole cover has been 'painted in', normal opening is likely to result in unsightly damage to paint finishes — instead, careful cutting around the opening with a sharp blade (retractable for safety) can avoid any damage.

Ladder(s) — A ladder allows access to roof voids and other elevated locations. The folding type ladders that may be set up as a 1.8 m step ladder or 3.6 m extension ladder are favoured for their compactness and the security benefits that come with it being stored within the vehicle rather than strapped on the roof racks. Depending on the kind of work, a larger extension ladder may be warranted.

Tools for cutting floor traps — Tools such as a hammer, pliers, nail punch, small crowbar, chisels, straight edge and carpenter's pencil, circular saw (some prefer drill and jigsaw), nails, small lengths of timber and safety glasses and earmuffs may be needed for cutting traps in wooden floors for access to subfloor areas. They facilitate the lifting of floor coverings, the cutting of the trap, and its proper and safe replacement. Note: Cutting floor traps can be a hazardous undertaking, given, for example, the possible presence of concealed pipes or electrical wires on the floor frame timbers near the cuts. The cutting of floor traps and any other potentially hazardous activities should be carried out only by qualified persons (eg a licensed builder).

Drills and drill bits — A relatively heavy-duty impact drill and drill bits facilitate the drilling of concrete slabs and paths for soil injection for termite control. Sometimes a smaller drill is also useful for drilling holes for the purposes of pesticide application and sometimes for inspection using a borescope. Much care must be exercised, owing to the possible presence of concealed pipes or electrical wires. Wherever possible, plans and specifications of the building should be sought to make the drilling process a safer one. Drill bits should be regularly sharpened or replaced. Protective equipment, such as safety glasses and earmuffs, should always be worn.

Inspection aids

Torch — This should be of the rechargeable type and a spare torch (and/or batteries/bulbs) should always be carried. Recharging should be available in the operator's vehicle (12V) and from a 240V source (in the office or on the job site). The torch should be easy to operate (even when wearing gloves), it should throw a strong light (for precision in inspection), it should be of durable construction (as some of its use will be in harsh environments such as subfloor areas) and the lens should be shatterproof plastic (not glass). A very useful accessory is a belt ring that holds the torch when not in use.

Probe — Often used in the inspection/sounding of timber for timber pest damage, a probe is often about 900 mm long and designed to allow the use of a high-density plastic head for tapping and a modified screwdriver for probing. The shaft should be of a non-conductive material for safety when working in areas where exposed electrical wires and old conduits may be live. Many operators also carry a small screwdriver and knife (with blade sheathed) for closer sounding, probing and splinter testing. Some operators carry a long iron rod (about 1 m long and pointed) for use in soil to locate subterranean termite nests.

Adhesive tape — The probing of timber that is infested with active termites can cause disturbance that sometimes results in the termites vacating the site. This can later impede control measures. Probing should normally be kept to a minimum (sufficient to confirm activity and determine the species) and it usually helps to tape over the probed sections with an opaque adhesive tape (eg duct tape).

Hand mirror — A small hand mirror, fitted with a handle (in some cases telescopic) and used with a torch can help in inspection of areas not normally visible, such as behind and inside equipment.

Hand lens (x 10) — A small, compact magnifier may help in the examination and identification of the various organisms that may be encountered.

Borescopes (also called endoscopes) — A borescope is a slender, tubular instrument that is inserted into a cavity (eg via a small drill hole or through an existing opening such as a weep hole) in order to examine normally concealed areas such as wall cavities. The tube diameter (often 6–9 mm) and length (often 200–500 mm) vary with makes and models. In-built light sources are usually rechargeable and there are variations in the direction of view (eg forward, oblique and 90º) and angle of view (eg 35º, 45º, 60º, etc). These instruments can be very useful in dealing with a range of urban pest management issues, including further investigations and extent of damage assessments relating to termite infestations.

Sound detection devices — These range from a basic stethoscope to more specific, purpose-built instruments that are used to detect and amplify the sound of concealed timber pests such as termites. These instruments are sometimes useful in helping to assess the extent of a termite infestation with minimal disturbance of the termites.

Moisture meters — These instruments are useful in relation to timber pest issues; for example, the detection of higher-than-normal moisture levels in a plasterboard wall may indicate a concealed plumbing leak or the presence of concealed termite activity and mudding.

Moisture meters are available principally in two types:

- Pad type meters which are non-destructive and can usually detect higher-than-normal moisture levels below the surface. Those models with a soft material on the pads are more suitable for running over walls than those with a hard pad surface that may mark wall finishes.
- Pin/Probe type meters which have two pins that must be inserted into the surface of the material being tested.

Some moisture meters have a range of settings calibrated for different building materials (eg wood, 'dry wall' and masonry). Those which do not have such options are usually calibrated for timber so that readings for other building materials (such as cement render and plasterboard) should be used as relative measures only rather than as true absolute measures of moisture content. Most moisture meters need to be checked for correct calibration at regular intervals.

Insect monitoring traps — Traps are increasingly becoming a monitoring tool for pest managers. They range from simple sticky traps that rely on the insect encountering them at random, to what are often more sophisticated devices that employ attractants (including synthetic pheromones or food attractant substances). When placed and managed properly, they can offer very useful feedback that may shed light on the location and/or extent of pest activity generally, the more specific location of so-called 'hot spots' (for example the one sack of infested grain), the potential sources of infestation and they may also be used to gauge the effectiveness of particular treatments (ie by setting up pre- and post-treatment programs).

The means to record findings

Computer technology — Aside from the normal office functions for the computer, such as business administration and accounting tasks, emailing and accessing the Internet for information, the advances in information technology are playing an increasingly important role for pest control operators in the field. Portable palm computers can be very useful in areas such as commercial, industrial and termite work. Such devices may be used to record bait and trap placement information as well as records of catches and inspection findings. Cameras can facilitate the recording of images that assist in the later recording and evaluation of job sites and in reporting to the client. The interfacing capability of portable palm computers and digital cameras with the office computer will mean that records are safely backed-up and available for inclusion in clients' reports.

Dictaphone — (or small mini-cassette recorder) can be useful on larger, more complex jobs for recording inspection findings or other details quickly and efficiently. Some operators prefer to use a notepad and pen to record on-site findings, while others use pre-printed data sheets that are formatted specifically for each job site/customer.

Plan of building/site — Where larger scale operations involving large, complex buildings are undertaken, a copy of the plan(s) of the building and/or site can be very useful for recording the inspection observations, pest monitoring /trapping results, reports of pest sightings by the occupants and other relevant information. Such a document can provide a very useful overview of the pest issues and patterns of occurrence throughout the entire building and this can help, not only in determining the most effective and appropriate pest management strategy, but also in reporting to and communicating with the client.

Sample tubes and adhesive labels — In cases where pest specimens need to be identified, it is useful to have a supply of sample tubes and adhesive labels handy so that specimens can be collected and labelled accurately. Usually, the specimens can be properly preserved a little later in the office or at home.

Items for cleanliness

When working in homes or workplaces, pest control operators are often climbing in and out of dirty places such as roof voids and subfloors. In the interests of being considerate and professional, it is important that operators pay due regard to cleanliness.

Drop sheet — A drop sheet is useful (often necessary) where operators are exiting from a dirty roof or subfloor. Before proceeding through the building, the operator can stand on the drop sheet, clean up, change shoes etc, carefully bundle up the sheet and leave without soiling the area.

Brush and pan — These may be needed for localised clean-up before treatment or for clean-up following cutting, drilling or exiting from dirty environments.

Plastic sheeting, plastic bags — These may be useful for protecting items, removing bird nesting material and so on.

Cleaning rags — Cleaning rags should always be carried on the job in case of a need for clean-up (eg of overspray).

Vacuum cleaner — A vacuum cleaner is sometimes used for the removal or reduction of pest populations such as cockroaches, carpet beetles, clothes moths and ants. This approach may replace or precede further techniques such as baiting, trapping or spraying. The vacuum cleaners used by pest control operators should be fitted with a HEPA filter (High-Efficiency Particulate Air filter) so as to prevent allergenic components (such as dust mite body parts and droppings) from becoming airborne. In some cases, such as in stored food handling facilities, the vacuum cleaner 'catch' may be examined and identified to determine pest species and assist in devising an integrated pest management strategy.

Warning signs — Warning signs may be needed where premises are to be kept vacant for a specified time, as may be the case with space-spraying procedures. Signs should be easily affixed to doors, should carry clear warning about the hazard involved and should give clear instructions about allowed time of entry, the chemical used, ventilation procedures, and how to contact the pest control company. Always check pesticide labels and state legislation for any specific requirements.

The need for any additional equipment will be dictated by the nature of the work. Operators should ensure that they are fully equipped to carry out their work in a tidy, efficient, effective and safe manner.

FURTHER READING

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CHAPTER 10

PESTICIDES — HAZARDS, PROTECTIVE CLOTHING & EQUIPMENT, SAFETY & FIRST AID

Pest control operators who handle pesticides regularly must be aware of the hazards of pesticide use. In relation to hazards that may involve pesticide poisoning in humans, a knowledge of how poisons enter the body, their effects and the procedures for immediate treatment of poisoning cases, must be clearly understood and known. The operator's own health depends significantly on the proper use of protective clothing and equipment. By wearing the appropriate protection and adopting safe practices in urban pest control procedures, operators can protect themselves, their clients (the public), pets and the environment at large. All operators should have an intimate knowledge of how to deal with pesticide-related emergencies and give first aid.

HAZARDS OF PESTICIDE USE

The term 'hazard' is often used in relation to pesticides and is sometimes misconstrued as meaning toxicity. The term 'toxicity' refers to the inherent poisonous potency of a particular substance (ie its capacity to poison) while 'hazard' refers to the risk or danger of poisoning and this can vary, not only in relation to different chemicals but also in relation to how they are used, handled or applied.

A highly toxic chemical that is carefully injected under a concrete slab may be less hazardous to the building's occupants than a less toxic material sprayed over foods or cooking utensils.

In addition, the type of occupants of a building will influence the issue of hazard. Buildings occupied by young children (eg day care centres), older people (retirement units) or people with compromised immune systems will require special consideration and care.

All pesticides are, to a greater or lesser extent, normally regarded as potentially toxic to humans. There are no entirely 'safe' pesticides. There are, however, numerous safe handling practices that can minimise or remove the risk of poisoning and other harmful effects.

Urban pest control operators may handle pesticides every working day. The risk of their becoming psychologically desensitised to the potentially harmful nature of pesticides is a real one.

All pest control operators should be aware of the types of risk that their work may involve:

Risk to the operator

Clearly, constant occupational contact with pesticides may harm the health of the operator. Such risks can be avoided by: choosing pesticides carefully, reading and following label directions, wearing proper protective clothing and equipment, using well-maintained equipment, having regular medical tests, adopting safety-conscious work habits, and knowing about the pesticides used and their poisoning characteristics. The risk of occupational poisoning may increase in the following circumstances:

- at the start of the warm season (when new, inexperienced workers begin to handle toxic pesticides);
- in very hot conditions (when the wearing of proper protective equipment and clothing may seem uncomfortable); and
- after a long, hard day's work (when operators may be tired and thus tempted to take short cuts at the expense of safety to themselves and the clients they serve).

Risk to the public

Most of the work of urban pest control operators involves the application of pesticides in and around buildings where people work and live. Operators must have a sound understanding of the potential for poisoning of all the chemicals they apply. They should apply chemicals so as to minimise the likelihood of human contact. They should be especially careful of the somewhat unpredictable behaviour of young children.

Risk to pets

Pets, ranging from fish (kept indoors or out) to cats, dogs, birds, and many others, often reside in domestic residences. Fish cannot escape contaminated water, birds may be very sensitive to space sprays, and cats are apt to groom and possibly ingest any dust picked up from a pest control treatment. Many other dangers may be imposed on pets. Careful application of selected pesticides can avoid the danger of poisoning pets.

Risk to wildlife and the environment

Life on earth depends on a very complex set of interactions between different life forms. Examination of the extent to which humans disrupt this arrangement is a relatively recent concern, but one that is now rapidly growing. The direct and indirect effects of pesticides on wildlife, waterways and the environment at large may be harmful and are entirely undesirable. For pest control operators, attempts at minimising the likelihood of non-target damage will often require care in relation to spray drift and (in-ground) leaching. At the core of this problem is the misuse of persistent pesticides, that is, pesticides that do not readily break down in the environment but instead move around in it, causing damage to various organisms in a given food chain. The action of some persistent chemicals is still relied on in some urban pest control procedures. With restricted, careful and selective applications of these chemicals, or preferably their replacement where possible by less stable chemicals, pest control operators can do much to reduce the risk to the environment.

RISK MINIMISATION — A KEY ISSUE FOR ALL PEST CONTROL COMPANIES

Pest control operators have not only a legal responsibility, but also a professional obligation to use pesticides in a safe manner. All pest control companies should conduct regular Occupational Health and Safety Training sessions and refresher courses for all personnel who handle pesticides. As a minimum, such training should cover:

- State regulations pertaining to the use, handling (including dealing with spills), storage and transport of pesticides;
- Pesticide product labels and Material Safety Data Sheet information for all products used; and
- Company OH&S policies, including:

. protective clothing and equipment;
. first-aid and emergency procedures (including dealing with spills);
. strategies for minimising risk in relation to the choice of pesticides and methods used (including approaches used on job sites involving pregnant women, young children, older and/or ill people);
. safe use and maintenance of power tools and application equipment;
. safe use and maintenance of ladders; and
. vehicle safety and maintenance.

PESTICIDES AND HEALTH

It is unlikely, in the near future, that we will gain a complete understanding of all the possible harmful effects that pesticides may have on human beings. Laboratory tests generally only use small mammals such as rats and mice and while these are useful, they have only a limited value when trying to gauge the potential effects of pesticides on people. In addition, our increasingly stressful lifestyles combined with the fact that we live in a chemically complex world (chemical additives to the food we eat; chemicals present in everyday cleaning compounds; chemicals in the very air we breathe and as essential elements of such commonplace products as cosmetics and deodorants) make it virtually impossible to determine the exact and precise effect a particular chemical may have on a particular individual.

There are two ways in which humans may experience the harmful effects of pesticides:

- *Direct Effect* — Acute or chronic exposure leading to manifestation of 'poisoning symptoms'. (These 'short term' effects may produce symptoms that last hours or days but the effects are usually reversible and mostly lead to total recovery.)

- *Indirect or Delayed Effect* — (Sometimes referred to as long term effects', these effects represent a form of chronic toxicity in which there can be a significant time delay between the last exposure and the development of symptoms). Examples include pesticide-induced embryo toxicity, neurotoxicity, mutagenicity and carcinogenicity.

PESTICIDE POISONING IN HUMANS

Direct effects

Pesticides may enter the human body by being inhaled, ingested or absorbed by the skin. The degree of poisoning is a function of dosage rate, that is, the amount of pesticide absorbed into a given amount of body weight. The more potent or toxic the pesticide, the smaller the amount required for a given body weight to become poisoned.

Two types of poisoning by pesticides may occur:

1 *acute poisoning* — where a single dose or intake of the poison causes poisoning symptoms ranging from mild to severe and perhaps death; and
2 *chronic poisoning* — where several small doses or intakes of the poison accumulate in the body over a period of time to cause poisoning symptoms and possibly death.

Where possible, jobs should be rotated between operators, so that the chance of chronic poisoning from continual use of the one pesticide is reduced.

Routes of entry of pesticides in humans

It is the responsibility of all pest control operators to use pesticides in a manner that minimises the possibility of human poisoning. To do this, there must be a clear understanding of all of the possible routes of entry of pesticides into the human body.

There are three routes by which pesticides may enter the human body: ingestion (oral), inhalation (respiratory) and absorption by the skin (dermal):

Oral The pesticide is ingested via the mouth and digestive tract. Many oral poisonings by pesticides are accidental, whereby poisons stored in food containers or drink bottles are accidentally ingested, especially by children. Suicide attempts may involve the ingestion of pesticides. In the occupational context, careless behaviour (eg smoking or eating without washing, contaminating food, blowing out blocked nozzles by mouth) may allow the oral intake of pesticides. Provided that the label does so advise, the poisoning effects of pesticide ingestion may be minimised by the inducement of vomiting, which reduces absorption into the body.

Respiratory The pesticide is breathed into the lungs as a gas, or as a very fine solid or as liquid particles. Constant use of correct respiratory protection significantly reduces the operator's risk of being poisoned by inhaled pesticides. Poor storage of pesticides in the operator's vehicle can, particularly in warmer conditions, expose the operator to respiratory poisoning. Particular care should be taken when preparing mixes and handling concentrates. Techniques of application that create a respiratory hazard to clients (eg space-spraying) should be programmed so as to avoid the possibility of people being poisoned by inhaled pesticides. This may involve an 'off limits' treatment time, to be followed by a ventilation period prior to reoccupation of premises.

Dermal The pesticide is absorbed into the body through the skin. Among pest control operators, dermal poisoning is usually the most likely route of entry of pesticides. Pesticide contamination of the skin may occur by splashing during mixing or application, by drift during application, by handling contaminated equipment, by wearing contaminated gloves, respirators, overalls and the like, or by a variety of other means. When skin is contaminated by pesticide, the pesticide proceeds to be absorbed. In the event of skin contamination, speed is important. Contaminated clothing should be removed as soon as possible, and contaminated skin should be washed thoroughly with soap and water. Quick and effective removal of the pesticide from the skin significantly reduces the amount absorbed into the body. For the operator's part, the need for regular washing of protective clothing and equipment cannot be overstated. In applying pesticides the operator should avoid leaving pesticide deposits on surfaces where human contact is likely. Careless work habits that allow dermal contamination to proceed unchecked can lead to an insidious and dangerous build-up of pesticides in the operator's body.

Measurement of toxicity of pesticides to humans

Pesticides vary greatly in their toxicity to humans. An average adult male may die from the absorption of less than 1 g of a particularly potent pesticide. On the other hand, some pesticides are, relatively speaking, much safer. Clearly, it is vitally important to have some idea of the level of toxicity of pesticides in common use. Some information is available from pesticide-related accidents and suicide attempts, but this is of limited value.

The standard measure of the toxicity of a pesticide is evaluated during its development. This measure, the relative mammalian toxicity, is arrived at by tests wherein the pesticide is administered, by various routes, to small, warm-blooded mammals that are not unlike humans in basic physiology (eg rats, mice, rabbits). In this way, some indication of the relative toxicity of pesticides to mammals is obtained.

Relative mammalian toxicity LD50 The standard method for recording the relative toxicity of a pesticide is by evaluating its LD50 (ie lethal dose 50%). This is a statistical estimate (based on test results) of the dose that, when administered via a given route of entry, kills 50% of the test animals. Most commonly, the acute oral LD50 (administered via the mouth in one dose) and acute dermal LD50 (administered to the skin in one dose) are available for a given pesticide.

The units of the LD50 measure are expressed as mg/kg, that is, milligrams of pesticide (usually its pure form) per kilogram of body weight. Thus, a pesticide with a small dermal LD50 (eg 3 mg/kg) would be regarded as being much more toxic to humans than one with a large dermal LD50 (eg 2000 mg/kg). Table 10.1 sets out the comparative levels of toxicity for some LD50 measures. Note: these are only broad categories and do not take into account several factors, including: effects of formulation additives, individual sensitivities and indirect or delayed effects.

It is important to note that toxicity data available as LD50s are not an absolute measure of toxicity to humans. At best, measures of relative mammalian toxicity give a comparative indication of the toxicity of different pesticides to small mammals. Broadly, LD50 measures are used only as an approximate guide to the relative toxicities of pesticides (important information in any case). The limitations inherent in this method are clearly evidenced by the variety of results obtained from different laboratories studying the same pesticide.

TABLE 10.1
LD50s and comparative levels of toxicity

Level of toxicity	Oral LD50 (mg/kg)	Dermal LD50 (mg/kg)
Extremely toxic	less than 5	10 or less
Highly toxic	5–50	10–100
Moderately toxic	50–500	100–1000
Slightly toxic	500–5000	over 1000

Poisoning by pesticides in common use Pest control operators should be familiar with the poisoning implications of the various pesticides they handle. Acute oral dermal LD50s of some pesticides in common use are given in Table 10.2 (toxicities of commonly used insecticides), and Table 10.3 summarises some effects of pesticides on humans and appropriate first aid treatments. Operators who handle pesticides not covered in Table 10.3 (eg weedicides, fumigants and certain rodenticides) should be familiar with the poisoning characteristics, symptomatology and first aid treatment for poisoning by the various chemicals they use.

TABLE 10.2
Acute mammalian oral and dermal LD50s* of some insecticides

Insecticide	Oral LD50 (mg/kg)	Dermal LD50 (mg/kg)
Inorganics		
arsenic trioxide	34–64	-
boric acid	>3,200	-
Botanicals		
pyrethrins	584–900	>1,500
Organochlorine compounds		
chlordane	457–590	>200 but <2,000
DDT	113–118	2,510
heptachlor	147–220	>2,000
Organophosphorus compounds		
azamethiphos	1,180	>2,150
chlorpyrifos	135–163	approx 2,000
diazinon	300–400	>2,150
dichlorvos	approx 50	approx 300
fenitrothion	approx 250	approx 2,500
fenthion	190–615	330–500
pirimiphos-methyl	2,050	>2,000
temephos	4,204–10,000	2,181
Carbamates		
bendiocarb	40–156	566–600
methomyl	17–24	>5,000
propoxur	approx 50	>5,000
Synthetic Pyrethroids		
allethrin	585–1,100	>2,500
alpha cypermethrin	79–5,000	500
beta cyfluthrin	140–500	>5,000
bifenthrin	54	>2,000
bioresmethrin	7,070–8,000	>10,000
cyfluthrin	900	>5,000
cypermethrin	251–4,123	>2,400
deltamethrin	135–>5,000	>2,000
lambda cyhalothrin	19–79	1,293–1,507
permethrin 25/75	1,479–4,672	4,000
phenothrin	>10,000	>10,000
Insect Growth Regulators		
diflubenzuron	4,640	>2,000
fenoxycarb	>10,000	>2,000
hexaflumuron	>5,000	>5,000
hydroprene	>5,000	>5,000
methoprene	>34,600	>3,500
pyriproxyfen	>5,000	>2,000
triflumuron	>5,000	>5,000
Miscellaneous		
fipronil	100	>2,000
hydramethylnon	1,131	>5,000
imidacloprid	150–450	>5,000

*LD50 data (mainly for rat) primarily sourced from: Tomlin C. (ed) 1997 *The Pesticide Manual* British Crop Protection Council UK.

Medical examination Regular medical examinations of pest control operators can detect instances of chronic poisoning before obvious symptoms occur. Because operators work close to a variety of pesticides for many hours, it is important that regular medical examinations be carried out. Usually, state health departments oversee the conduct of medical examinations specifically for workers involved with pesticides. Where this service is unavailable, a doctor should undertake the tests.

Indirect effects

The development of new pesticides now costs many millions of dollars and takes several years. Much of this cost and time is directly related to testing and evaluations that attempt to investigate health and environmental implications. Typically, tests and evaluations will probably look at:

- Acute oral, dermal and inhalation toxicity to mammals
- Eye and skin irritation
- Dermal sensitisation
- Reproductive toxicity effects such as:
  - Teratogenicity
  - Embryo toxicity
  - Mutagenicity *and*
- Neurotoxicity effects
- Sub-chronic feeding tests
- Chronic feeding tests
- Wildlife effects
- Environmental fate

Delayed effects of some pesticides may include:

Carcinogenicity — refers to the ability of a given substance to induce cancers (malignant tumours) in animal tissues.

Mutagenicity — refers to the ability of a given substance to change genes in an organism (which may lead to changes in a range of life processes, including metabolic and behavioural processes — mostly tested with bacteria).

Teratogenicity — refers to the ability of a given substance to produce abnormalities in offspring following exposure by the pregnant female.

Embryo toxicity — refers to ability of a given substance to induce symptoms of toxicity in an embryo upon the exposure of the pregnant female.

Neurotoxicity — refers to the ability of a given substance to cause adverse effects in nerve tissue (eg brain or spinal cord).

Other toxic effects of pesticides may include so called sub-lethal effects. These effects are very difficult to measure and attribute to any one cause, so the degree to which pesticides play a role in relation to these effects is uncertain. Such effects include behavioural changes, restlessness, asthmatic reactions, memory loss, muscle weakness, chemical sensitisation and adverse effects on the immune system.

This book deals only with the direct poisoning effects. Indirect and delayed effects of pesticides on human health is a complex and contentious subject beyond the scope of this book. Pest control operators and those who select chemicals and determine application methods for operators should make a point of keeping themselves up-to-date on the subject and be constantly aware of the potential hazards whether they be short term and visible, or longer term and less obvious.

PROTECTIVE CLOTHING AND EQUIPMENT

Pest control operators are sometimes inclined to avoid wearing proper protective clothing and equipment because clients nearby during the treatment may be unduly worried about their own health. This situation should not arise. If the treatment is one that creates a hazard to clients, it should have been programmed for a time when the building was unoccupied. If the treatment does not pose a hazard to clients nearby, and if the operator's protective clothing and equipment worry clients, the operator should explain that he or she is occupationally exposed to chemicals virtually every working day and therefore quite justified in seeming to be more protected than the client.

Pest control operators should be dressed and equipped appropriately for each and every job that involves pesticide application. A knowledge of the pesticides used, information contained on the label and in Material Safety Data Sheets (MSDS), relevant legislation and safe practices in handling pesticides should ensure that the operator is well aware of what is the appropriate protective clothing and equipment for each pesticide and each job.

The use of uncleaned and badly maintained protective clothing and equipment may facilitate poisoning. Owing to the possibility of 'on the job' contamination, the operator should always carry at least one spare set of clean protective clothing and equipment. Spares of consumables (eg respirator cartridges) should always be kept readily available.

It is essential that all protective clothing and equipment be comfortable and well fitting. Ill fitting equipment may not give the protection that it ought to and, in any case, may tempt the operator not to wear it.

Basic items for protection

For many pesticide application jobs that urban pest control operators may engage in (excluding fumigation), the basic items of clothing and equipment that should be worn are: overalls, gloves, boots, hat and respiratory protection. However, with the development of products such as some lower hazard applicator-applied baits, the recommended protective clothing and equipment may be less rigorous.

Always check label directions, State legislation and Material Safety Data Sheets.

TABLE 10.3

Effects of some common pesticides on humans, and first aid treatments (Note: Always refer to product labels and/or Material Safety Data Sheets for first aid advice.)

Type of pesticide	Physiological effects	Symptoms of poisoning	First aid treatment
Organochlorine compounds eg Aldrin Chlordane Dieldrin Heptachlor (mostly as emulsifiable concentrates)	Cause instability of the central nervous system (mechanism not completely understood). Repeated doses may induce changes in liver and kidneys. Many of these insecticides, or their degradation products, may become stored in body fat, where they may remain, apparently with no effect while bound in fat. Because of this, chronic symptoms take longer to appear in operators carrying excess weight. Sudden loss of weight can invite the onset of poisoning symptoms. Normal medical checks carried out on operators monitor organochlorine levels only in blood, not fat.	Diarrhoea, vomiting, numbness of extremities, restlessness and increased excitability, which may be followed by muscular twitching and possibly convulsions, which may lead to death. Onset of symptoms depends on dose and rate of absorption.	In cases of ingestion, do not induce vomiting, but call the Poisons Information Centre (131126 throughout Australia) immediately. Milk or oils must not be given, as they aid absorption. In cases of skin contamination, the clothing should be removed immediately and the skin washed gently but thoroughly with soap and water. Ensure that the patient is breathing properly. Artificial respiration may be required. The patient should rest. Medical aid should be sought. Doctors may administer drugs that counter symptoms and advise a period of 'no contact' with organochlorine compounds.
Organophosphorus compounds eg Azamethiphos Chlorpyrifos Diazinon Dichlorvos Fenthion Fenitrothion Maldison Trichlorphon (mostly as emulsifiable concentrates and wettable powders)	Inactivate cholinesterase enzymes in the body. These enzymes normally hydrolyse acetylcholine — a nerve transmitter substance. The subsequent build-up of acetylcholine upsets proper functioning of the nervous system. Symptoms of poisoning usually do not occur until the enzyme activity is reduced to about 30% of normal. While some of the enzyme (pseudocholinesterase) may regenerate within days of poisoning, red cell cholinesterase is regenerated only by the replacement of red blood cells, and this may occur at the rate of approximately 1% of normal per day. Full recovery from organophosphorus poisoning may take 4–8 weeks. Organophosphates are not stored in body fat. Normal medical checks carried out on operators monitor blood cholinesterase levels.	Headache, fatigue, giddiness, salivation, sweating, blurred vision and pinpoint pupils, tightness of the chest, difficulty in breathing, rapid heartbeat, nausea, vomiting, abdominal cramps and diarrhoea, convulsions and paralysis, which may lead to death. In cases of massive exposure, death may occur within minutes.	If the organophosphate has been swallowed, do not induce vomiting, but call the Poisons Information Centre (131126 throughout Australia) immediately. In cases of skin contamination, contaminated clothing must be removed and the skin gently but thoroughly washed with soap and water as quickly as possible. Where the cause of poisoning is known with certainty to be an organophosphorus compound, atropine tablets (0.6 mg) may be given each 15 minutes until dryness of the mouth occurs. Atropine blocks most of the actions of excess acetylcholine already accumulated. If respiration has failed, resuscitation should proceed. Medical aid should be sought as soon as possible. Doctors are likely to advise a period of 'no contact' with organophosphorus and carbamate compounds.

Type of pesticide	Physiological effects	Symptoms of poisoning	First aid treatment
Carbamate compounds eg Carbaryl Bendiocarb Propoxur (mostly as wettable powders and dusts)	Similar to those of organophosphates; but although carbamates are inhibitors of cholinesterase enzymes, the recovery of enzyme activity can be quite rapid, involving perhaps hours or days. They are referred to as 'rapidly reversing inhibitors' of cholinesterase. Normal medical checks carried out on operators monitor blood cholinesterase levels.	Headache, abdominal pain (if ingested), salivation, sweating, confusion, constricted pupils, muscular tremors. Recovery may be rapid. Symptoms may be similar to those of organophosphorus poisoning.	If a carbamate is ingested, do not induce vomiting, but call the Poisons Information Centre (131126 anywhere in Australia) immediately. If absorbed by skin, contaminated clothing should be removed and the skin washed gently but thoroughly with soap and water. Where the cause of poisoning is certainly a carbamate (or organophosphorus), atropine sulphate (0.6 mg) should be given each 15 minutes until dryness of the mouth occurs. Seek medical aid.
Pyrethrins (mostly as space sprays in aerosols etc)	Irritates nasal and throat passages. Possibly causes respiratory paralysis. Sometimes causes dermatitis. Large doses may cause nervous excitation, but such a large dose in humans unlikely. Pyrethrins is regarded as a relatively safe insecticide, although some people are sensitive to it.	Irritation of the nose, throat and eyes. Allergic reactions may include numbness of lips and tongue, nausea, vomiting and headache. Skin contact may cause dermatitis.	Remove from source of poisoning (often space spray droplets). Advise sedation, perhaps anti-histamine. If necessary, seek medical aid.
Arsenic compounds eg Arsenic trioxide (mostly as a dust)	Attacks the cells of the intestinal tract and other organs contacted. Suspected of causing skin cancers.	Gastro-intestinal upsets, vomiting, diarrhoea, pallor, low fever, excessive salivation, irritation of nose and eye membranes. Residues may be found in nails, urine and hair.	Remove from possible contact with arsenic. Call the Poisons Information Centre (131126 anywhere in Australia) and/or obtain medical aid. Most of the arsenic is excreted within 8 weeks.
Solvents eg Toluene Xylene (mostly in emulsifiable concentrates)	May facilitate the entry of insecticides into the body. May produce nausea, headache and dizziness themselves.	Nausea, headache, dizziness.	Removal from source of contact. Obtain medical aid.
Rodenticides (anti-coagulant type) eg Brodifacoum Bromadiolone Coumatetralyl Diphacinone Warfarin (usually as dry or liquid baits, tracking powders and wax blocks)	Have two important actions: (a) they reduce the ability of the blood to clot, and (b) they damage fine, blood-conveying tissues. Bleeding usually occurs where the body is damaged.	Back, stomach and intestinal pains; nose-bleeding; vomiting; blood in urine; heavy bruising, especially at knee and elbow joints.	Obtain medical aid. Vitamin K is antidotal.

Overalls

Overalls (boiler suit) should have sleeves and be buttoned at wrists and throat. Once contaminated, overalls may carry the pesticide so that it is available for absorption by the skin. Such absorption is facilitated by perspiration. Overalls should be washed at the completion of each day's work (at least). Spare, clean overalls should be kept in the operator's vehicle in case of accidental contamination. Overalls used on the job should be removed before travelling to the next job, to avoid contamination of the driving cabin area.

Gloves

Gloves should be of the thick, PVC, gauntlet (elbow-length) type. They should be washed on the outside (while wearing) at the completion of each operation. They should be regularly tested for pinholes by filling with water and squeezing. If holes are evident, gloves should be discarded. They should be regularly washed with soap and water both inside and out.

Boots

Footwear should be impervious and preferably ankle covering. Heavily waxed or otherwise protected leather boots may be sufficiently impervious and more comfortable than rubber boots. Socks should be washed after each day's work, and boots should be regularly washed inside and out to remove any contaminating pesticide.

Hat

The hat should be washable and unobtrusive without a wide brim to obstruct vision. Beret-type hats are much favoured.

Respiratory protection

A variety of respirators are used by pest control operators. It is important that the respirator chosen be appropriate for the particular type of pesticide application. Beards interfere with respiratory protective devices so should be avoided.

Half-face respirators This is the most commonly used respirator in urban pest control operations (except fumigations). Usually constructed of soft, pliable rubber, the face piece fits over nose and mouth. Traditionally, these respirators have been of the 'twin cartridge' type; however, 'single cartridge' designs are also available for those who prefer this type. Different sizes are available to allow correct facial fit. Different brands of respirator can also have different fitting characteristics so it is very worthwhile to investigate the range of products available to ensure that the respirator selected is comfortable and fits well.

Exhalation and inhalation valves should be regularly checked and replaced if necessary. Filter cartridges appropriate for the pesticides used should be selected. These should be changed regularly depending on use patterns (some recommend changing after the equivalent of eight hours continuous use or immediately an odour is detected — if this occurs, the aim then is to change prior to odour is detection in the future — always refer to manufacturer's recommendations). At the end of each day's work, the cartridges should be removed and the face piece washed with soap and water. The respirator should be stored in a closed plastic bag to avoid contamination by pesticides.

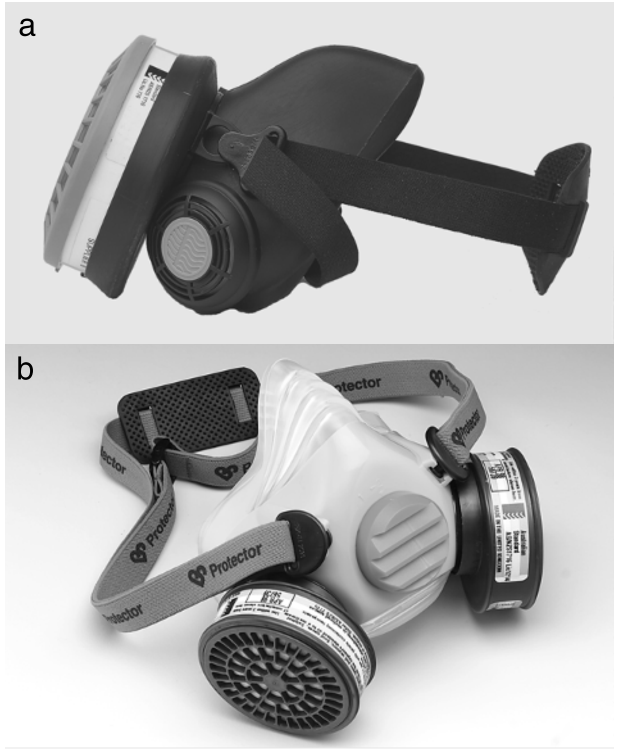


Figure 10.1 Examples of half-face respirators:
(a) Sundström SR 100 half-mask respirator, (b) Protector R60 half-mask respirator

Full-face, canister-type respirator This unit provides protection for eyes, nose and mouth. The mask should be multi-strapped to facilitate a comfortable and tight seal against the face. The nose and mouth section is preferably separated from the viewing lens section, to reduce fogging problems. The unit may be fitted directly with a 500 ml replaceable canister; or where a 1 litre canister is preferred, this may be harnessed around the waist and connected by tubing to the respirator. Although used mainly in fumigation procedures, full-face, canister-type respirators are also useful in some pest control operations where more protection is needed than is afforded by half-face respirators. One example of such an operation is the space-spraying of dichlorvos, during which the operator should wear a full-face, canister-type respirator. In this sort of use, the canister should be replaced regularly (eg after about eight hours' use or immediately an odour is detected). After each use the canister should be removed and the face piece washed. When not in use, the respirator should be protected in a plastic bag and stored away from pesticides.

Figure 10.2 Example of full-face mask respirator (Sundström SR 72 full-face mask)

Respirator Maintenance

The wearing of a respirator does not in itself protect the operator from poisoning by inhalation.

- The respirator should be appropriate for the particular job.
- It should be a good fit affording a perfect seal against the face.
- The cartridge(s) should be replaced on regular basis consistent with work load (some operators record the date of changing on the new cartridge).
- The respirator should be disassembled regularly and all parts (except for the cartridge) should be washed (usually with warm water and a mild detergent).
- All parts should be regularly checked (especially valves) to ensure there is no cracking or deterioration.
- Spare inhalation and exhalation valves should always be kept in case of immediate need.
- When not in use, the respirator should be stored in a clean plastic bag or other appropriate container, well away from pesticides.

Miscellaneous protective equipment

Beyond the basic items of protective clothing and equipment outlined above, some other protective devices may be useful for particular situations:

Dust masks/pads This very basic form of respiratory protection should never be used where any type of pesticide is employed. Operators who do inspections of buildings may find them beneficial for dusty areas (eg roof cavities); however, given the possibility of pesticide residues being present from previous treatments, it would be advisable to wear a proper respirator.

Apron An apron made of rubber or plastic may be useful in preventing contamination during mixing and loading operations (particularly when handling concentrates). It should be washed after each use.

Figure 10.3 Example of face shield (Protector Safety F 600 BG face shield)

Face shield Usually of plastic construction with a replaceable visor, a face shield may be useful for protecting face and eyes while mixing or while spraying in conditions of possible drift, or in elevated locations (eg under eaves). It should be washed after each use.

Goggles Preferably of the non-fogging type, goggles may be useful for eye protection during mixing or in conditions of possible spray drift.

Agricultural respirator hood This is a waterproof hood fitted with a visor for viewing and a twin cartridge respirator. It provides protection for the whole head against splashes while mixing or drift while spraying.

Positive-pressure, supplied-air respirator This equipment comprises a full-face mask connected to a cylinder of compressed air. It is used mainly for emergencies in fumigation operations and firefighting, being suitable for entering atmospheres that are highly toxic and/or low in oxygen. Normal pest control procedures seldom call for its use. From the viewpoint of the operator's safety, the importance of wearing appropriate clean and well-maintained protective clothing and equipment cannot be overemphasised. In some cases the use of uncleaned, unchecked clothing and equipment may do more harm than would be the case if no such equipment were worn.

SAFE PRACTICES IN URBAN PEST CONTROL PROCEDURES

As urban pest control procedures often rely on the application of pesticides in and around buildings where people work and live, harmful effects are distinctly possible. To avoid such effects, operators must work in such a manner that they protect themselves, clients (the public), pets and the environment at large. By incorporating safe practices into daily work habits, much of the risk of hazardous pesticides is removed. Operators must be intimately familiar with State Regulations pertaining to pesticide use, label directions and material safety data sheets for all products used.

A range of safe practice procedures is given below:

In the pest control operator's vehicle

- The driver's cabin should be distinctly separated from chemicals and equipment. Some vans may be converted by installing an effective wall and appropriate ventilation.
- The compartments containing pesticides and equipment must be entirely lockable, to prevent unauthorised access. Ensure that they are locked.
- The vehicle should be regularly serviced and checked, to lessen the possibility of accidents.
- Emergency telephone numbers, such as the Poisons Information Centre (131126 in all states) and the State Department of Health, Workcover or equivalent (in case of spillages or other emergencies) should be displayed and accessible for easy reference.
- Carry Material Safety Data Sheets for all pesticide products used and have them in an easily accessible form.
- Before travelling, read the labels and know the potential hazards of all the pesticides carried.
- Store protective equipment in a clean plastic bag in the front compartment of the vehicle, away from pesticides. Regularly changed, disposable plastic bags are preferable.
- Ensure that equipment is free of leaks and pesticide contamination and is well maintained.
- Ensure that the bulk tank is empty while in transit.
- The bulk tank should be clearly labelled to indicate the hazardous nature of the contents and the name of the particular pesticide contained.
- Ensure that items of equipment and pesticide containers are well secured by bracing or some other effective means.
- Ensure that pressurised cylinders are securely harnessed, with the main cylinder valve in the 'closed' position when not in use.
- Avoid glass pesticide containers. If they are necessary, ensure that they are well padded.
- Ensure that pesticide containers are clean, free of pesticide residues and tightly closed.
- Ensure that all containers of pesticides are clearly and accurately labelled.
- Pesticides should be kept in their original containers with original labels intact.
- If pesticides are not kept in their original containers, they should be kept in a container designed for pesticides.
- Keep a fire extinguisher within easy access.
- Keep a handy supply of an absorption product designed for chemical spillages (eg chemical spill kit — usually available in a form for easy storage and quick access — essential in case of accidental spillages). Sturdy plastic bags for clean up should also be carried.
- In the event of a spill, the spill should be immediately contained with the use of an absorptive material. Depending on the scale of the spill, the material should be cleaned up immediately or the relevant authorities should be notified.
- Keep clean, spare protective clothing and equipment in the driver's cabin.
- If street clothes are at any time worn under overalls, keep a set of spare, clean street clothes in the driver's cabin. Street clothes worn during the day should be washed at the end of the day.
- Any food and drink carried should be kept in a receptacle impervious to pesticides. This receptacle should be placed in the driver's compartment, well away from pesticides.
- Keep a comprehensive, appropriate first aid kit in the driver's cabin and within easy access.
- Keep washing gear (soap and towel) in the driver's cabin. It is advisable (especially in country areas) to carry at least 20 litres of clean water for washing. This container should be appropriately labelled.
- The vehicle should be washed and cleaned, inside and out, regularly. Particular attention should be paid to door handles, driver's cabin, steering wheel and pesticide storage area.
- Check State regulatory requirements in relation to the transport of hazardous materials

Approaching pest control treatment

- Know clearly the purpose of the treatment; that is, the pest(s) to be controlled (or, as may be the case with termites, to be prevented).
- Know the habits and biology of the pests concerned.
- Consider and, where possible and appropriate, implement non-chemical measures towards the control or prevention of pests.
- Choose appropriate, clean and well-maintained equipment, and use it correctly.

- Where pesticides are to be used, choose:
  - registered pesticides;
  - pesticides with the lowest mammalian toxicity that are appropriate and effective for the particular job;
  - pesticides with the least persistence that are effective for the job; and
  - pesticides with the lowest perceived hazard level.
- Take special care in the selection of pesticides and formulations in jobs involving sensitive conditions (eg buildings occupied by very young or very old people and buildings containing sensitive equipment/technology that may be damaged by some sprays and dusts.
- Read the labels of pesticides carefully, to ensure appropriateness and safety.
- Ensure that the proper protective clothing and equipment for the chosen pesticides are available for the job.
- Thoroughly survey the area to be treated:
  - Cover and/or remove dishes, utensils etc.
  - Ensure that no food is directly exposed to the treatment.
  - Cover plastics where dichlorvos is to be space-sprayed.
  - Remove aquariums (where feasible), other pets, pet feeding bowls etc.
  - Exclude pets from treated areas until treatment is complete and all areas are dry and ventilated.
  - Cover fish ponds in gardens if pesticide contamination is possible.
  - Check adjoining properties for beehives, aviaries, fish ponds and the like if pesticide drift is a possibility.
  - Check for pilot lights and turn off, assuming pesticide applications to be flammable, unless certain knowledge dictates otherwise.
  - Give clear instructions to people present about staying clear of treatment procedures, vacating premises, and so on, as may be required.

Preparing for a pest control treatment

- Remember that concentrates are usually much more potent poisons and have much higher concentrations of strong solvents than their diluted spray mixes.
- Do not allow children or pets to be nearby when handling, mixing or applying pesticides.
- Read mixing instructions on labels, and follow directions accurately.
- When handling concentrates, wear appropriate protective clothing and equipment while mixing. This may include a face shield to protect against splashes, and/or a respirator to protect against inhalation.
- Handle pesticide containers with care, to avoid damage to the container or its label. If a container leaks, the contents should be transferred to an appropriate container that is duly labelled.
- Prepare spray solution in a well-lit ventilated area.
- Use scissors to open sachets more cleanly with a minimum of spillage/drift.
- Pour liquids and dusts carefully, to avoid drift.
- Fit a pouring device to drums that are otherwise difficult to pour from.
- When opening pesticide containers, keep the face away from the opening.
- When filling the bulk tank, do not allow the feeder hose to come into contact with the spray solution. A drop in local water pressure could facilitate 'back siphoning', which could contaminate the local water supply.
- Do not combine different pesticides, unless label information clearly indicates that you can.
- Calculate and mix only the amount of chemical needed for the job.
- Before commencing pesticide application, ensure that the area to be treated has been thoroughly surveyed and that any necessary safety measures have been implemented.

During a pest control treatment

- Read pesticide labels, and follow application directions, safety directions and precautions. Do not overdose.
- Do not allow adults, children or pets nearby while applying pesticides.
- Ascertain that pesticides in your vehicle or elsewhere are inaccessible to children, pets and the like.
- Wear appropriate protective clothing and equipment as indicated on the label and/or in relevant state government legislation.
- Do not eat, drink or smoke while applying pesticides. Always wash face and hands (at least) before eating, drinking or smoking.
- Do not apply pesticides to entire walls, as this is likely to create a hazard.
- Do not directly treat areas or surfaces on which pets sleep (unless label permits). These should be laundered or disposed of.
- Do not apply pesticides directly to food, food preparation surfaces, utensils etc.
- Do not place poison baits within access of children or pets.
- Do not agree to treat pet animals directly. Only appropriately registered, specific products for that purpose (eg powder, shampoo, rinse) should be used, by the owner or a vet.
- Do not give or sell pesticides to clients.
- Do not rub the eyes or touch the mouth during pesticide application.
- Do not 'blow out' nozzles with the mouth.

- If clothing becomes contaminated by pesticide, quickly remove clothing and wash skin thoroughly. To avoid poisoning, time is of the essence. Wash contaminated clothing before reuse.
- When spraying outdoors, do not do so if wind is likely to cause spray to drift. Use a relatively 'heavy' droplet size with relatively low pressure to reduce the possibility of drift. Fine mist sprays are much more likely to create drift problems.
- Do not contaminate waterways (eg creeks, streams, lakes, stormwater channels) with pesticide.
- Do not spray persistent chemicals liberally around gardens or other grounds. Where spraying with such chemicals is necessary and appropriate, localised, specific treatments should be carried out.
- Should a pesticide be spilt, contain its movement by applying specific absorption material for spillages (or if unavailable, sand, soil or some other absorptive material that will safely contain the spill, and immediately contact the relevant authorities (usually the state Department of Health).
- Should a poisoning or suspected poisoning occur, carry out appropriate first aid measures, call the Poisons Information Centre (131126) and notify the state Department of Health.
- Do not spray firewood or any type of fuel as, when set alight, it may release toxic smoke.

After the treatment

- Rinse or clean out application equipment at the end of each job.
- Return cleaned equipment (and pesticide containers) to vehicle or other store.
- Make the necessary arrangements for not allowing persons or pets into the treated area for a specified time. This may involve posting 'warning signs' and giving instructions regarding ventilation before reoccupation.
- Do not leave mixed pesticides in application equipment for extended periods.
- Remove protective clothing and equipment. Store respirator in protective plastic bag.
- Wash at least face, neck, hands and arms (shower if feasible), and put on clean clothes.
- Maintain a record/diary of pesticides used.

After the day's work

- Clean respirator(s). Remove canister or cartridges (discard if appropriate). Wash face piece with water and detergent, shake and allow to dry. Check inlet and outlet valves.
- Wash gloves inside and out. Check for leaks and allow to dry.
- Wash clothes worn during the day's work. Contaminated overalls should be washed separately from other laundry.
- Shower thoroughly. Pay particular attention to the neck, hair and under fingernails.

Storage and disposal of pesticides and their containers

- Check State Regulations in relation to pesticide storage so as to ensure compliance. Local fire fighting authorities should be advised of the hazardous nature of the storage area.
- The pesticide storage facility should be located remotely from human or animal dwellings, preferably in a shady area.
- The storage facility should be:
    - constructed of fire-resistant materials;
    - well ventilated;
    - equipped with fire extinguishers,
    - clearly labelled on the outside as to the hazardous nature of the contents eg:

DANGER — HAZARDOUS PESTICIDES STORAGE
(check requirements under State legislation and regulations).

    - entirely lockable and inaccessible to children and pets;
    - built with an impervious floor surface (not carpet, wood, foam and the like);
    - built with sufficient bunding, to prevent run-off in case of spillage, and this should drain into a pit where spills can be neutralised;
    - have easily accessed absorption material in case of spill.
- Protective equipment (eg respirators) should not be stored in close proximity to pesticides.
- Containers of stored pesticide should be tightly closed, clean and with their original label intact.
- Containers should be periodically checked for any potential leaks owing to corrosion.
- Food must never be kept in the pesticide storage area.
- Product labels and Material Safety Data Sheets should be read before storing pesticides, in case there are specific directions relating to storage.
- Unregistered pesticides must not be purchased or stored without the permission of the relevant government authority.
- Dispose of empty pesticide containers safely:
    - When finishing a glass, metal or plastic container, rinse it with water several times. Rinsings can be incorporated in spray mix being prepared at the time.
    - Always keep empty containers for disposal securely locked in the pesticide storage facility.
    - Aerosol containers must never be punctured or burnt. They are usually accepted at dumps (but check first).
    - Large metal drums may be thoroughly rinsed and passed on to a drum reconditioner who

can handle containers that have held hazardous pesticides.
    - Smaller metal containers, when well rinsed (with water and detergent where necessary) should be rendered unusable by punching holes in the tops and bottoms and crushing where possible. The drums may then be buried or disposed of at an appropriate dump depending upon local/state regulations (consult relevant waste management authority).
- Where pesticide is to be disposed of, consult the relevant waste management authority for guidelines.
- Avoid the need to dispose of pesticides by planning treatments accurately and making up spray mixes according to how much will be needed.
- Do not keep unregistered or unlabelled pesticides, as these also should be disposed of, unless special arrangements with the authorities dictate otherwise.

PESTICIDE-RELATED EMERGENCIES AND FIRST AID*

It is important to realise that different pesticides affect humans in different ways, and a knowledge of symptoms of possible poisoning is essential for all who use pesticides. Any unusual signs or symptoms in people exposed to pesticides during the preceding eight hours must be treated as possible poisoning. The following alert procedures should be adopted:

- Remove victim immediately from source of exposure.
- Remove contaminated clothing, including shoes, and wash skin thoroughly but gently with soap and water. DO NOT SCRUB SKIN.
- Check the pesticide label for correct 'safety directions' and 'first aid'.
- Start first aid procedures immediately, call a doctor, and keep patient quiet, warm and comfortable.
- Contact the Poison Information Centre on 131126, anywhere in Australia.
- If label prescribes administration of antidotes and these are available, follow directions accordingly.
- DO NOT GIVE ANYTHING BY MOUTH IF VICTIM IS UNCONSCIOUS.
- If victim is not breathing, apply artificial respiration.

In all cases of poisoning, speed is essential. Removal of source of contamination, rapid implementation of first aid procedures, and transport to hospital or doctor may save a life.

How pesticides affect humans and how to recognise these effects

IMPORTANT: The information in this section may help to save a life — yours. Or your friends'.

Even if this manual is close by when an accident occurs, there may not be time to find and read this section, or the one on first aid, before you are obliged to take action.

This information should be in your head — not just in the manual.

The ways in which pesticides affect humans and other mammals are commonly referred to as 'modes of action'. The modes of action of a number of pesticides in use today are either not known or, in some instances, are only partially understood. However, medical research does provide sufficient information to permit certain generalisations.

Even though it may not be known exactly how a pesticide poisons the body in all cases, the signs and symptoms resulting from such poisoning should be recognised by those who use pesticides.

Remember, everyone is subject to various sicknesses or diseases. Therefore, it cannot be assumed that, because an individual is in the vicinity where pesticides are or have been used, certain signs or symptoms are the result of pesticide poisoning. But if any signs or symptoms appear after contact with pesticides, call your doctor and advise him or her of the nature of the pesticide involved.

You should be alert to the early stages of signs and symptoms of poisoning, and immediately and completely remove the source of exposure (chemical), such as contaminated clothing. By so doing, you may prevent additional exposure and minimise injury. In some instances, early recognition of these warnings and immediate and complete removal of the source of exposure may save your life.

NOTE: The symptoms and signs described here may occur in a person who has been suddenly exposed to lethal quantities of a toxic material, or they may occur in a person who has been continuously exposed to smaller quantities of toxic material over an extended period of time. In either case the same emergency procedure should be followed.

Modes of action — signs and symptoms

Organophosphorus insecticides Examples include dichlorvos, diazinon, maldison, azamethiphos, chlorpyrifos, fenthion.

These pesticides attach themselves to a chemical in the blood that is normally present and necessary for proper nerve functions. This chemical is an enzyme known as cholinesterase. Since the action of the organophosphorus insecticides 'ties up' the enzyme cholinesterase, they are referred to as 'cholinesterase inhibitors' or 'anti-cholinesterase compounds'.

When cholinesterase is 'tied up' and unable to perform its normal function, the nerves in your body continue to send messages to certain muscles, which make them move constantly. These constant muscle twitchings and weaknesses are referred to as tremors or fibrillations. If this muscle action becomes intense, you may have fits or convulsions, which are simply uncontrolled, violent muscle actions.

Other signs and symptoms may be pinpointing of pupils of the eye (miosis); blurred vision; eyes watering (lacrimation);

uncontrollable drooling or watering at the mouth (salivation); dizziness (vertigo); excessive sweating; rapid heartbeat (tachycardia); vomiting; stomach cramps, watery stools (diarrhoea); difficult breathing (dyspnoea); loss of ability to use muscles; loss of ability to control bowels; unconsciousness (coma). These last four signs are seen only in advanced or severe cases of poisoning. Even though the patient may be near death at this stage of poisoning, he may be saved if the proper medical treatment is obtained quickly, and continued for a long enough period of time.

Carbamate insecticides Examples are bendiocarb, propoxur, carbaryl, methomyl.

The mode of action of these compounds is very similar to that of the organophosphorus compounds, that is, they inhibit the enzyme cholinesterase. However, they differ in action from the organophosphorus compounds in that the effect on cholinesterase is brief, because the carbamates are broken down in the body rather rapidly. Carbamates are referred to as 'rapidly reversing inhibitors' of cholinesterase. The reversal is so rapid that, unless special precautions are taken, measurements of blood cholinesterase of human beings or other animals exposed to carbamates are likely to be inaccurate and always in the direction of appearing to be normal.

The symptoms of carbamate poisoning are essentially the same as those caused by the organophosphorus pesticides.

Organochlorine insecticides Examples are aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, lindane.

These compounds act on the central nervous system, but the exact mode of action is not known. Large doses cause diarrhoea and vomiting. Repeated large doses can cause liver and kidney damage in animals, but these signs have not been demonstrated in man. Nervousness and convulsions may occur.

Arsenic Examples are arsenic, arsenic pentoxide, arsenic trioxide and sodium arsenate.

Arsenical compounds poison the cells of most body tissues and also affect certain enzymes, thereby slowing down a number of the body's normal functions. The victim may experience stomach and intestinal pain, vomiting, diarrhoea, and a severe drop in blood pressure, which may cause dizziness. In chronic cases the skin, liver and nerves may be affected, and the patient may experience difficulty in walking. Chronic poisoning has not been a problem with pesticide applicators.

Sodium fluoroacetate (rodenticide - compound 1080)
The mode of action of this chemical is poorly understood. It affects the heart and nervous system in most animals and certain muscles in some species. It is only available to trained and licensed operators and should not be allowed in the hands of unauthorised persons.

Botanicals (plant derivatives) Botanical insecticides vary greatly in their chemical structure as well as their toxicity to humans, ranging from pyrethrum, one of the least toxic to mammals of all the insecticides currently in use, to strychnine, which is extremely toxic.

Pyrethrum — Injury to man from pyrethrum usually results in minor cases of skin allergies, sneezing, runny nose and, in some instances, stuffiness of the nose. Usually, such signs and symptoms are of a mild nature. However, some people are sensitive to pyrethrum.

Do not confuse the pyrethrum derivatives from natural sources with the newly developed range of synthetic pyrethroid compounds. Many of these synthetic pyrethroids are toxic to mammals, fish and other forms of wildlife.

Anticoagulants Examples are warfarin, diphacinone, coumatetralyl, brodifacoum, bromadiolone.

There are two types of actions from poisoning with the anticoagulants. One is an effect on the blood, which reduces the body's ability to produce blood clots, and the other is damage to certain tissues that carry blood throughout various portions of the body. This leads to bleeding if any portion of the body is even slightly damaged. The first symptoms of a person who attempted suicide using warfarin, in which he consumed the equivalent of 1 pound (454 g) of bait (0.025% warfarin) per day for six consecutive days, were back and stomach and intestinal pains. These occurred one day after the six daily doses had been consumed in this suicide attempt. One day after the symptoms began to appear, vomiting and several attacks of nose bleeding occurred. On the second day of illness, small red patches appeared on the skin in the form of a rash. There was blood in this patient's urine. When laboratory tests were run on this individual's blood, it was found that it took much longer than usual for the blood to form clots. In another case massive bruises developed at the knee and elbow joints, as well as on the person's buttocks. Extensive nose-bleeding occurred about a day later. Effective antidotes are available.

Methyl bromide Methyl bromide is among the most hazardous materials used in pest control. The mode of action of this compound is to affect the protein molecules in certain cells of the body. The signs and symptoms produced by this compound are severe chemical burns of the skin and other exposed tissue, delayed chemical pneumonia, which produces water in the lungs, and severe kidney damage, as well as extreme nervousness. Any of these effects can be fatal. If a person inhales smaller amounts of methyl bromide, it sometimes produces effects that give the appearance of alcoholic intoxication. Repeated mild exposures do accumulate and produce skin rashes. Sometimes mental confusion, double vision, tremors, lack of co-ordination follow, and often the slurring of speech. Victims of poisoning have been jailed or sent to mental hospitals by mistake. The effect of methyl bromide poisoning is permanent and irreversible.

Carbon tetrachloride This chemical affects the nerves and damages the cells in the kidneys and the liver severely, and great care should be taken when handling carbon tetrachloride. Good ventilation is essential, as the effect is permanent.

Synthetic pyrethroids Examples include bioresmethrin, cypermethrin, deltamethrin, fenvalerate and permethrin.

The synthetic pyrethroid compounds are only a relatively new development, and no known cases of poisoning have yet been recorded.

Reports have been submitted on laboratory and field workers who have had exposure to these compounds. They have experienced transient sensations in the peri-orbital area of the face, these being likened to the sensations experienced when a dental anaesthetic is wearing off, or the sensation after contact with stinging nettles (no blisters or rash are recorded).

The sensations last for a few hours but have been known to persist for a full day after exposure.

In view of the widely differing properties of this group of compounds, care should be exercised, especially when handling concentrates.

Emergency treatment in the event of chemical poisoning

Poisoning due to a known mishap or accident

- Follow First aid's DRABC:
  - Remove yourself and patient from Danger.
  - Check for Response from patient to determine consciousness.
  - Check Airway.
  - Check Breathing.
  - Check Circulation (pulse).
- Using protective gloves and a mask, remove any contaminated clothing.
- Start the first aid treatment immediately. See product label for details.
- Call a doctor or the Poisons Information Centre on 131126 (anywhere in Australia) as quickly as possible, but do not abandon the first aid treatment.
- Keep the patient as quiet as possible, and complete the first aid treatment. Keep patient warm and comfortable.

IF YOU ARE ALONE WITH THE VICTIM

FIRST — Ensure no danger to yourself from contaminants.

SECOND — Check that the patient is breathing. If not, give artificial respiration. (Remove any contaminants from the patient's face with clean water.)

THIRD — Decontaminate patient immediately; that is, wash thoroughly. Speed is essential.

FOURTH — Call a doctor or medical assistance.

NOTE: Do not substitute first aid for professional treatment. First aid is only to relieve the patient before medical help is reached.

IF ANOTHER PERSON IS WITH YOU AND THE VICTIM

Speed is essential: one person should begin first aid treatment while the other calls a doctor and/or the Poisons Information Centre on (131126).

The doctor will give you instructions. He or she will very likely tell you to get the victim to the emergency room of a hospital. The equipment needed for proper treatment is there. Only if this is impossible should the doctor be called to the site of the accident.

GENERAL

1 Give mouth-to-mouth artificial respiration if breathing has stopped or is laboured.
2 Stop exposure to the poison; if poison is on skin, cleanse the person, including hair and fingernails. If swallowed, do not induce vomiting unless advised by the Poisons Information Centre or a doctor. Do not give anything if the victim is unconscious.
3 Save the pesticide container and material in it if any remains; get readable label or name of chemical(s) for the doctor. If the poison is not known, save a sample of any vomit.

POISON ON SKIN

- Remove clothing, taking care to avoid contact with the poison.
- Drench skin with cool water (shower, hose, tap or bucket).
- Cleanse skin and hair thoroughly with soap and water; rapidity in washing is most important in reducing extent of injury.
- Dry and wrap in blanket.
- Call the Poisons Information Centre (131126).

POISON IN EYE

- Hold eyelids open, wash eyes immediately, gently, with stream of clean running water. Use copious amounts. Delay of a few seconds greatly increases extent of injury.
- Continue washing for 15 minutes or more.
- Do not use chemicals or drugs in wash water. They may increase the extent of injury.
- Call the Poisons Information Centre (131126).

INHALED POISONS (dust, vapours, gases)

- IF VICTIM IS IN ENCLOSED SPACE, DO NOT GO IN AFTER HIM WITHOUT AIR-SUPPLIED RESPIRATOR.
- Carry patient (do not let him walk) to fresh air immediately.
- Open all doors and windows.
- Loosen all tight clothing.
- Apply artificial respiration if breathing has stopped or is irregular.
- Call a doctor and/or the Poisons Information Centre (131126).
- Prevent chilling (wrap patient in blankets, but don't overheat him).
- Keep patient as quiet as possible.

- If patient is convulsing, watch his breathing and protect him from falling and striking his head on the floor or wall. Keep his chin up and head back, so his air passage will remain free for breathing.
- Do not give alcohol in any form.

SWALLOWED POISONS

- Call a doctor and/or the Poisons Information Centre (131126) immediately.
- Do not induce vomiting unless advised to by the Poisons Information Centre.
- If the patient can swallow after ingesting a corrosive poison, (any material which, in contact with living tissue, will cause destruction of tissue by chemical action, such as lye, acids, Lysol, etc.) give the following substances by mouth:
  - — For acids: milk, water, or milk of magnesia (1 table spoon to 1 cup of water).
  - — For alkalis: milk or water; for patients 1–5 years old, 1–2 cups; for patients 5 years and older, up to 1200 ml.
- If the symptoms are those of a moderate or severe case of organophosphorus or carbamate poisoning, and the patient is conscious, give two atropine tablets (0.5 mg each) immediately.
- If medical help cannot be obtained or is delayed, transport the patient to the nearest hospital, doctor's surgery, or Poisons Information Centre. Take the pesticide label or any available records of pesticides used; and any other information.

CHEMICAL BURNS OF SKIN

- Wash with running water for up to 15 minutes.
- Remove contaminated clothing.
- Immediately cover with loosely applied clean wet cloth; any kind will do, depending on the size of the area burned.
- Avoid use of ointments, greases, powders and other drugs in first aid treatment of burns.
- Treat shock by keeping patient flat, keeping him warm and reassuring him until the doctor arrives.

First aid treatment

GENERAL

MOVE VICTIM WELL AWAY FROM ANY PESTICIDE

Quickly move the patient to safe, uncontaminated surroundings, and remove any contaminated clothing.

IF BREATHING IS VERY WEAK OR HAS CEASED

1. Give artificial respiration.
2. Oxygen can be beneficial but should be applied only under expert supervision.

IF PESTICIDE HAS BEEN SWALLOWED

1. If the patient has not vomited, do not induce vomiting unless advised by the Poisons Information Centre (131126).
2. Give milk or cold water freely.

   DO NOT GIVE ANYTHING BY MOUTH TO A PERSON WHO IS UNCONSCIOUS, OR HAVING CONVULSIONS.

IF PESTICIDE SPLASHED IN THE EYE

1. Wash the eye with clean water, immediately. Speed is essential to prevent injury to the eye.
2. Use large amounts of clean water gently to irrigate the eye.
3. Continue for at least 15 minutes.

IF PESTICIDE SPILLED ON THE SKIN

1. Remove all contaminated clothing. Cover patient with clean clothing or a clean blanket.
2. Wash the skin thoroughly with plenty of soap and water immediately.
3. Clean under fingernails and toenails.

IF RESPIRATION BECOMES WEAK OR IRREGULAR

1. Give artificial respiration. Maintain breathing and prevent worsening of condition.
2. Oxygen can be beneficial but should be applied only under expert supervision.

   ARTIFICIAL RESPIRATION TAKES PRECEDENCE OVER ALL OTHER FIRST AID.

IF CONVULSIONS OCCUR

1. Keep patient warm and dry.
2. Prevent injury. Use gentle restraint.

IF UNCONSCIOUSNESS OCCURS

1. Place patient on side. Ensure patient can breathe adequately. Push jaw forward to prevent tongue falling back.
2. Keep patient warm and dry.

   DO NOT GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON.

IF ORGANOPHOSPHORUS OR CARBAMATE PESTICIDES ARE INVOLVED AND SYMPTOMS ARE SEVERE

Administer 2 atropine tablets of 0.5 mg each if available. Do not give atropine if patient is already turning blue because of inadequate respiration, or is unconscious.

IF YOU KNOW THE TYPE OF PESTICIDE

Check the appropriate pesticide group (see Table 10.3) for additional first aid information.

OBTAIN MEDICAL ATTENTION AS QUICKLY AS POSSIBLE

First aid kit

This should include:

- Clean water
- Nail brush
- Pure soap
- Skin lotion
- Scrubbing brush
- Boracic acid
- Methylated spirits
- Clean blanket
- Clean clothing
- Atropine tablets
- Shaped plastic airway for mouth-to-mouth resuscitation

Antidotes — their use by non-medical people

An antidote is a remedy used to counteract the effects of a poison, or prevent or relieve poisoning.

Therefore, good judgement and safety practices, including the use of protective clothing, safety devices and knowledge of first aid, are in a sense antidotes, since they can and most times do prevent poisoning. However, the general public is inclined to think of antidotes almost exclusively in terms of special chemicals that must be purchased from a chemist or prescribed by a doctor.

This brief discussion of some of the more common antidotes will group these materials as to internal or external use, general mode of action, and from whom they may be obtained.

In addition, note the warning statements against the misuse of two antidotes (atropine and 2-PAM), which are drugs requiring a prescription from a doctor before they may be purchased.

Antidotes for external use

Clean water dilutes and washes away poisons. Recommended for poison in eyes or on skin and other tissues. Always have readily available at least 20 litres of clean water for emergency use when you are handling pesticides.

Soapy water dilutes and washes away poisons. Recommended for poison on skin, hair, under fingernails and other external tissues not irritated by soap.

Note: In an emergency use any source of reasonably clean water, such as irrigation canals, dams, ponds, watering troughs and so on. Don't let the victim die while you worry about how dirty the water is.

Antidotes for internal use

CHECK FIRST AID INSTRUCTIONS BEFORE GIVING ANYTHING TO A PERSON BY MOUTH.

- Clean water dilutes poison.
- Milk dilutes poisons and helps counteract acid or alkali poisons.
- Milk of magnesia counteracts acid poisons. It is often readily available from home medicine chests or it may be obtained from a chemist.

Universal antidote Have your chemist mix 2 parts activated charcoal, 1 part magnesium oxide, and 1 part tannic acid. Use 15 g in half a glass of warm water as an antidote to absorb or neutralise poisons but only if advised to by the Poisons Information Centre.

Activated charcoal alone absorbs many poisons. It can be administered as a thick soup (slurry). Obtain from a chemist.

Vitamin K (phytonadione) is used against anticoagulants, such as warfarin (rodenticide), and can only be given by a doctor.

BAL (dimercaprol) is a specific antidote for arsenic poisoning. It must be injected by a doctor.

Atropine is used to counteract the effects of cholinesterase inhibitors, such as organophosphorus and carbamate pesticides. Dangerous if misused and can be difficult to obtain. Keep away from children. Obtain an emergency supply of 0.5 mg tablets.

2-PAM (protopam) is used to counteract effects of many organophosphorus pesticides. It has been most effective against parathion poisoning. 2-PAM is frequently suggested for use in conjunction with atropine for organophosphorus poisoning. It is not to be used against the organophosphorus insecticide malathion (maldison), or the carbamate pesticides, as it is virtually ineffective.

Use of atropine and 2-PAM Neither atropine nor 2-PAM should be taken by workers as a prophylactic measure. They will not prevent poisoning. Workers should not carry atropine or 2-PAM for first aid. Oral atropine has no place in a real poisoning emergency. The dose is much too small, and the victim cannot take oral medication when he is vomiting or stuporous. Atropine tablets can mask temporarily or delay early symptoms of poisoning, and this procedure can be detrimental in at least two ways. Workers can go back to work and continued exposure; or if the worker is taken to a doctor who does not know that atropine has been taken, the diagnosis of poisoning can be missed or delayed. Although two atropine tablets are not very toxic to an adult, they do give a false sense of security, delay or prevent prompt medical treatment, and they cause important first aid measures to be neglected.

Artificial respiration procedure

Expired air respiration (either mouth to nose or mouth to mouth) is the accepted artificial respiration method. Learn the method well.

A few minutes of practice to develop coordination and know-how is an investment that may some day save the person whose life depends on you. DO NOT WASTE TIME. Start immediately, and don't stop. Seconds and perseverance may save a life.

Warning: Ensure the casualty's facial skin is free of pesticide contamination, which may incapacitate the person administering resuscitation.

The Australian Resuscitation Council suggests the use of the following procedures when using mouth-to-mouth resuscitation:

- Clear the airway
- Tilt
- Blow
- Look
- Listen

1 **Clear the airway** (This should take no more than 3–4 seconds.) Quickly turn the casualty on his side. Remove any vomitus or foreign material with fingers, if necessary. Also remove loose dentures. Firmly fitting full dentures should be left in position, as they will make the mouth seal easier.

2 **Tilt** Turn the casualty on his back and tilt his head backward, supporting the jaw but avoiding any pressure on the neck.

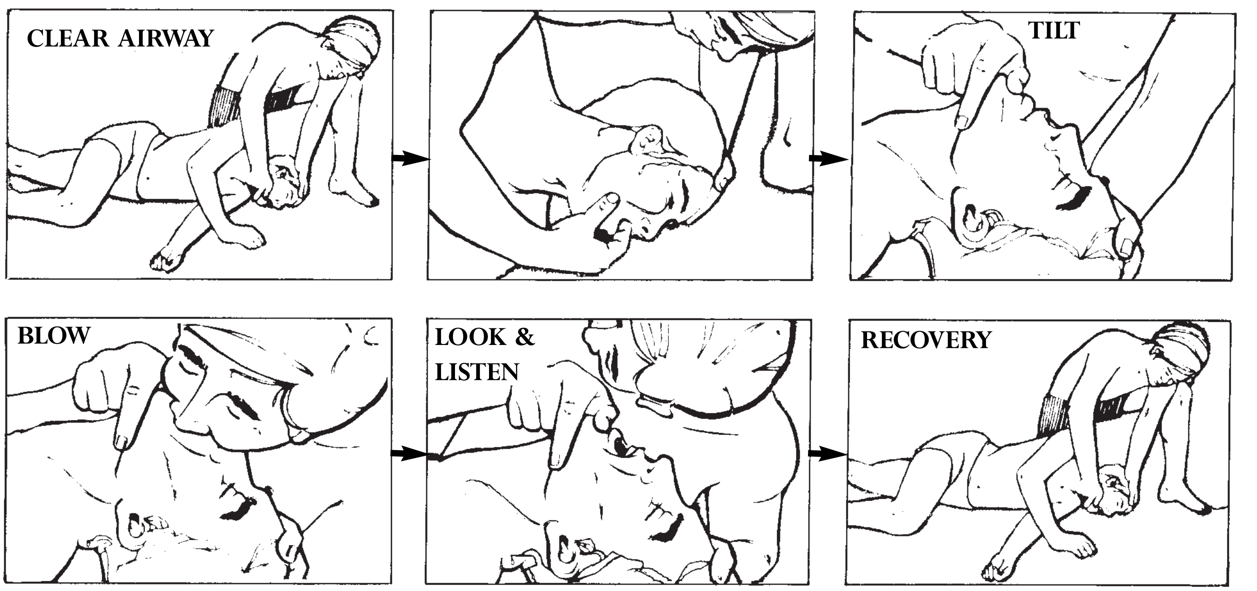
3 **Blow and look** Place your widely open mouth over the casualty's slightly open mouth, sealing the nose with your cheek. and blow to inflate the casualty's lungs. If the chest does not rise, check for obstruction in the airway.

4 **Listen and look** Following inflation of the lungs with an obvious rise of the chest, lift your mouth from the casualty's, turn your head to the casualty's chest, and listen and feel for the air being exhaled.
Observe the casualty's stomach, to ensure that it has not been distended with air. If stomach is distended, check airway.
DO NOT APPLY PRESSURE TO THE STOMACH.

5 **Repeat** Repeat this cycle 15 times per minute for adults, 20 times per minute for children.

6 **Synchronisation** Once the casualty starts to breathe, keep your breath in time with his until breathing appears adequate.

7 **Recovery** Once the casualty can breathe adequately for himself, he should be nursed on his side (the lateral or recovery position as shown opposite). A check should be maintained on his airway, breathing and circulation.



*Reproduced and adapted from *A Manual of Safe Practice in the Handling and Use of Pesticides*, prepared by Pesticides Section, Department of Primary Industry, Canberra. Document PB377. 1982 Chapter 11: 'Emergencies'.

NOTE:
Always carry Material Safety Data Sheets in an easily retrievable form for information pertaining to emergency procedures or other issues as they relate to each particular pesticide product.

FURTHER READING

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Tomlin C. (ed) 1997 *The Pesticide Manual* British Crop Protection Council UK

Turnbull G.J. (ed) 1985 *Occupational Hazards of Pesticide Use* Taylor & Francis London

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CHAPTER 11

HOUSEHOLD PESTS

The pests dealt with under the heading of 'household pests' do not, to any extent, limit their activities to 'household'-type buildings. The term probably derives from the traditional association of certain pests with 'households', which historically have been much more self-sufficient than is the case now. The complexity of contemporary urban environments is such that 'household pests' can find and exploit a vast range of micro-environments within the commercial and industrial sector as well as in domestic dwellings.

In common usage, the term 'household pests' often refers to pests such as cockroaches, ants, flies, mosquitoes, fleas, bedbugs, lice and fabric pests. The ways in which these insects intrude on environments, and the types of problems posed, vary greatly.

Cockroaches and ants Both of these groups can be described as scavengers. Those species of cockroaches and ants that have achieved pest status are often involved in exploiting foods that humans, for the main part, make available for them. Within buildings, inefficient waste disposal, inadequate food protection, and poor general conditions of sanitation and hygiene often provide the means for supporting their activities. The role that such scavengers may play in the transmission of diseases to humans is perhaps the most significant aspect of their pest status.

Flies and mosquitoes The problems presented by flies and mosquitoes are diverse. Flies may be regarded as scavengers, so standards of sanitation and hygiene are often, but not always, directly connected with the extent of the fly problem posed. Mosquitoes utilise contained water, artificial or natural, to produce adults, of which the females require blood meals for reproduction. The great mobility of the adults of both flies and mosquitoes not only can result in widespread disease transmission and pervading irritation, but also severely constrains the effectiveness of attempts at control.

Fleas, bedbugs and lice These three groups are parasites, which vary in their mode of operation. Fleas in urban environments are largely a result of widespread pet ownership. The young stages of fleas are basically scavengers in the environment that pets and humans occupy. On attaining adulthood they acquire greater mobility and a dietary requirement for blood, which may result in disease transmission or just mild to severe irritation of either pets or humans. Bed bugs are parasites of humans. They spend most of their time hiding in humans' sleeping quarters, visiting the sleeping human only very fleetingly for a blood meal, which is the obligatory diet throughout their entire life history. Their distribution is relatively limited, and irritation is the chief concern. Head lice, body lice and crab lice are also parasites of humans and require blood meals throughout their entire life history. However, unlike bedbugs, they live on, or very close to, the human body. The incidence of 'lousiness' has tended to decrease with socio-historical increases in personal hygiene. Certain levels of louse-related problems that are still evident may involve disease transmission or just mild to severe irritation. Because they live in such intimate contact with their human hosts, treatment lies largely in the domain of medical and health authorities.

Fabric pests Problems associated with insects that damage fabrics, paper, and certain other animal or plant products, may involve the activity of carpet beetles, clothes moths and silverfish. In the cases of carpet beetles and clothes moths, the immature feeding stages are largely responsible for damage. The more mobile adult forms often disperse and ensure that the next generation gets a good start in life. Booklice have a nuisance value but do not usually cause serious damage.

In urban environments, the activities of 'household pests' continue to be problematic in domestic premises, small-scale food handlers (restaurants, cafes, food bars, hotels, motels), warehouses, factories, shops, hospitals, schools, offices and most other types of buildings in which humans live or work.

COCKROACHES

Cockroaches are close relatives of termites and belong to the insect Order Blattodea. They represent a primitive and highly successful group of animals whose origins extend back at least 300 million years. Fossil evidence suggests that little change in their general body form has occurred since that time.

As a group, cockroaches have exploited a diverse range of ecologies, living among decaying leaf matter, under bark, in caves and burrows, on the foliage of shrubs and in the nests of social insects, boring into wood and even adopting a semi-aquatic habit. While there are about 3500 species of cockroach worldwide, only about 10 species have seriously exploited the dwellings of humans. Some species have become very successful scavengers that cohabit with people in many, indeed most of the human communities around the world.

Despite their somewhat misleading common names, most pest cockroaches that occur in Australia and many other countries probably originated in tropical or subtropical Africa. Their wide distribution is attributed to transport in ships, carriages, and later trains and aeroplanes, facilitated by a remarkable degree of adaptation to built environments. In dwellings and various utilities for waste disposal, people have created conditions that make food, shelter and often suitable temperatures available to these very opportunistic insects. Their wide distribution and close association with humans, coupled with the high frequency with which they carry human diseases, in and on their bodies, have given them a very high pest status in most parts of the world.

Structure

Adult cockroaches are medium to large insects that, viewed from above, are mostly oval-shaped, with the head hidden beneath the pronotum. They are dorsoventrally flattened, so can make use of tight hiding places in cracks and crevices. Antennae are usually long and thread-like. Legs are often endowed with protective spikes and are suitable for crawling and running on a variety of surfaces. Compound eyes are usually well developed. Their primitive, chewing-type mouthparts allow them to exploit most types of food. Wings may be well developed, reduced or absent. In fully winged species the forewings are narrower and leathery (called tegmina), covering and protecting the more membranous hindwings. Abdomen is large and carries a pair of often prominent cerci.

Nymphs are generally similar to adults, except for the wings, genitalia and sometimes body colouring.

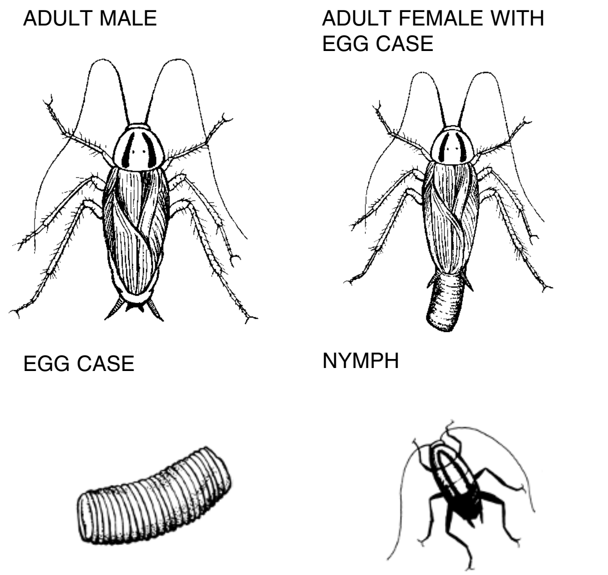


Figure 11.1 The German cockroach

Life cycle

Most cockroaches reproduce sexually and this often involves attractant pheromones (usually secreted by the female and detected by chemoreceptors on the male's antennae), courtship procedures and end-to-end copulation. Eggs developed in the female are encapsulated in a purse-shaped egg case (ootheca). Oothecae may contain about 12–40 eggs, depending on the species concerned and conditions of growth. The egg case may be dropped or glued to a surface just prior to, or months before, hatching. After hatching, the nymphs tend to congregate with the adults, coexisting in a somewhat gregarious manner. Nymphal development involves a number of moults and may take 2–4 months in some smaller species, or up to a year or more in others. Adult lifespan may be a few months to over a year, and in this time each female may produce about 5–30 oothecae, depending on the species and conditions of growth.

Habits

Typically, infestations of pest cockroaches develop in and around buildings and other structures that provide food, shelter, and often the preferred conditions of temperature and humidity. A commercial kitchen may support hundreds or even thousands of cockroaches at varying stages of development. They may be carried from place to place as live individuals or as egg cases, in foods and their packaging, luggage, furniture, buses, trains, ships and aeroplanes.

Some aspects of cockroach habits and behaviour warrant consideration:

Omnivorous feeding habit

Cockroaches eat virtually any human or animal food or beverage and any dead animal or vegetable materials. These may include leather, cardboard, fabrics, hair, glue, wallpaper glue and starchy bindings in books. They are most effective scavengers. Those bred in laboratories often subsist well on water and dog biscuits. In buildings, dried beer on carpets, spattered grease droplets and tiny crumbs can all afford nutriment. The importance of scrupulous housekeeping in any cockroach control program cannot be overemphasised.

Nocturnal behaviour

Cockroaches are mostly nocturnal creatures which hide during the day and become active soon after the onset of darkness, seeking food. In some cases activity patterns are based on sunset, while in other cases the lighting regime within a particular building dictates activity patterns. Occupants of infested premises are often unaware of the extent of cockroach activity that commences after dark. Night inspections of cockroach-infested premises can reveal much about the size of the infestation, feeding habits, hiding places and so on. Automatic insecticidal space-spray systems can be programmed to spray when the cockroaches are most active, thus maximising contact action. Active cockroaches observed during daylight hours often indicate overpopulation.

Thigmotactic behaviour

Most cockroaches rest in tight cracks and crevices with the 'security' of contacting surfaces above, below and around them. In such places, they may spend three-quarters of each day. The operator may apply an insecticide with a flushing action (eg pyrethrins) as an aerosol to such areas, causing the insects to become active and leave their hiding places, and thus giving some idea of the extent and location of infestations. In the application of surface-spray insecticides that have some residual action, the operator will attempt to treat surfaces within cracks and crevices and surfaces where significant contact with the insects is more likely to occur.

Gregarious behaviour

Immature and mature cockroaches often congregate and rest together. In some, an aggregation pheromone found on the cuticle and in the faeces induces aggregation during rest, and probably acts as a kind of 'signpost' on their return from feeding ventures. Conditions of overcrowding can cause activity even during daylight. In extreme cases of overcrowding, mass migrations of cockroaches may occur.

Grooming behaviour

Like many other animals, cockroaches frequently indulge in grooming themselves. This behaviour probably plays an important role in keeping sensory receptors clean and well functioning. Grooming often consists of running the antennae and legs through the mouthparts with a nibbling action. This behaviour may be exploited in their control. Dusts, and to some extent other types of formulation, are picked up on the body and ingested during grooming.

Why cockroaches are considered pests

Cockroach species that have established some type of cohabitation with humans are widely regarded as pests. While their role in the transmission of diseases to humans is usually the main concern, there are various reasons for pest status:

Contamination

Cockroaches may contaminate food products, utensils and various areas with droppings, cast skins, empty egg cases, dead cockroaches and vomit marks on surfaces.

Annoyance or fear reaction

Many people are annoyed or scared by the sight of cockroaches. This may be related to their fast, unpredictable movements and perhaps very spiky legs. Many find their presence abhorrent.

Odour

Where a substantial cockroach infestation exists, an unpleasant odour may develop, owing to secretions from the mouth and cuticle.

Allergic reactions

Some people are allergic to cockroaches. Extracts of cockroaches can bring about positive skin reactions in sensitive people, and may cause an asthma attack in asthmatics. The allergen may be ingested where foods are contaminated with faeces, or inhaled when dried faeces becomes a part of house dust.

Bites

Cockroaches have been known to bite people, although such incidences are rare. In ships where the cockroach population was exceedingly high, sailors have suffered bites and gnawing of the fingernails, toenails, calloused parts and occasionally softer skin.

Disease transmission

Cockroaches carry diseases of humans. Although cockroaches have never been irrefutably proved to have transmitted pathogenic diseases to humans, several factors point to the likelihood that they play an important role in such disease transmission:

- Cockroaches often dwell in environments that support the growth of organisms causing diseases harmful to humans (eg sewers, grease traps, other sources of polluted water).

- The same cockroaches may contact various surfaces (including food) in kitchens and food processing or handling facilities.
- Cockroaches are known to carry, on their cuticle and in their gut and faeces, disease organisms of humans. Each cockroach may typically carry several million bacteria on and inside its body. A variety of disease organisms may be carried, including *Salmonella* (a genus of bacterial organisms that cause diseases, including food poisoning conditions, in humans and other animals), and other organisms causing gastroenteritis, dysentery, tuberculosis, hepatitis, typhoid fever and many other human disorders. Organisms that have been found naturally contaminating cockroaches include:
  - forty species of bacteria pathogenic to humans;
  - the eggs of seven species of worms parasitic to humans;
  - a variety of viruses potentially harmful to humans; and
  - several pathogenic protozoa.

The health threat posed by cockroach populations that closely cohabit with humans is considered by most to be very serious. It is likely that cockroaches are responsible for much transmission of human diseases — perhaps most commonly intestinal-type diseases (eg *Salmonella* food poisoning). This reason by itself justifies, indeed, some would say necessitates, the control of cockroaches in premises.

Important pest cockroaches

Tables 11.1 and 11.2 give some information on the life history, features and occurrence of pest cockroaches.

German cockroach (*Blattella germanica*)

The relatively small German cockroach is probably the most widespread and successful cockroach that coexists with humans in buildings. It is the most prolific breeder of all the pest cockroaches, taking as little as 40 days to develop from hatching to adulthood. Adults are light amber-brown, with two dark longitudinal dark stripes on the pronotum. Egg cases are usually carried by the female until just prior to hatching, and these may contain 30–40 eggs. Generally, there may be 3–4 generations a year.

This cockroach seeks conditions that provide warmth, moisture and food. The vast majority of infestations are associated with kitchens or other food-handling areas, both domestic and commercial. Within such areas, adults and nymphs find cracks and crevices in which they hide during the day. If numbers of cockroaches are seen during daylight, or if cockroaches are observed in non-food-handling areas within a building (eg bedrooms), it is likely that the building is supporting an enormous population. In kitchens, pantries, storerooms and other food-handling areas, the German cockroach is usually found under sinks and cupboards, in and under drawers, in and around water heaters and appliances such as refrigerators, stoves, and in wall voids adjoining kitchens and bathrooms. Infestations are common in food-handling factories, warehouses, storerooms, restaurants, cafes, food bars, domestic kitchens and the catering or canteen areas of office blocks, hospitals, hotels, clubs, schools, convalescent homes and most other types of buildings. It will eat almost any organic material found in food-handling areas, ranging from crumbs to built-up grease. Where water is available, adults may survive up to about a month without food.

Figure 11.2 Female German cockroach (*Blattella germanica*) with egg case — (Family Blattellidae)

Although adults are winged, this cockroach does not seem to fly. Its very wide dispersal is attributable largely to human error, whereby egg cases or, more often, nymphs and adults are transported to new locations in food packages, crates of drinks, cardboard boxes and the like. Its small size facilitates establishment in small cracks and crevices, and its prolific breeding capacity allows it to build up large populations in a relatively short period of time. Often, efforts aimed at controlling this most successful scavenger are regularly and constantly made.

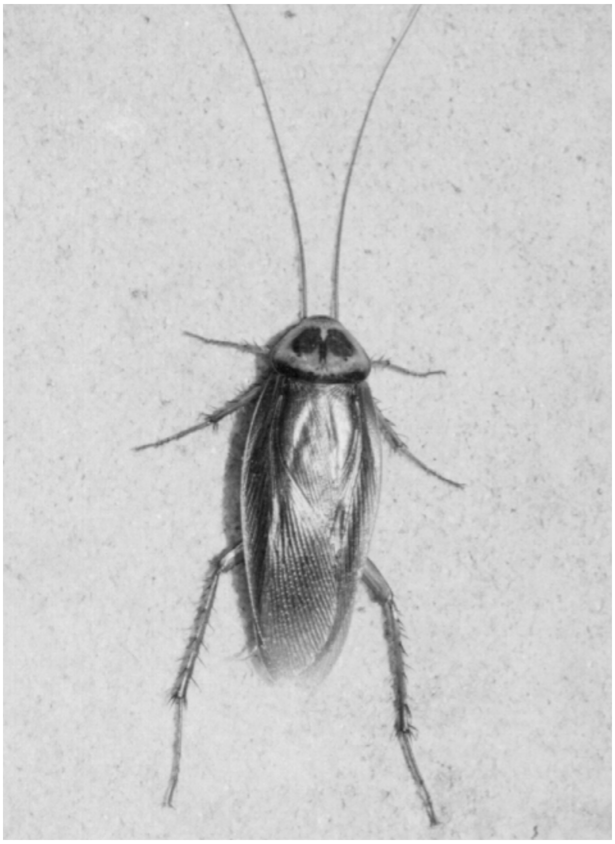


Figure 11.3 American cockroach (*Periplaneta americana*) — (Family Blattidae)

American cockroach (*Periplaneta americana*)

The American cockroach is probably the largest cockroach that infests dwellings and utilities. Adults are red-brown in colour with a pale yellow border around the pronotum. Egg cases are usually dropped or glued to surfaces within reasonable proximity to food and water. Up to 16 eggs may hatch from each egg case, and the nymphs may take 6 –12 months to develop into adults. Adult lifespan may be 6–12 months and females may produce up to 50 egg cases

As the American cockroach prefers warm, moist, dark conditions, it tends to live indoors in colder regions but mainly outdoors in warmer regions. Partly because of its large size, it tends not (so often) to infest the dwelling parts of buildings (unlike the German cockroach). Nevertheless, it is a very widespread pest, occurring in wall, roof and subfloor voids and in and around sewers, drains, moist cellars, grease traps and rubbish dumps. Buildings infested or visited include hospitals, bakeries, food stores, warehouses, factories and domestic residences. It seems to have a preference for decaying organic matter, but will eat most human or animal feeds and also book bindings, paper and clothing (particularly if soiled). Adults with a water source may survive for about 2–3 months without food.

The American cockroach is fully winged and apt to fly in warm weather (albeit for only relatively short distances at a time). Egg cases glued to food packages or boxes, pallets and the like, may play an important role in its dispersal.

Smokybrown cockroach (*Periplaneta fuliginosa*)

The smokybrown cockroach is relatively large, and adults are dark brown to almost black with no pale markings. Its life history is somewhat similar to that of the American cockroach. Egg cases dropped or attached to surfaces by females may contain up to 26 eggs, which, when hatched, may require 6–12 months for nymphal development. Adult lifespan is probably about 6–12 months, and during this time, a female may produce close to 20 egg cases.

The habits of the smokybrown cockroach are in some ways similar to those of the American cockroach, and it is often found in garages, sheds, subfloor areas, roof voids and in and around grease traps and drains. The smokybrown cockroach does, however, seem to have a particular preference for food materials of plant origin, so is often a pest in greenhouses, nurseries and gardens. It is most often regarded as an outdoor species, and very seldom does it infest the dwelling parts of buildings.

Adults are fully winged and can fly short distances in warm conditions, often being attracted to lights at night.

Australian cockroach (*Periplaneta australasiae*)

The Australian cockroach is relatively large. In appearance, adults are similar to the American cockroach; but the body is a darker brown, the yellow markings on the pronotum are more clearly defined, and the foremargins of the forewing s have a distinct yellow marking. Egg cases that are dropped or glued to surfaces by females may contain up to 24 eggs which, after hatching, require some 6–12 months for nymphal development. Adults seem to live about 4–8 months, during which time females may produce up to 20 egg cases.

Preferring food of plant origin, this cockroach may be encountered in greenhouses and under bark or leaf litter in gardens. As well, it is found in subfloor voids, wall voids, roof voids, around utilities in factories and other buildings, in outhouses, and in and around woodpiles. It tends to be more frequently encountered in warm, subtropical to tropical conditions.

Brownbanded cockroach (*Supella longipalpa*)

The brownbanded cockroach is relatively small. Adults are pale brown in colour with very pale bands across thorax and abdomen. The female's wings are somewhat reduced, while those of the male extend past the abdomen. Egg cases, which may contain up to 18 eggs, are glued to surfaces, and the hatched nymphs require 2–4 months to develop into adults. Adults typically live for up to 6 months, during which time the female produces up to 13 egg cases.

Figure 11.4 Female brownbanded cockroach (*Supella longipalpa*) with egg case — (Family Blattidae)

This cockroach tends to be an indoors pest, frequently infesting the dwelling parts of buildings, as well as offices, hospitals, restaurants, storerooms and so on. Unlike the German cockroach, however, its activity may be scattered throughout a building rather than being restricted mainly to kitchen areas.

Egg cases (glued), nymphs and adults may be found in wardrobes, dressers and cabinets and behind bookshelves or wallpaper. It prefers warm temperatures, but does not seem to require as much moisture as the German cockroach.

The brownbanded cockroach is very active and may fly if disturbed or in warm conditions. Sightings of individuals during the day are not unusual. Its wide dispersal within premises can make control difficult.

Oriental cockroach (*Blatta orientalis*)

The medium-sized oriental cockroach is dark brown to black. The female has much reduced wings (present as wing buds), while the male has wings that cover most, but not all, of the abdomen. Egg cases are usually glued to surfaces and may contain up to 16 eggs. Nymphal development may require 6–18 months. Adult lifespan is usually about 3–6 months, and a female may produce up to 14 egg cases during her adult life.

The oriental cockroach is the major pest cockroach of buildings in Britain. Its preference for relatively cool conditions is reflected in its more southern distribution in Australia, where it is commonly encountered outdoors (under leaf litter and bark) and in damp subfloors, around drainage systems. It is relatively sluggish and is usually located at or below ground level in buildings. It feeds on a variety of decaying organic matter, frequently feeding in garbage disposal areas. As well, starches and sizing of wallpaper and books may be attacked.

TABLE 11.1
Life history data for some pest cockroaches

Cockroach	No. of eggs per egg capsule	Duration of nymphal development	No. of moults	Adult lifespan	No. of egg cases per female
German cockroach *Blattella germanica*	30–40	6–12 weeks	6–7	4–6 months	5–8
American cockroach *Periplaneta americana*	12–16	6–12 months	7–10	6–12 months	10–50
Smokybrown cockroach *Periplaneta fuliginosa*	22–26	6–12 months	9–12	6–12 months	15–17
Australian cockroach *Periplaneta australasiae*	16–24	6–12 months	10–12	4–8 months	12–20
Brownbanded cockroach *Supella longipalpa*	10–18	2–4 months	6–8	3–6 months	6–13
Oriental cockroach *Blatta orientalis*	12–16	6–18 months	7–10	3–6 months	8–14

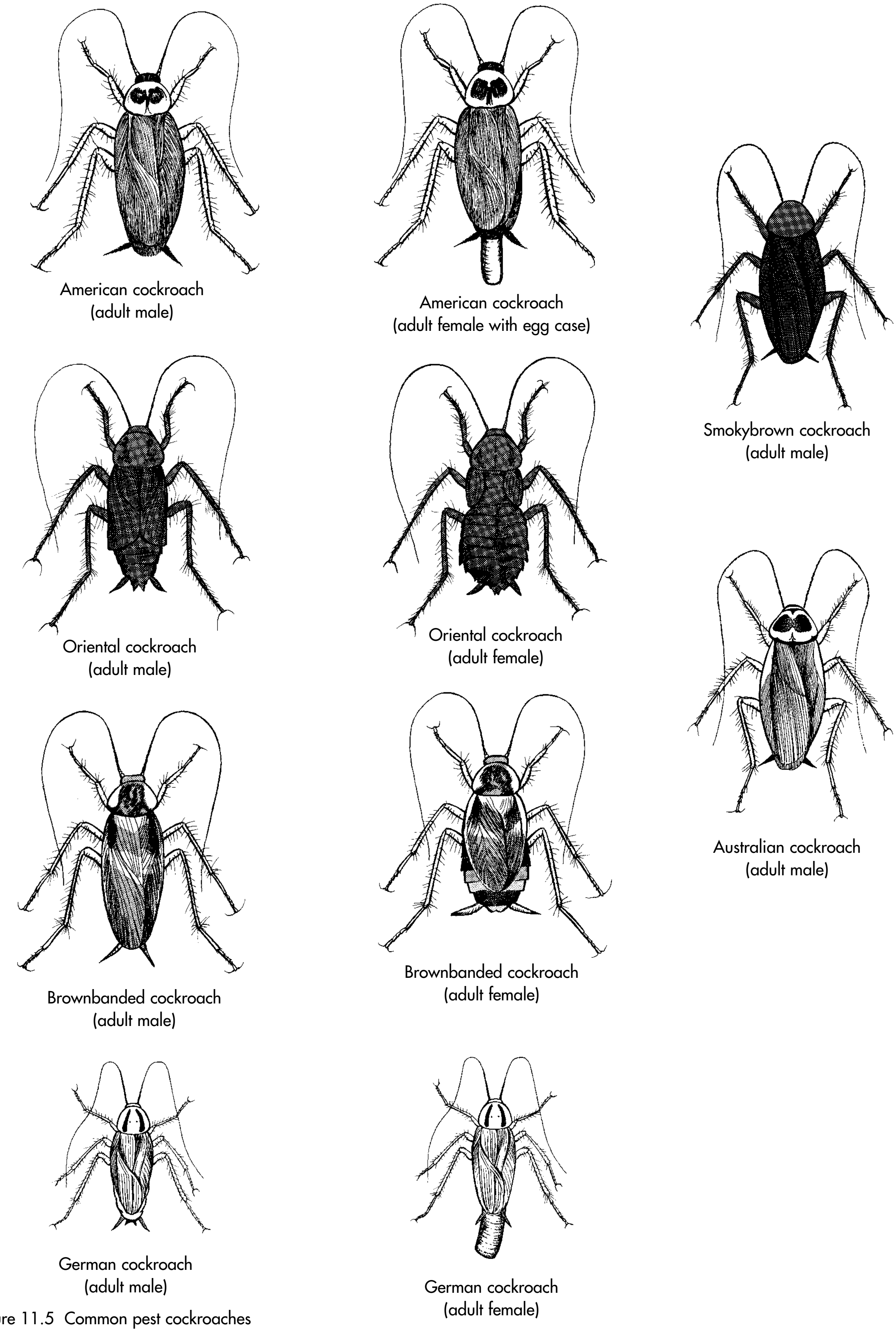


Figure 11.5 Common pest cockroaches

TABLE 11.2
Identification features and areas of occurence of some pest cockroaches

Cockroach	Adult body length	Adult identification features	Typical areas of occurrence and general remarks
German cockroach *Blattella germanica*	12–15 mm	Light amber-brown with 2 dark longitudinal stripes on pronotum.	Commonly infests the interior of buildings. Mostly in and around kitchens (domestic and commercial pantries, storerooms and other food handling areas. Found in and behind stoves, sinks, refrigerators, water heaters and various other appliances. Prefers to be close to food, moisture and warmth. Does not fly.
American cockroach *Periplaneta americana*	35–40 mm	Reddish brown, legs paler, pale yellow border around pronotum. Wings completely cover abdomen.	Often found dwelling in subfloors, sewers, grease traps, cellars, wall voids, roof voids, and in and around rubbish dumps. Often travels for food. May be a problem around bakeries, hospitals, foodstores, warehouses and other areas that handle food. Flies in warm weather.
Smokybrown cockroach *Periplaneta fuliginosa*	30–35 mm	Dark brown to almost black with no pale markings. Wings cover abdomen.	Often regarded as an 'outdoor' cockroach. Prefers plant materials. Often a pest in nurseries. Found also in garages, woodpiles, subfloors, wall voids and roof voids, around drains and under garden mulch. Flies in warm weather. Sometimes attracted to light at night.
Australian cockroach *Periplaneta australasiae*	30–35 mm	Brown with clearly defined yellow border around pronotum and foremargin of forewings distinctly yellow. Wings cover abdomen.	Mostly an 'outdoors'-type cockroach. Prefers plant materials. Often found under bark of trees, among woodpiles and in other locations that offer moist, decaying vegetable matter. Also found in subfloors, wall voids, garages and sheds. May fly in warm weather.
Brownbanded cockroach *Supella longipalpa*	10–14 mm	Pale brown with very pale bands across thorax and abdomen. Female has reduced wings. Male is fully winged.	An indoor cockroach pest, commonly infesting houses, offices and other buildings. Not restricted to kitchen areas. Prefers dryer areas in furniture (bookcases, desks, wardrobes), around picture frames, in light fittings, among stored files and paper etc. Unlike the German cockroach, often infests throughout entire buildings. Flies when warm or disturbed.
Oriental cockroach *Blatta orientalis*	20–25 mm	Dark brown to black. Female has much reduced wings, present as wing buds. Male has wings that usually cover most, but not all, of abdomen.	Prefers relatively cool conditions. May infest indoors or outdoors. May be found in cool damp cellars and subfloors, around drains, inside walls, in and around equipment, under garden debris, in dumps etc. Does not fly.

Cockroach control

Effective control of pest cockroaches in and around buildings often relies on:

1 a comprehensive inspection/survey of the building(s);
2 a high standard of sanitation and hygiene, which will reduce the food, water and shelter that facilitate population growth;
3 the application of insecticides in a manner that makes likely their contact with the target insects; and
4 follow-up inspection and monitoring (that may involve the use of traps in some situations).

Such a combination of chemical and non-chemical methods of control usually relies heavily on the co-operation of those in charge of the building concerned. Such co-operation is sometimes forthcoming, but unfortunately, often it is not.

The problem of reinfestation at some time after a treatment program is a very real one. One source of reinfestation may be the subsequent hatching of egg cases that were present during the treatment but not directly affected by insecticidal action. Alternatively, reinfestation may arise from untreated adjoining areas. Where possible, treatments in larger buildings should deal with all sites of infestation during the one 'extended' treatment. This makes necessary an initial extensive survey and thorough inspection of all the areas concerned.

Inspection/survey

Inspection for cockroaches requires a good torch, a probe and often a flushing agent (eg a pyrethrins aerosol) to mobilise the cockroaches out of their harbourages. Wearing knee pads can be very beneficial and tools are sometimes necessary for the removal of kick panels or other parts of equipment. In the longer term, carefully placed sticky traps can be very useful in monitoring the presence of cockroaches. Findings should be recorded so that pre- and post-treatment survey results can provide useful information about the effectiveness of insecticide treatments and/or changes undertaken by the client (such as sanitation improvements).

Non-chemical methods of prevention and control

Non-chemical methods of prevention and control of cockroaches usually involve matters about which pest control operators must 'educate' their clients. As cockroaches living in and around buildings require food, water and shelter sites, reducing the availability of resources is likely to lead to reductions in population size. The following practices will make buildings less suited to infestation:

1 Clean-up after food-handling should be immediate, thorough and regularly carried out. Dishes and utensils should not be left unwashed overnight. Pets' feeding bowls should not be left unwashed for periods. Clean-up of offices, clubs, bars and so on should, where possible, proceed immediately the day's activities are finished, so that food-contaminated surfaces are not available overnight.

2 Water availability should be reduced where possible. Unnecessary containers with water, accumulations of water from cleaning activities, leaky taps or pipes should all be checked.
3 Foods should be stored in tight cockroach-proof containers. Cereals, flours, meats and all other food materials should be kept in a refrigerator or in containers that can be tightly closed.
4 Food storage involves:
   - inspection of incoming stock;
   - regular stock rotation;
   - sound food-storage practices, whereby food is stored above ground level and, where appropriate, away from contact with walls.
5 Garbage should be stored in tightly closed containers.
6 Where feasible, cracks and crevices that may harbour cockroaches should be filled in. Entry points (eg around pipes) through floors or walls should be blocked off to lessen the possibility of reinfestation or harbourage.
7 Equipment in food-handling areas should, where possible, be located above floor level, to facilitate easy and thorough cleaning and thus avoid the build-up of wastes underneath.
8 Reasonably regular clean-up of 'longer term' build-up of waste foods (eg grease accumulation around stoves and vents, or spilt food materials at backs of shelves) should be carried out. Vacuuming of shelves and cupboards will reduce the build-up of food particles in cracks and crevices.

Usually, a thorough survey of the building will reveal the extent to which practices and procedures need to be modified. Where very poor sanitation and hygiene practices exist, chemical treatments will be limited in their effectiveness.

Chemical control

The way in which insecticides are used to control cockroaches in a building will depend on: the species of cockroach concerned, the size of the population, the distribution of the infestation through the building, the schedule of occupancy of the building by humans, the type of construction concerned, the nature of the building's contents, and many other factors.

Cockroach control procedures often include the use of organophosphorus, carbamate and synthetic pyrethroid insecticides as well as natural pyrethrins, IGRs and miscellaneous insecticides.

Appendix VI outlines some of the insecticides that are used in the control of cockroaches at the time of writing. (Note: always check current product labels to ensure appropriate registration status for the intended purpose.)

Where possible, particularly in conditions of poor hygiene, a clean-up prior to insecticide application can be most beneficial. Broadly, some types of insecticide formulations and methods of application are summarised as follows:

Surface-sprays Emulsifiable concentrates, suspension concentrates and wettable powders are commonly used in cockroach control. Typically, wettable powders and suspension concentrates are preferred where porous, absorptive surfaces are to be treated. The application of these materials as surface sprays is usually directed to cracks, crevices and voids that may serve as harbourages and to surfaces on which cockroaches are likely to travel. Surfaces on which food is handled or that are likely to be frequently washed down are not treated. Treatment of kitchen areas can be facilitated by the emptying of cupboard and pantry contents onto a table, where they can be protected by sheeting. Surface-spray treatments may render surfaces insecticidally active for periods of up to a few months — perhaps longer in the case of slow-release, lacquer-type formulations. Surface-sprayed insecticides usually exert a contact action whereby the insecticide enters the insect through the cuticle.

IGRs are usually used in conjunction with an adulticide.

Space-sprays Where treatments are to be carried out indoors and occupants can vacate premises for a period, space sprays may be applied as high-pressure aerosols, mists or fogs. In some cases, good penetration may result from the use of high-pressure or normal aerosol equipment modified for the treatment of cracks and crevices. However, treatment of only the interior space of the building usually achieves only limited penetration into harbourages. Typically, non-residual, fast-knockdown, flushing-type insecticides are applied as space-sprays. Where other application techniques are involved in one job, space-spraying must be the final procedure. Insecticides used as space-sprays may rely on contact action alone or they may exert a vapour action and kill by inhalation poisoning.

Dusts Dusts are mostly applied to areas where wet sprays are problematic in terms of staining or damage to electrics (eg in appliance motors and switchboxes). They are often applied to cracks and crevices, in and around some types of equipment (applied very lightly) around filing cabinets and in wall and roof voids. Dusts should always be applied lightly and carefully, in such a way as to prevent the likelihood of humans contacting or disturbing any of the dust deposits. Organophosphorus and carbamate dusts are widely used, and these are likely to have a few weeks to a few months of residual activity (depending upon conditions). Where longer term protection is desired, inorganic boric-acid dust will remain insecticidal indefinitely, provided that deposits are kept dry and clean. Insecticidal dust may enter cockroaches via the cuticle or, more commonly, via the mouth and digestive system during grooming.

Baits and traps Baits are increasingly useful and effective in cockroach control programs. They are sometimes used alone but are often used in conjunction with other types of insecticide application, such as residual sprays and dusts. Sticky traps, placed appropriately, will capture some cockroaches but seldom, on their own, do they achieve high levels of control. As monitors of cockroach populations, such traps can provide useful information.

The use of baits and/or traps can sometimes offer safety advantages in some more sensitive situations in which, for example, non-target animals, such as laboratory test animals, may be at risk if other types of insecticide formulations (eg surface sprays) are used.

A combination of formulations and methods of application is usually undertaken to achieve worthwhile levels of cockroach control.

Treatment of German cockroaches is usually restricted to the interior of dwellings and, further, to the kitchen or food-handling area within the building. Here, thorough treatment of all cracks and crevices, voids and surfaces on which the cockroaches are likely to travel (within the constraints of safe practice) is usually carried out. Sometimes, in cases of severe German cockroach infestation, the treatment may need to be more extensive, extending throughout the building.

Brownbanded cockroach control usually requires extensive treatment throughout the entire building, paying particular attention to furniture, closets, drawers, cabinets and other such harbourages.

Control of the larger species of cockroaches (eg the American, smokybrown and Australian) usually requires attention to roof and wall voids, subfloor and cellar or basement areas, grease traps, drains, garbage disposal areas, and adjacent wall and fence lines.

Control by natural enemies

There are many parasites and predators that exert some natural control on cockroach populations. Predators of cockroaches in nature include various arthropods, frogs, lizards, birds and mammals. Some wasps are known to be parasites of cockroach egg cases. Commonly, the adult wasp punctures an egg case and lays an egg inside. On hatching, the larva commences to eat the contents of the case, eventually pupating within it when feeding has ceased. After transformation, the adult emerges from the egg case in search of a mate.

The parasite wasps of cockroaches have received much attention from the viewpoint of their potential for the biological control of various pest cockroaches.

Some researchers are also investigating cockroach control using a naturally occurring fungus that is set in a bait station-like chamber. Cockroaches contaminated by contacting the fungus may then contaminate other cockroaches which they contact.

Biological control methods of this kind offer considerable advantages in relation to minimising the hazards that chemical procedures may pose to non-target organisms.

In summary, the effective management of cockroaches in and around buildings often requires:

- an initial, thorough inspection and survey of the entire premises;
- the adoption of appropriate non-chemical strategies (eg 'good housekeeping') that make the environment less conducive to cockroach infestation;
- the careful application of appropriate insecticide(s) applied so as to maximise the likelihood of contact with the cockroaches; and
- regular inspections and monitoring.

ANTS

Ants belong to Family Formicidae within Order Hymenoptera — the group of insects that includes ants, bees, wasps, sawflies and wood wasps. In Australia, about 3000 species of ants are known.

Ants are social insects that live in more or less permanent nests. Colony sizes vary enormously and are mostly located in soil, wood and among rocks. In relation to their feeding habits, ants may be predators, perhaps with specific prey (eg termites), or scavengers, which again may have a specific diet (eg the honeydew or sugary excretions of plant-sucking bugs) or a general one. The latter types may be almost omnivorous; that is, ants for which almost any type of food is acceptable. Being very common intruders in and around buildings, ants tend to be very familiar insects. They are commonly observed around foundations and in walls, roof voids, kitchens, lawns and gardens, the wood of decaying trees, and rockeries. As a group, ants are considered by many to be among the most successful of all insects.

Structure

Typically, ants have three clearly defined body segments: head, thorax and abdomen. In most, the first one or two anterior abdominal segments (which connect with the thorax) are much smaller than the rest, producing a distinctly 'waisted' appearance. These smaller basal abdominal segments, known as the pedicel, usually have one or two projections called nodes, which may serve as important features in identification. The head carries compound eyes, elbowed antennae and sometimes ocelli. When present, wings are membranous, and forewings tend to be broader and longer than hindwings.

Life cycle

Individual ants undergo a complete metamorphosis during their development. Eggs are mostly small and ovoid in shape. The larva that hatches out is a whitish grub that is narrower towards the head. The larvae are fed by the adults, and after sufficient feeding and several moults, the larva pupates. The pupa is similar in shape to the adult but is usually soft, creamy-white and inactive. In some species the pupa is protected within a silk cocoon. Eventually the adult emerges, and a few hours or perhaps even days may be required for the process of cuticle-hardening and darkening. The development from egg stage to adulthood may require from 6 weeks up to very long periods, depending on the species concerned, food availability, temperature, season and a range of other factors.

There are three castes of ants:

1 ***Male*** — Adult males are winged. Their specific function is to mate with the female.

2 ***Female*** — This caste is usually the largest in body size. The female begins adult life as a winged insect, but the wings are dropped soon after mating. Normally the female mates only once, and she will care for the first young. Some ant species have only one female reproductive ('queen'), while others may have many. Typically, females may live for up to 15 years.

3 ***Worker*** — This caste comprises sterile wingless females. They are the most numerous caste, serving the colony by nest-building, foraging for food, feeding immature ants and other castes, caring for eggs, defence and so on. In some species there are different kinds of workers. Large workers with well-developed heads are sometimes called soldiers. Workers mostly live for about 1 year.

The female or 'queen' regulates the colony. After one mating with a male (after which the male usually dies), the female commences egg-laying. Those eggs which are fertilised become females (mostly workers), and those eggs which are not fertilised develop into males. At certain times of the year, large numbers of winged males and reproductive females are produced. These usually swarm in a colonising flight, during which mating on the wing usually occurs. The male dies soon after. The female, if successful, will drop her wings and find an appropriate nesting site in which to start a new colony.

Some ant species seldom swarm. Instead, these ants may mate within the nest, eliminating the male afterwards and developing numbers of female reproductives. Some females, having been fertilised within the original nest, may, with numbers of workers, leave to form a new colony. This method of colony formation, sometimes called 'budding-off', seems important in the Argentine ant and Pharaoh's ant.

Habits

Most ants live in more or less permanent nests, but in adverse conditions a change of nest location is not uncommon. Typically, worker ants forage from the nest for food. Many do this by travelling in fairly well-defined trails, once a food source has been established. Methods employed in trail marking may include reference to landmarks, orientation with respect to light and, very commonly, the laying down of 'scent trails' in the form of trail-marking pheromone secretions. More generally, orientation and communication in ants may rely on smell (as in trail-marking or alarm pheromones), taste (as in food exchange by regurgitation), hearing (as may be the case with tapping and stridulation), touch (as in antennal stroking), or sight (in ants with well-developed eyes).

In their feeding habits ants tend to be predators or scavengers with a wide range of specificity. Some predatory species are very specific (eg preying only on termites), while others are general predators. A very common scavenging habit is the attendance of plant-sucking bugs on plants. Here, ants consume honeydew and, sometimes, in exchange for this food, they will protect the often fairly sedentary plant suckers from predators. Several species of ants are almost omnivorous scavengers, consuming a very wide range of animal or plant products. It is these scavengers that have most successfully exploited people's dwellings.

Why ants are considered pests

Ants are often regarded as 'nuisance' pests in and around buildings. Small mounds resulting from their excavations may be considered unsightly along garden paths, on balconies, and around skirting boards and architrave bases. Occasionally, such excavations under paths may be sufficiently extensive as to cause cracks in older paths. Trailing of the ants themselves, in and around buildings, is considered unsightly by many. Where plants are grown, ants may attack and damage or consume seeds and seedlings. Swarming may occur within premises, and this may prove particularly disturbing to occupants.

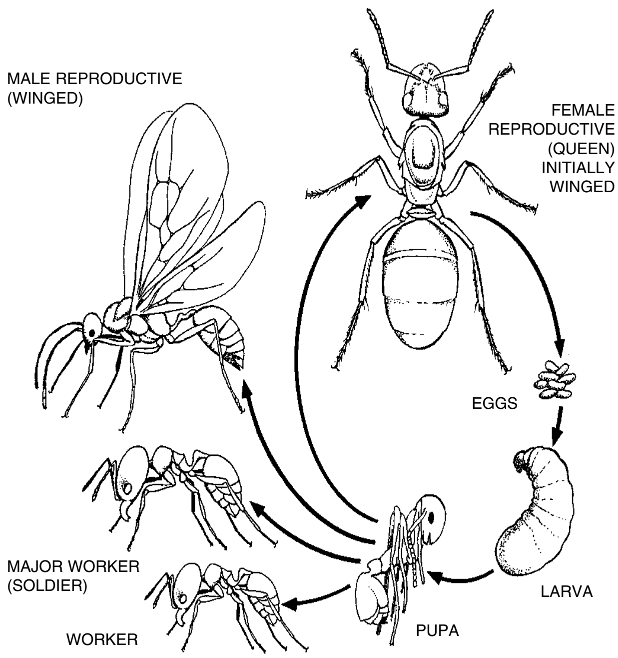


Figure 11.6 Generalised ant life cycle and castes

As well as general 'nuisance' aspects, ants may present a health risk. There are known instances of ants mechanically carrying, on their bodies or in their digestive tract, disease organisms causing dysentery, smallpox and a variety of pathogenic bacteria, including *Salmonella*. As ants commonly scavenge in kitchens and other food-handling areas, as well as in garbage cans, dog excrement and other possible sources of disease organisms, their potential for transmitting diseases to humans should not be overlooked. Such a threat to health can be very serious in the case of severe infestations in hospitals.

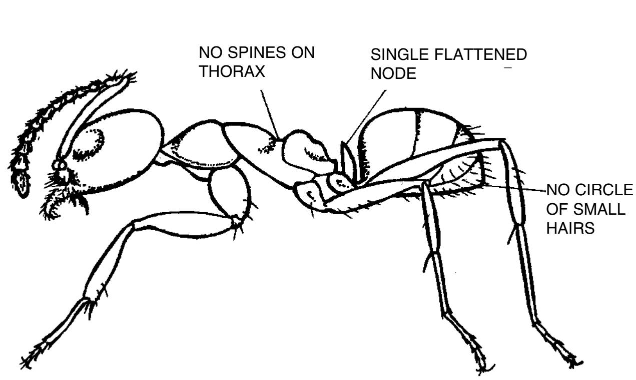
In addition to the health threat posed and nuisance aspects, some ants may bite or sting humans.

Table 11.3 describes the appearance and nesting and feeding habits of commonly occurring ants, including pest species.

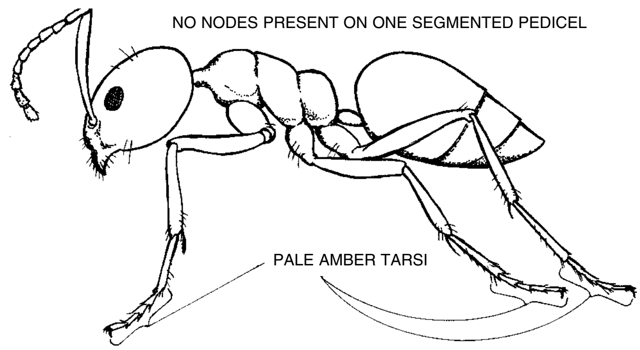
Ant control

Effective control of ants often relies on a knowledge of their foraging and nesting habits. At the broad level, a knowledge of the nesting habits and feeding habits of important pest species can be helpful. More specifically, where a given infestation is being treated, a thorough survey and inspection should be carried out. By following trails — particularly, where possible, those of workers loaded with food — the location of the nest, either approximately or precisely, may be

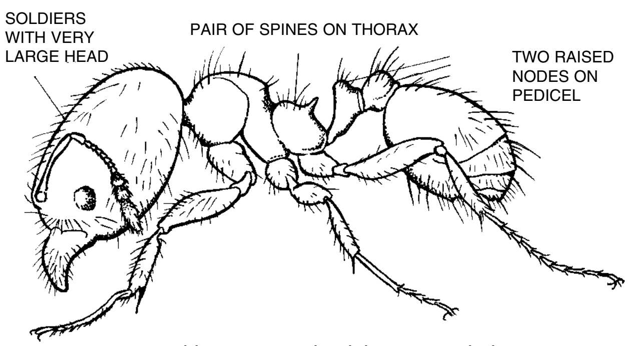
Figure 11.7 Some common ant pests



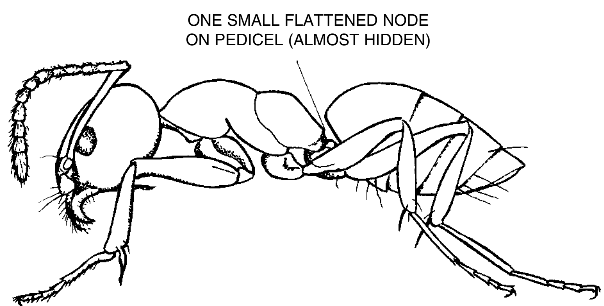
Argentine ant (*Linepithema humile*)



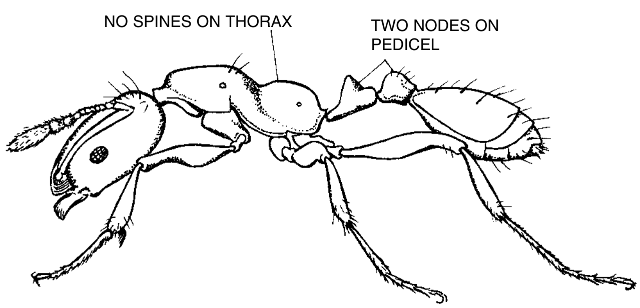
Whitefooted house ant (*Technomyrmex albipes*)
[Black household ant — Victoria]



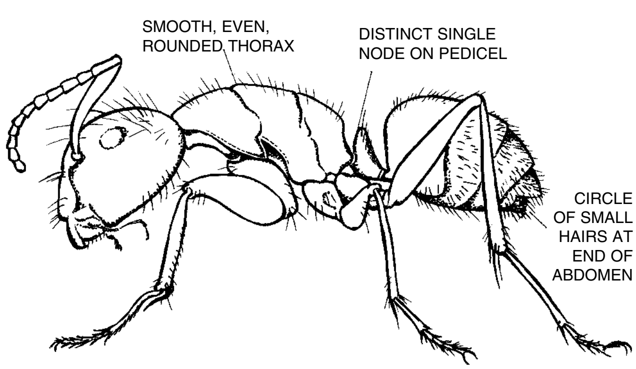
Coastal brown ant (*Pheidole megacephala*)



Odorous ant (*Tapinoma minutum*)



Pharaoh's ant (*Monomorium pharaonis*)



Carpenter ant (*Camponotus* sp.)

TABLE 11.3
Ants of common occurrence: identification and nesting and feeding habits

Small brown ants		
Argentine ant *Linepithema humile*	1.5–3.0 mm. Light brown to brown. Single flattened node on pedicel. Eyes close to base of antennae. Trail in populous columns. No formic acid odour when crushed. Will walk over a hand if placed on trail. Will drive other ants from their area of occurrence.	*Nesting habits*: Often nests in exposed soil or under cover in rotting logs, plant cavities etc. Often moves indoors in wet weather. Seldom swarms. Usually mates within the nest. Usually a colony has several queens. *Feeding habits*: Prefers sweet foods but will eat meats, insects, seeds, fruit and honeydew from sap suckers. May damage soiled clothing. The ant is a native of South America and widely regarded as the most successful scavenging ant that is a pest of man. So serious is the threat posed by this insect that, in most parts of Australia its sighting should be reported to local council or appropriate state government authorities before any control action is taken.
Coastal brown ant *Pheidole megacephala*	1.5–2.5 mm. Light yellowish brown to brown. 2 raised nodes on pedicel, hind node more rounded. 1 pair of small spines on hind part of thorax. Has 2 workers castes: those with enlarged, darkened head ('major' workers, sometimes called soldiers), and numerous smaller minor workers.	*Nesting habits*: Often located within building structures, in crevices in brickwork, in cavity walls, and behind skirtings and architraves. Sometimes nests around paths and rockeries. *Feeding habits*: Prefers materials of animal origin, including dead insects, meat particles, fat and grease.
Pharaoh's ant *Monomorium pharaonis*	1.5–2.0 mm. Light yellowish brown to darker brown. Top and tip of abdomen slightly darker. 2 nodes on pedicel. No spines on thorax. Antennae clubbed with 3 enlarged segments. No odour when crushed.	*Nesting habits*: Typically forms large colonies, with many queens. May travel considerable distances for food. Commonly nests indoors in wall voids, beneath floors, around foundations, in ceilings and in other parts of buildings. Often nests in warmer parts of buildings (eg adjacent to heating ducts). Seldom swarms. *Feeding habits*: Eats almost any type of food material. Prefers high protein materials (eg meat, blood) as well as fatty foods and vegetable matter. Also attacks sweets.
Odorous ant *Tapinoma minutum*	2–3 mm. Brown to dark brown. 1 small flattened node on pedicel (almost hidden by abdomen). Distinct odour similar to rancid butter when crushed	*Nesting habits*: Commonly nests within buildings in walls, under stoves and cupboards, and in subfloor voids. Seldom swarms. *Feeding habits*: Eats most types of household food. Prefers sweets but will eat meat, breadcrumbs etc.
Singapore ant *Monomorium destructor*	2–3 mm. Light brown with darker posterior abdomen. 2 rounded nodes on pedicel. No spines on thorax. Terminal segments of antennae enlarged but do not form club. Head flattened and blocky.	*Nesting habits*: Typically nests in and around buildings, in cracks, crevices, wall cavities, behind skirtings, under paths etc. *Feeding habits*: Eats a variety of food materials, including protein and sugar-type materials. Probably prefers animal materials to sweets.
Brown house ant *Doleromyrma darwiniana*	2–3 mm. Uniformly brown. 1 node on pedicel. Distinct odour of formic acid odour when crushed.	*Nesting habits*: Typically forms small colonies around paths and rockeries, in crevices, and in joints in brick and stonework. *Feeding habits*: Prefers high protein (eg blood, meat, insects).
Small black ants		
Whitefooted house ant *Technomyrmex albipes* also called Black household ant (in Vic.)	2.5–3 mm. Black with pale tarsi. No nodes present on one-segmented pedicel.	*Nesting habits*: Commonly nests indoors and outdoors. Nests found around paths and rockeries, inside cavity walls, behind skirtings and architraves, under and behind kitchen cupboards etc. *Feeding habits*: Somewhat general feeder, eating meats and sweets. Probably prefers sweets.
Black house ant *Ochetellus* spp. (*glaber* gp.)	2.5–3 mm. Black.	*Nesting habits*: Most commonly nests outside, against paths, in rockeries and other crevices. May nest in cavity walls and sometimes indoors or in subfloor areas. *Feeding habits*: Eats a variety of food materials, but prefers sweets.
Larger and miscellaneous ants		
Carpenter ants *Camponotus* spp.	7.0–12.0 mm. Colour variable. Distinct single node on pedicel. Smooth, evenly rounded thorax. Circle of tiny hairs at end of abdomen.	*Nesting habits*: Most commonly nests in decayed or moist wood. Sometimes nests in soil. May travel great distances for food. Mostly associated with bushy areas. *Feeding habits*: Forages mostly at night. Eats dead and live insects, honeydew from sap suckers and a variety of household wastes. Attracted to sweets.
Greenhead ants *Rhytidoponera* spp. (*metallica* gp.)	5.0–6.0 mm. Black with metallic green head. Distinctive appearance and odour.	*Nesting habits*: Typically nests in small colonies under paths and among rockeries. Mostly associated with bushy areas. *Feeding habits*: Feeds mainly on materials of vegetable origin. Seldom enters houses. Can inflict a painful sting.
Meat ants *Iridomyrmex* spp.	13–14 mm. Red and black.	*Nesting habits*: Typically makes a large nest in soil such that it has a topping of gravel. Mostly occurs in bush areas. *Feeding habits*: Eats mainly animal materials and honeydew from sap suckers. Does not sting.
Jumper ants *Promyrmecia* spp.	13–15 mm. Usually yellow and black. Jumping habit. Very aggressive.	*Nesting habits*: Typically nests outdoors in soil, building mound-type nests. Located mostly in bushy areas. Seldom enters buildings. Can inflict a very painful sting.
Bulldog ants *Myrmecia* spp.	18–20 mm. Tends to be red or black. Very aggressive.	*Nesting habits*: Typically nests outdoors in soil and under logs, rocks etc. Located mostly in bushy areas. Seldom enters buildings. Can inflict a very painful sting.

determined. Direct treatment of the nest, where possible, can provide the most effective, longer-term control. Alternatively, the use of chemical barriers that interfere between the nest and possible food sources is often effective.

Non-chemical prevention and control

The state of hygiene and sanitation in and around buildings influences the likelihood of infestation by scavenging ants. Indoors, all areas should be kept free of food particles. Typically, surfaces that become contaminated with crumbs and other food particles include kitchen bench surfaces, shelves and drawers, floors, tables, chairs etc. Feeding utensils should be washed up soon after use and not left unwashed for long periods. Outdoors, the area should be free of food sources (eg bones, unclean pet feeding bowls and unrinsed drink bottles and cans). As well, tolerating sap-sucking insect pests on plants around a dwelling may serve to support and encourage a variety of ant species.

Chemical control

The effective use of chemicals to control ants relies on a thorough inspection prior to application of chemicals. The inspection should attempt to locate nesting sites, feeding sites and the routes of travel between them. Care should be taken when making assumptions about nest location. For example, suppose that ants are trailing under skirting and into a wall void. If a spot treatment to the wall void is carried out, on the assumption that the nesting site lies within it, the ants may simply change their route if they are, in fact, nesting elsewhere and merely passing through that particular wall void.

Once the exact or approximate location of the nest(s) is established, control procedures may involve:

1 The direct treatment of the nesting site. This may be accomplished by the application of dusts, residual surface-sprays or space-spray type systems where nests are located within the confines of wall voids and the like. Such direct treatment may require drilling or other modifications for access.

2 The formation of residual barriers between nest and food sources. Often it is not possible to treat ant-nesting sites directly. Where this is the case, dusts or surface-sprays may be applied to those surfaces, cracks and crevices over which the ants travel for food. As ants can be repelled by certain insecticides, and as they can be most resourceful in finding new routes to a food source, it is important that the barrier treatment be a comprehensive one that, within the constraints of safe practice, attempts to isolate the nesting site from food sources.

In broad terms, chemical treatments restricted to the inside of premises may achieve good control if all nesting sites are located indoors. If, however, nesting sites are located outdoors as well, interior treatments alone may be very limited in their effectiveness.

Appendix VI outlines some of the insecticides that are used in the control of ants at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

Broadly, some types of insecticide formulations and methods of application for ant control are summarised as follows:

Surface-sprays In ant control, surface sprays in the form of emulsifiable concentrates, wettable powders and suspension concentrates are widely used. Such treatments may involve treating outdoor nesting sites and/or spraying surfaces over which the ants travel. These may include cracks in paths, wall-path junctions, points of entry such as window sills and door jambs, and wall voids. Indoors, areas serving as travelling routes might be treated. These may include the bases of skirtings behind kitchen equipment, window and door frameworks, corners among cupboards and benches, and various cracks and crevices. Common types of insecticides used in ant control include organophosphorus, carbamate and synthetic pyrethroid insecticides. When used effectively, these chemicals, backed up by sound sanitation and hygiene practice, should give suitably long term protection.

Space-sprays Insecticides applied as space-sprays have limited application in ant control procedures. Where the method of application has facility for crack and crevice treatment, this may prove useful for the direct treatment of nesting sites that are reasonably confined (eg in brick cavity walls) — provided that safety implications are taken into account.

Dusts Insecticidal dust formulations can be useful in ant control. They may be applied directly into nesting sites (where known) or lightly on surfaces over which the ants travel. Dusts can be particularly appropriate in the treatment of sensitive areas such as switchboxes, some equipment and wall and roof voids.

Baits Insecticidal baits are used mostly in situations where nest location and treatment is difficult or impossible, or where insecticides in the form of sprays or dusts are not appropriate or allowed. The baiting approach usually relies on the transference of insecticidal baits back to the nest, where all the individuals, including the reproductive female(s), will eventually consume the poison in sufficient quantity to cause death. Baits are increasingly effective in the control of a variety of ant species. This may be a relatively slow procedure. Competition from other food sources is a common hindrance to the effectiveness of baiting. In placing baits, the safety of children and pets should be considered.

In summary, ant control often relies on:

1 a thorough inspection and survey/analysis of activity patterns;
2 direct treatment of nests where possible;
3 formation of insecticidal barriers between nests and food sources and/or the placement of baits in appropriate locations; and
4 the adoption of high levels of sanitation and hygiene.

FLIES

The term 'fly', in proper usage, refers to those insects which belong to Order Diptera (di = two, ptera = wings), so they are characterised by the presence of only two wings. Some familiar members of the order are house flies, blowflies, mosquitoes, midges, gnats, hover flies and fruit flies. The order is a large and very successful one, with more than 150,000 species worldwide and just over 7700 species in Australia.

Flies have exploited a very wide range of food sources. Various species may be found breeding in vegetation (growing or decayed), in soil (with sufficient organic matter), in decaying organic matter (eg animal excrement, compost, leaf litter, garbage), in water (filtering organic materials, eg immature mosquitoes), in foods for human consumption and, as parasites, in or on other animals.

The activities of some flies may be regarded as beneficial (eg pollination, parasitism of certain arthropods). Several species of flies are pests of agricultural and horticultural activities. The overwhelming importance of the group in relation to humans, however, is its medical and veterinary implications for human and animal health. As well, the flying habits of adults frequently cause annoyance, as can the bites of some species, even if disease transmission is not likely.

Structure

Typically, adult flies are very small to medium sized and have only two wings. In place of hindwings, flies carry a pair of club-shaped balancers called halteres. Flies usually have compound eyes and a pair of often short antennae. Adult mouthparts are of the sucking or piercing and sucking type. Larvae are legless and mostly maggot-like in appearance, often tapering towards the head end of the body. Some variations, however, exist (eg the wriggler form of mosquito larvae). Pupae are mostly barrel-shaped and immobile, but again there are several exceptions.

Life cycle

All flies undergo a complete metamorphosis during their development. Eggs, or sometimes live young, are laid in the medium that will serve to feed the larvae. Mosquitoes, then, lay eggs on the surface of water, while house flies and blowflies lay eggs in decaying organic matter (eg animal excrement, animal carcasses). Larvae often feed voraciously. The feeding activity of house fly and blowfly larvae often raises the immediate temperature, facilitating faster development. The majority of dipterous larvae undergo about 4 moults during their larval life. Larval feeding may take a few days or weeks, depending on temperature, food quality, fly species and other factors. At the completion of feeding, the larvae pupate. In aquatic species (eg mosquitoes), this occurs in the same environment in which larval feeding occurred. Many of the terrestrial scavengers (eg house flies, blowflies) tend to crawl away from their larval-feeding medium to a drier location (eg the soil adjacent to the animal carcass on which larval feeding occurred). The pupal stage may last for a few days to weeks or even months. Emerging adults usually disperse, on the wing, to find a mate and, in the case of females, an egg-laying site. Flies often overwinter as adults (inactive, hidden and protected) or as larvae that develop very slowly.

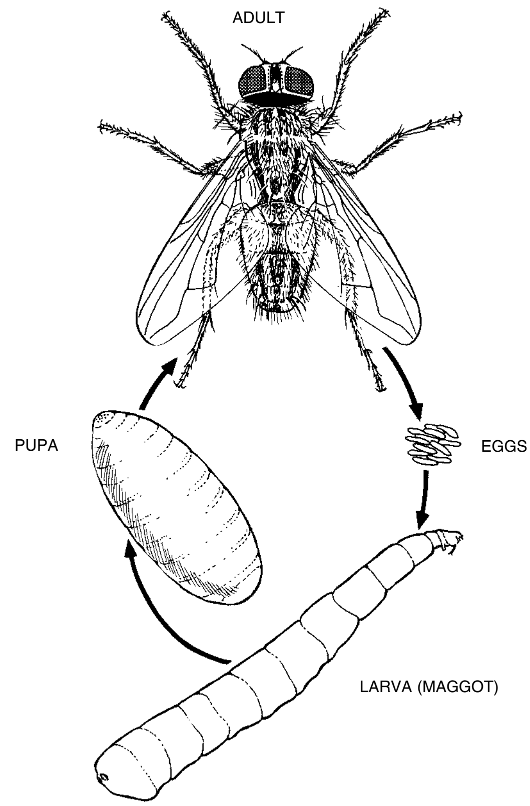


Figure 11.8 Life cycle of the house fly

Habits

The development of flies is such that larvae are largely restricted to their feeding medium (eg a compost heap in the case of house flies, or water accumulated in old tin cans in the case of mosquitoes). Winged adults, on the other hand, are mobile. When a given population of adults develop from a particular larval-feeding area, the extent to which they travel and their direction of travel will be determined by a number of factors, among which is an attraction to areas that offer food, moisture and egg-laying sites. Wind may play an important role, as is the case in the dispersal of adult bush flies into coastal New South Wales each year. Random movements of flying insects cease to be random when preferred conditions of temperature, humidity, wind velocity, light, odours or other factors attract the insects to certain 'favourable' locations.

The population of flies and mosquitoes depends largely on seasonal and climatic conditions and on the availability of suitable breeding sites. The dispersal of flies from breeding sites commonly extends no more than about 50 metres from the breeding site. In cases of substantial breeding sites (eg badly managed garbage dumps), flies that develop in the site may disperse several kilometres. Where favourable winds play a role in dispersal, as in the case of the bush fly, the adult insect may travel hundreds of kilometres from its original breeding site.

In urban environments, the multiplicity of suitable breeding sites, attractive odours and favourable micro-environments continually encourages the presence of sometimes huge populations of flies. Depending on the species concerned, this may, to a lesser or greater extent, be problematic to humans.

Why flies are considered pests

Perhaps the most widespread factor contributing to the pest status of flies is the extent to which their flying habit is a source of annoyance to humans. In Australia at certain times of the year, the bush fly becomes an annoying constant companion outdoors, while the house fly annoys people indoors. The enormous sales of household-insecticide aerosol cans in Australia are probably testimony to the extent of annoyance.

A more important consideration is the threat that flies pose to public health. The structure and habits of many flies (eg house fly, blowfly) are such that they can efficiently transmit diseases to humans. They have hairy bodies that can carry disease organisms, and sponging mouthparts that often involve vomiting in the eating process. They are very mobile and freely interchange between decaying excrement or wastes (often ubiquitous in urban areas) and human foods and utensils. Studies have shown correlations between a high incidence of enteric disease and the presence of a large fly population.

The list of disease-causing organisms that flies may harbour on or in their bodies is enormous. Diseases that can be spread by flies include *Salmonella* food-poisoning, dysentery, typhoid fever, cholera, hepatitis, tuberculosis, poliomyelitis, various parasitic worms and many others.

Some adult flies (eg the biting midges and mosquitoes) pierce the skin of humans or other animals in order to suck blood. Because they are apt to inject saliva, mild to severe irritation may ensue. As well, this feeding habit may serve to distribute diseases (eg malaria, dengue fever) by 'cyclical' or 'biological' disease transmission. The role of mosquitoes in disease transmission is considered below. Hereafter, flies and mosquitoes are considered separately.

Important pest flies

House fly (*Musca domestica*)

The house fly is very widespread and, in Australia, is probably the most annoying flying insect pest indoors. Coupled with this is a strong incrimination regarding the mechanical conveyance of diseases to humans and other animals. The house fly typically alternates between materials that are likely to harbour disease-causing organisms (eg animal excrement) and human foods, utensils and food preparation surfaces. The wide distribution of available breeding sites largely present as human or animal wastes, encourages its development in rural and urban areas. The abundance of house flies in a given area is sometimes used as an indicator of the efficiency of waste disposal and of the general sanitary standards of that region.

The adult is about 4–8 mm long. Thorax and abdomen are greyish, with four darker longitudinal stripes on the thorax. Sides of the abdomen are pale. It has sponging-type sucking mouthparts, which usually take in liquids but may, by regurgitation of saliva onto solid foods, ingest these as well.

The adult female house fly, within a week of reaching adulthood and mating, begins egg-laying. She usually lays batches of about 100 eggs in material suitable for larval feeding. Warm, moist, organic materials are preferred, and these may include decaying vegetable or animal material, heaped lawn clippings, manure and various wastes from food-handling operations. The tapered, maggot-shaped larvae may hatch from the eggs within a day. Larvae moult about 4 times during their feeding, which may last up to a week or even less in more favourable conditions. At the completion of feeding, the larvae usually crawl away from the moist food to find a drier location in which to pupate. The pupae remain immobile for up to a week, at which time the adult usually emerges from the pupal case. The length of adult life is usually about 2–4 weeks. As adults, house flies feed on milk, sugar, meat and most human foods, in addition to decaying organic matter (eg animal excrement). Overall, the life cycle of the house fly is usually 2–4 weeks. In summer, when conditions are most favourable, up to 12 generations may be produced.

Where breeding sites, food, shelter and moisture are available within a given area, house flies seem, in the main, to remain within a few kilometres of their own breeding site. Occasionally, they may travel much greater distances. However, this seems uncommon; it may involve 'hitchhiking' on vehicles or carriage by wind, and probably tends to occur where overpopulation in a given area forces individuals to disperse.

Typically, flies are more active during daylight or in artificial light, and are slow-moving or inactive in the dark. Their movements and behaviour as adults seem to be influenced by temperature (they are often found resting on warmer parts of buildings), humidity, light, wind, and even the colour and texture of surfaces. Where substantial populations exist, certain areas or surfaces may be favoured for resting at night. These may be 'signposted' with multitudes of fly specks and may be suitable locations for surface treatment with insecticides (safety implications permitting).

Bush fly (*Musca vetustissima*)

The bush fly is possibly the most widely known and annoying fly pest in the outdoors during Australian summers. The adults seek large animals, including humans, and remain on and around them for hours at a time, being attracted to sweat, tears, saliva and, in the case of grazing animals, faeces. They are known to play an active role in the transmission of certain eye infections to humans and livestock and may also serve in the transmission of enteric diseases of humans.

The adult is about 5–6 mm long. Its appearance is similar to that of the house fly, except that it is smaller and has only two dark longitudinal bands on the thorax.

The life cycle of the bush fly is somewhat similar to that of the house fly and usually takes about 2–5 weeks to complete. Eggs are inserted into the excrement of large animals, especially grazing cattle. The eggs usually hatch within a day, and the larvae pass through 3 instars before feeding is completed. Fully fed larvae usually leave the feeding medium to pupate in adjacent soil. Emerging adults can subsist on a variety of human and animal wastes, but they have a habit of circling and landing on large animals, attracted by their saliva, tears and sweat.

Adult bush flies tend to avoid shady areas and are most active in open areas where temperatures are warm. They do not seem to overwinter in the cooler southern parts of Australia but migrate from the warmer north (with the aid of winds) each year. Their presence in buildings is uncommon. Much use of personal insect repellent products during the spring and summer is attributable to this very widespread, annoying fly.

Lesser house fly (*Fannia canicularis*)

Although less common than house flies and perhaps blowflies, the distinctive circling and darting flight of the lesser house fly can make it quite conspicuous and annoying. It is frequently found in sheltered locations and indoors, seeming to prefer slightly cooler conditions than those preferred by house flies.

The adult is about 3–6 mm long. It is smaller than the house fly and more slender. Thorax and abdomen are dull grey, with indistinct stripes on the thorax. At rest, wings are parallel and overlapping.

Eggs are laid in a suitable feeding medium, which may be very moist and may include animal excrement and decaying vegetable matter (eg heaped lawn clippings). Eggs hatch within 2 days, and the larvae, equipped with spine-like processes on the sides and top of the body, feed for perhaps 10 days. After feeding, the larvae move to drier parts and pupate, remaining as pupae for about 10 days. The life cycle, then, is about 3–4 weeks in suitable conditions. Adults seem to live about 2–3 weeks.

The lesser house fly survives well on chicken manure and can be troublesome around chicken farms. In more urban areas, dog excrement, pigeon excrement and inefficient waste disposal may all serve to support its presence. It may also be attracted to honeydew from sap-sucking insects on plants.

Stable fly (*Stomoxys calcitrans*)

The stable fly superficially resembles the house fly, but a marked difference is the piercing and sucking mouthpart, with which it may pierce the skin and suck blood. Seldom found in domestic premises unless associated with domestic animals, the stable fly is more populous around dairies and other intensive animal production facilities. Biting and annoyance of livestock can reduce yields. On occasions it attacks humans, and in such cases bites usually occur around the ankles. Both males and females suck blood.

The adult is about 5–7 mm long. It has distinctive piercing and sucking mouthparts. There is a light-coloured area on the thorax between the longitudinal stripes. At rest, wings are held widely apart.

Female stable flies must have a blood meal prior to egg production. Eggs are laid on a suitable feeding medium, which may be vegetable wastes, compost, lawn clippings, decaying hay or grain, manure, chicken droppings or even seaweed accumulated on seashores. Eggs hatch within a few days. The larvae feed for about 1–3 weeks, then crawl to drier parts to pupate. Adult flies may emerge after 1 week or more, and the life cycle typically takes 3–5 weeks when conditions are favourable. The adults feed on the blood of animals and tend to remain outdoors in sunny locations. They are strong fliers and travel some distance from the breeding site.

Blowflies (*Calliphora* spp., *Chrysomya* spp., *Lucilia* spp.)

The presence of blowflies indoors is usually conspicuous owing to their large size, loud ‘buzzing’ and attraction to light through windows. As they frequent both animal excrement and human foods, they pose a serious threat to human health. Meat left exposed may be ‘blown’, that is, a female blowfly is attracted to it and lays eggs, or sometimes live larvae, in it. Occasionally, the presence of large numbers of blowflies, or even wandering fully fed larvae, inside buildings is attributable to eggs laid in rodent or bird carcasses. Blowflies can be a serious problem with livestock, sometimes laying eggs or larvae in the crutch or wounds of livestock.

The adult may range from 8 to 12 mm in length. Their appearance varies between species. Common blowflies may be metallic green, brown or brown and blue.

Eggs (or sometimes larvae) are deposited in a suitable feeding medium. Preferred egg-laying sites are animal carcasses and meat, including fish. As well, eggs are often laid in animal excrement and decaying human food wastes (eg at garbage disposal sites). The batches of 100–200 eggs usually hatch within a day, and the larvae feed voraciously for 3–10 days, after which they usually crawl away from the feeding site to pupate in soil or some other drier location. Adults may emerge some 5–10 days later. The life cycle typically takes 2–5 weeks. Adults may be attracted to food odours, animal excrement, ripe fruit, decaying wastes and spoilt meat. They are most active in warm sunny conditions and have been known to travel some kilometres from their original breeding site.

Flesh flies (Family Sarcophagidae)

Flesh flies present a similar problem to their close relatives, blowflies. They can be rather conspicuous, owing to their size, and their habit of being attracted to decaying wastes, excrement and human foods brands them as a threat to human health.

Adults are about 6–14 mm long, depending on the species concerned and its nutritional history. Thorax is light grey and has three dark longitudinal stripes. Abdomen also is light grey, spotted with dark patches to give a checkerboard appearance.

Female flesh flies usually deposit live larvae on a suitable feeding medium. Usually, the spoilt meat of fish or other animals is preferred, but they may breed in dog excrement, manure and even decaying wastes from human food-handling operations. Larvae feed for a number of days, then move away from the feeding medium to pupate in adjacent drier parts. The life cycle usually takes 2–4 weeks to complete.

Vinegar flies (Family Drosophilidae)

Also called ferment flies or fruit flies.

Vinegar flies are small flies that can be very numerous, annoying and a threat to human health. Because of their attraction to materials of fruit or vegetable origin, particularly fermenting materials, they can be most troublesome around canneries, breweries, wineries, and fruit and vegetable markets and shops. As so many may develop from a single discarded piece of fruit left under a bench or from the unwashed remains in a tomato sauce container, they can be an obvious problem in restaurants and various other food-handling facilities, including domestic kitchens.

The adult is 2.5–4.0 mm long. It is usually brownish yellow or brownish black. At rest, wings are folded one on top of the other.

Eggs are laid on an appropriate moist feeding medium at the rate of about 25–35 eggs per day. Materials suitable for larval feeding include overripe fruit and vegetables, fermenting materials, alcohol, dirty garbage cans, contents of discarded milk and drink containers and the like. Eggs hatch within a day, and the maggot-like larvae feed for about 4 days, after which they move away from the moist food source to pupate. Pupation usually lasts for about 4 days, so the entire life cycle is usually about 8–14 days.

Adult vinegar flies are strong fliers and often tend to be more active around dawn and dusk. Large populations can build up quickly from relatively small amounts of food or wastes. Sometimes their small size can allow them to enter through normal screening. They can be a severe nuisance pest around food-handling facilities, and this can pose a serious contamination threat.

Cheese skipper (*Piophila casei*)

The cheese skipper is a relatively widespread pest of various food-production and handling facilities. The adult can be annoying and possibly instrumental in disease transmission, and human consumption of maggot-infected cheese or other foods can lead to mild to severe irritation and disease.

The adult is about 2.5–4.0 mm long. It is black with a metallic bronze colouring on the thorax. At rest, wings fold flat over the abdomen.

The adult female lays eggs on a suitable medium for larval feeding. Such media may include cheese, ham, bacon, smoked fish, cured pork or animal carcasses. The maggot-like larvae bore into the food and have a characteristic jumping or 'skipping' movement at times. On completion of feeding, the larvae move away from the feeding site to pupate in drier locations. The complete life cycle ranges from 2 to 6 weeks. Adults seem to feed mostly on the liquids in larval foods and usually live for less than a week.

Moth flies (Family Psychodidae)

Moth flies are small, hairy, moth-like flies that may be observed around bathrooms, in damp subfloors, in greenhouses and in other locations where moisture and the presence of decaying organic matter will support their presence. In homes, these flies usually breed in the built-up slime around drains and pipes. The adults do not bite, but in some cases, where numbers are enormous (eg around sewage plants), allergies may occur, owing to inhalation of the flies or their body parts.

Adults are usually 2–4 mm long. The flies are usually dark greyish in colour, with body and wings covered densely with hairs. At rest, wings are held roofwise over the body.

The female lays eggs (10–200) in polluted shallow water, organic muck that accumulates in and around drains, dirty garbage containers and other such locations. Eggs hatch within a day and the legless worm-like larvae are usually aquatic. The larvae feed for 4–15 days, and on completion of feeding may pupate near the food or within it. The entire life cycle may take 2–4 weeks, depending on conditions. Adults are not strong fliers and have a jerky movement about them. They probably feed on nectar and polluted water, and are usually short-lived. The cleaning up of accumulated organic material usually does much to control this fly.

Biting midges (Family Ceratopogonidae, especially *Culicoides* spp.)

Also called sand flies.

Adult biting midges have piercing and sucking mouthparts and are mostly predators or bloodsuckers. They are common around certain coastal lagoons, estuaries and mangrove swamps, usually breeding in tidal flats. At such locations their habit of biting humans can be most troublesome and annoying.

The adult is 1.5–4.0 mm long. These tiny adults have long antennae and prominent eyes. Legs are short, and wings are usually folded over the abdomen when at rest. Thorax often has dark spots and markings.

Females lay batches of eggs (30–100) on mud surfaces, wet soil near swamps, decaying leaf litter, and other moist organic materials associated with saline, brackish or fresh water. Eggs usually hatch in a few days and the larvae feed on organic matter for several days, then pupate. The entire life cycle may take 3–10 weeks, depending on conditions. Usually, adults are inactive in windy weather, and most bites seem to occur at dawn or dusk.

Fly control

In urban areas the quick and efficient disposal of garbage and wastes is of fundamental importance in fly control. The abundance of flies in a given area may be regarded as an indicator of the efficiency of waste disposal and general standards of sanitation in that area. The use of insecticides in fly control may, at best, serve as a back-up to improvements in hygiene and sanitation, if the attempt to control flies is a serious one.

The approach to any fly control problem must, of necessity, involve a thorough survey and inspection of the premises and adjacent areas, to determine, if possible, the location of larval breeding sites. Sometimes these seem or are known to be located quite remotely from the premises concerned. In such instances efforts may be directed to the control of adult flies only, and other action (eg consultation of local health authorities) may need to be sought in relation to the remote breeding sites. Where breeding sites are located within the premises, it is very likely that improvements in waste disposal and general 'housekeeping' will do much to lessen the problem.

The control or exclusion of adult flies may employ non-chemical or chemical control procedures, or often a combination of both. In such an integrated approach, the use of insecticides must be judicious and efficient. The more prevalent pest species of fly breed very rapidly, and resistance to certain types of insecticides often develops.

Non-chemical methods of control

The control of adult flies has seen much use of fly swatters and trapping devices, ranging from the humble 'sticky flypaper' to more sophisticated designs that may employ very smelly baits. Presently, light traps, which electrocute flies mostly by chance encounter, are widely used and offer some control of adults.

Where possible, flies should be excluded from premises. In some food-handling premises, air curtains can be very effective. The installation of insect screens over windows, doors and other points of access is a very widespread practice. The removal of attractant odours by suitable ventilation, clean-up soon after food-handling and good housekeeping practice all serve to make the area less attractive to flies.

The methods so far described deal only with adult flies. Any serious attempt at fly control must involve a decrease in the availability of breeding sites. In most urban areas, various species of flies very successfully exploit garbage and wastes before these are made unavailable. Specific policies and legislation at local government level often aim at standards of hygiene and sanitation that may do much to reduce the extent of fly-breeding that normally occurs.

In relation to garbage disposal, garbage bins should be kept clean and, if possible, dry. Wrapping garbage before placement in the bin, with regular washing out, may prevent breeding and make bins less attractive to adults. As garbage bins are apt to attract the interest of flies, they should be located away from doorways or other openings to buildings. Where there is a significant amount of wastes (eg in restaurants or other food-handling facilities), garbage pick-up should be frequent, perhaps each day if necessary. If local government services cannot make sufficiently frequent visits, a private waste-disposal contractor should be sought. Garbage disposal trucks should be frequently washed so as to reduce their role in dispersing flies from garbage dump sites. Quick burial or, where tolerated, incineration of wastes will reduce the likelihood of their serving as fly-breeding mediums. In the handling and disposal of wastes, procedures should aim at reducing attraction to flies and reducing or preventing the breeding of flies. Avoiding accumulations of lawn clippings, dog excrement, manures and other such potential breeding sites can do much towards fly prevention in urban areas.

Chemical control

Backed up by sound hygiene and sanitation practices, insecticides can play an important role in fly control. In practice, insecticides are used mostly for adult fly control and there is a heavy reliance on organophosphorus and carbamate insecticides, as well as natural pyrethrins and various synthetic pyrethroids. Unfortunately, some organophosphorus resistance is also apparent in some strains.

The use of insecticides in fly control may involve killing larvae, repelling adults, or killing adults with the use of residual surface sprays, space sprays or baits. Often a combination of these methods is employed.

Larvicides The use of insecticides to control fly larvae is not a common practice because:

1 sanitary methods of dealing with breeding sites are often preferred and are the sounder approach;
2 effective application that will give good contact with the target insects within the breeding medium is difficult to achieve;
3 frequent applications are usually required for any reasonable level of control; and
4 it is likely that poor application techniques can, in dealing with larvae, lead to the undesirable development of resistance.

Although baits and dusts are used as larvicides, the most common approach is to use water-based surface sprays that wet the larvae and their feeding sites. Thorough treatment that will contact the larvae is important, and this may require probing or even temporarily moving or disturbing the medium to reach hidden feeding sites. A relatively coarse spray that will not drift away from the target is preferred.

Fly repellents In Australia, significant sales of personal insect repellents, particularly during the warmer months, indicate the extent of the fly problem. Formulations for personal use are available as roll-ons, lotions and aerosols. Many contain a low concentration of natural pyrethrins — which may be supplemented with chemicals developed specifically for their repellent effects (eg diethyl toluamide and N-octyl bicycloheptene dicarboximide). Well-formulated repellent preparations should give a few hours relief from the immediate presence of flies.

As well, insecticides may be used to repel flies from a given area. Automatic space-spray systems, commonly employing a non-residual active constituent (such as natural pyrethrins or synthetic pyrethroids), may be set to give a very short burst of insecticide each 30 minutes. High-pressure aerosol systems may be employed for such purposes, as can smaller lower-pressure aerosol dispensers. The system is usually set so that the spray emitted is not sufficient to kill flies but rather has a distinct repellent action. The exact programming of a particular system will be determined by the factors surrounding the particular area. Such systems have been utilised in outdoor situations with some success (depending, of course, on prevailing weather conditions, attractiveness of odours, size of local fly population and many other factors).

Adult fly control Appendix VI outlines some of the insecticides that are used in the control of adult flies at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

Where possible, particularly in conditions of poor hygiene, a clean-up prior to insecticide application can be beneficial. Broadly, some types of insecticide formulations and methods of application are summarised as follows:

Surface-sprays The effectiveness of surface-sprays in fly control depends largely on which surfaces are treated, as sprays must be applied to surfaces that are constantly frequented by flies. Perhaps aided by discussions with the client about the exact nature of the fly problem, a thorough inspection of the premises may indicate favoured resting surfaces. Some flies (eg house fly) may have night resting places that are remote from the areas frequented by day. A build-up of fly specks on surfaces may indicate resting places, and areas that offer a warm, sunny location close to attractive odours (eg a garbage disposal area) may also be favoured.

Insecticides used for the residual control of flies include organophosphorus, carbamate and synthetic pyrethroid-type materials. These are usually applied to appropriate surfaces to just short of run-off. Typically, surface-type residual insecticides may give about 2–6 weeks (perhaps up to a few months) activity against adult flies, provided that the treated surfaces are not washed down or otherwise disturbed. Wettable powder and suspension concentrate formulations are likely to be more effective than emulsifiable concentrates when porous surfaces are treated. Some products advise the inclusion of sugar in the spray to enhance its activity.

Care should be taken, particularly in food preparation areas, to ensure that food, utensils and surfaces on which foods are handled remain uncontaminated by insecticides. As well, the treatment of certain surfaces may almost guarantee that dead flies will drop into food containers, food and so on. In food-handling areas, this potential problem should be borne in mind.

Space-sprays In most homes in Australia, the problem of flying insects is dealt with by using space-sprays in the form of low-pressure aerosol formulations. The most common constituents of these products are natural pyrethrins and synthetic pyrethroids, because they are relatively safe to use and can give very rapid knockdown and kill of flying insect pests.

In commercial or industrial contexts, space sprays for fly control are often applied when fast knockdown and kill are required. Usually, the premises are vacated, foods and utensils are protected, and a space spray is applied using fogging or misting equipment, high-pressure aerosol, or some other aerosol-generating equipment. Non-residual insecticides are used in the main, but some space-spray applications of more residual insecticides are carried out.

In space spraying, the intention is that droplets of insecticide will make contact with flying or resting insects. Usually it is advisable that treated premises be left closed up for a few hours, after which the area should be ventilated prior to reoccupation. In areas where the presence of flying insect pests is severe, automatic space-spray systems can be programmed to treat at appropriate times. Such systems may be extensive, treating very large areas regularly.

Baiting The use of insecticidal baits in fly control can give effective results, but these may be short-lived. Some surface-spray products advise the inclusion of sugar in the spray mix. This practice can significantly enhance the effectiveness of the surface-spray treatment. As well, ready-to-use baits, scattered in areas close to fly aggregation sites, can give good control of adult flies. Competition from attractive odours or feeding materials can reduce the effectiveness of baits.

In summary, effective fly control relies on:

1 thorough inspection/analysis of the problem;
2 modification of hygiene and sanitation procedures, to reduce fly-breeding and the attraction of flies; and
3 judicious use of insecticides, to further reduce breeding or to control mobile adults that pose a serious threat to health.

MOSQUITOES

Mosquitoes are small, delicate members of the Order Diptera, which as adults have piercing and sucking mouthparts. They constitute the Family Culicidae, which in Australia is represented by just over 270 described species.

The blood-sucking habit of the female has given the group significant pest status, which is mostly manifest in the way in which they may affect the health and comfort of humans and livestock. While much annoyance and irritation is attributable to mosquitoes, in the worldwide context these insects have claimed, and continue to claim, untold numbers of human lives by the efficient biological transmission of a variety of diseases.

Structure

Adult mosquitoes are usually about 3–6 mm long, slender, long-legged, narrow-winged and equipped with piercing and sucking mouthparts. Larvae are aquatic and have a well-developed head, a pair of spiracles located at the hind end and a body often covered with tufts of bristles. Pupae appear oval-shaped with a tail-like abdomen.

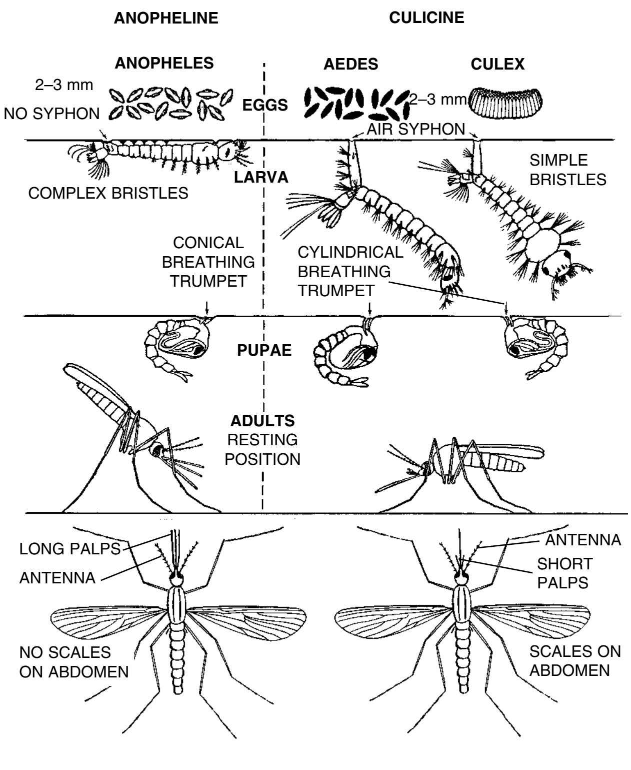


Figure 11.9 The mosquito life cycle showing some differences between Anopheline and Culicine types

Life cycle

Females require a blood meal before egg production. Eggs are usually laid on the surface of water (fresh, brackish or saline, depending on the species) or on surfaces that will be wetted (eg flood plains). The larvae, often called 'wrigglers', are aquatic and feed on organic matter filtered from their environment. They usually undergo 4 moults after which they pupate. The pupa is often called a 'tumbler', does not feed but is quite mobile. The adult emerges from the pupal case on the surface of undisturbed water. The life cycle may be complete within a week but may be much longer, depending on temperature, food, species and other factors. Adult males are short-lived and feed mostly on honeydew, nectar or other plant secretions. Adult females may live for several weeks and may pierce the skin of a variety of animals in order to suck blood.

Habits

Mosquitoes are very good at finding and exploiting a range of water containments, including natural and artificial sources of temporary or permanent water. Lakes, streams, pools, swamps, dams, irrigation ditches, tree holes, septic tanks, drainage pits, salt water rock pools, and water captured in tin cans, old tyres and other rubbish, may all serve as larval habitats. Adults may remain in close proximity to their breeding site, but dispersion can be over several kilometres, depending on the species and many other factors.

Mosquitoes as pests

Mosquitoes pose a significant threat to the health and comfort of humans and livestock.

The term 'biting' is widely applied to the piercing and sucking feeding action of adult female mosquitoes. This habit can be so annoying and irritating that it can reduce livestock yield. Humans, too, may suffer mild to severe irritation. Host-finding probably relies largely on the detection of warmth, moisture and carbon dioxide in the atmosphere. Certain colours may, in some cases, be more attractive than others, and subtle chemical presence (eg sweat components) may also play a role. Irritation from bites arises from the injection of saliva into the skin. The saliva comprises mainly proteins /peptides, which may serve anticoagulant and anaesthetic functions. Humans vary in their response to the injection of such foreign substances, and desensitisation may occur.

The importance of the role that mosquitoes play in the transmission of diseases cannot be overstated. Millions of human lives have been lost to diseases distributed and transmitted by adult female mosquitoes. The more dangerous diseases transmitted by mosquitoes rely on biological transmission. Here, the female receives a disease-infected blood meal, the disease-causing organisms multiply within her body, and at some later stage she injects the disease organisms into a new host. The types of diseases transmitted by mosquitoes include:

TABLE 11.4
Some characteristics of the main types of mosquitoes

	Anopheline	Culicine	
Genus	*Anopheles*	*Aedes*	*Culex*
Eggs	Laid singly. Have floats.	Black and spindle-shaped. Laid singly. Often overwinter.	Spindle-shaped. Massed together in the form of a raft.
Larvae	Hang parallel to water surface. Hind spiracles on body surface.	Hang at an angle away from the water surface. Hind spiracles at end of a siphon-like process.	
Pupae	Breathing trumpets relatively conical in shape.	Breathing trumpets relatively cylindrical in shape.	
Adults	Abdomen without scales. At rest body at angle to surface. Females with palps as long as proboscis.	Abdomen covered with scales. At rest body almost parallel with with surface. Females with short palps.	
General remarks and disease associations	Widely represented, but most species tend to feed on domestic and wild animals. Various species capable of acting as vectors of malaria.	Very widespread group, well represented in Australia. Include vectors of yellow fever and dengue fever.	Often common pest mosquitoes in urban areas. Include vectors of myxomatosis, filariasis, dog heartworm and arboviruses (eg Murray Valley encephalitis).

- protozoan-type diseases (eg malaria);
- nematode (round worm)-type diseases (eg filariasis); and
- virus-type diseases (eg Ross River virus, Murray Valley encephalitis virus).

In Australia, mosquitoes have been responsible for the transmission of a range of diseases in humans:

Malaria
Malaria involves the transmission of certain parasitic protozoans (*Plasmodium* spp.) to humans by *Anopheles* mosquitoes. This disease, which causes severe fever and sometimes death, now occurs only occasionally in Australia. Travellers who are already infected and enter Australia appear to be the source of local infections.

Dengue
The Dengue virus also seems to be sourced from travellers entering Australia who are already infected with the virus. The disease is transmitted by *Aedes aegypti* and infected humans suffer muscle and joint pains and fever. Death may result.

Ross River virus and Barmah Forest virus
These viruses are transmitted by a range of mosquito hosts. Infection in humans can cause polyarthritis, a disease which can result in severe debilitation for periods varying from months to years.

Murray Valley encephalitis virus, Kunjin virus and Japanese encephalitis virus
These viruses cause encephalitis in humans and this may result in brain damage or death. *Culex annulirostris* appears to be the main vector.

Tables 11.4 and 11.5 describe the habits, distribution, pest status and some characteristic features of the main types of mosquitoes and some common pest species.

Mosquito control
The nature of mosquito-breeding habits is such that control measures may need to be extensive and costly. Although individuals may use screens to exclude and coils or aerosols to kill adult mosquitoes, any serious attempt at mosquito control must involve some disruption of larval feeding habitats. Such a procedure may involve identifying the mosquito species present, extensively sampling and surveying to determine distribution, and developing a mosquito control program that will probably rely on a combination of non-chemical and chemical control methods, public education and cooperation, and adequate funding. Where there is an immediate threat of disease epidemic, the use of insecticides can give rapid control.

Non-chemical methods of prevention and control
The disruption of breeding sites can do much to reduce a mosquito problem. Individuals can prevent localised breeding by preventing water accumulations as may occur in rubbish (eg tin cans, old tyres) and blocked roof guttering. Where possible, unnecessary water accumulations should be drained/avoided. Where large-scale bodies of water are concerned, a water management program should involve thorough investigation of the mosquito ecology of the area. Biological mosquito control may involve the use of mosquito-eating fish (eg *Gambusia*), but such projects must involve local fisheries and wildlife authorities. A variety of mosquito parasites and pathogens are being investigated for their potential in

TABLE 11.5
Mosquitoes: some common pest species

Mosquito	Typical larval habitat	Period of activity (adult)	Areas where mosquitoes bite people	General remarks and disease associations
Common Australian anopheline *Anopheles annulipes*	Often in rural freshwater (natural or artificial, temporary or permanent).	Mostly night	Mostly outdoors	Adult females feed mainly on domestic and wild animals (mammals mainly). May be associated with transmission of myxomatosis, malaria and filariasis.
Dengue mosquito *Aedes aegypti*	Closely associated with human habitation in natural and artificial containers with water.	Day and night	Indoors and outdoors	Can cause much annoyance in domestic situations. Vector of dengue fever and dog heartworm.
Domestic container mosquito *Aedes notoscriptus*	Commonly found in natural or artificial contained water. Common in blocked roof guttering. Rural and urban.	Day and night	Indoors and outdoors	Can be a very annoying biter in shade and at night. May play a role in the transmission of myxomatosis and dog heartworm.
Saltmarsh mosquito *Aedes vigilax*	Mainly coastal areas, in brackish marsh and mangroves.	Day and night	Indoors and outdoors (mostly outdoors)	Can disperse many kilometres from breeding site. Important pest in coastal areas. May be a vector of Ross River and Barmah Forest viruses and dog heartworm.
Greystriped mosquito *Aedes vittiger*	More common inland, mostly in temporary freshwater.	Day and night	Mostly outdoors	Can disperse widely. May be a vector of myxomatosis.
Common banded mosquito *Culex annulirostris*	Widespread, in freshwater, pools, swamps etc.	Mostly night	Indoors and outdoors	Can disperse widely. May be a vector of myxomatosis, Ross River and Barmah Forest viruses, Murray Valley encephalitis, Kunjin and Japanese encephalitis viruses and dog heartworm.
Brown house mosquito *Culex quinquefasciatus*	Widespread. Closely associated with human habitation, in polluted containers, pools etc.	Mostly night	Mostly indoors	Commonly enters homes. Females and adults feed mainly on birds (chickens) and humans. May be a vector of filariasis and dog heartworm.

mosquito control. Much protection from adult mosquitoes is afforded by the screening of doors, windows, vents and other openings to buildings.

Chemical control

Owing to the rapid life cycle of the mosquito and the history of insecticide use against it, insecticide resistance is a widespread problem. Organochlorine resistance is significant, and it is likely that some strains of organophosphorus resistance also occur.

Use of insecticides may involve killing larvae and/or repelling or killing adults. Adult control may be effected by residual surface sprays, space sprays, smokes or vapours.

Larvicides Appendix VI outlines some of the insecticides that are used in the control of mosquito larvae at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose). Because of the likely intensity of larvae in a given area, treatment of larvae is often more economical than widespread treatment for the control of adults. Larval breeding sites may be treated with sprayers or granule application, which in some cases may involve aerial application. An inherent advantage of temephos is that it has a very narrow spectrum of activity, acting fairly specifically as a mosquito larvicide. In smaller-scale breeding sites, and where the use of insecticides is preferably avoided, a light film of mineral oil across the water surface will effectively control larvae, by preventing them from breathing. Biological control of mosquito larvae is possible using the bacteria *Bacillus thuringiensis*.

Mosquito repellents A range of mosquito-repellent products, including aerosols, roll-ons and lotions, provide temporary personal protection from mosquitoes. Typically, these may be active for up to a few hours and, when applied, may treat clothed as well as exposed body parts (bites through socks, for example, are not uncommon). Diethyl toluamide and dimethyl phthalate are commonly incorporated as active constituents in mosquito repellents. Space-sprays (eg aerosols) and mosquito coils containing natural pyrethrins and/or synthetic pyrethroids can control and/or repel mosquitoes in a treated area temporarily.

Adult mosquito control Appendix VI outlines some of the insecticides that are used in the control of adult mosquitoes at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

Broadly, some types of insecticide formulations and methods of application are summarised as follows:

Surface-sprays A range of organophosphorus, carbamate and synthetic pyrethroid insecticides are effective as contact poisons when mosquitoes rest on treated surfaces. When applied to surfaces, these materials are usually sprayed to just short of run-off, and they may remain active for up to a few months, depending on a range of factors. Surfaces known to be frequented by mosquitoes should, within the constraints of safe practice, be treated.

Space-sprays These are widely used for rapid relief from mosquito annoyance. Household aerosol insecticides are frequently relied on in the home for relief from mosquito intruders. The more common active constituents in these include pyrethrins and synthetic pyrethroids. On a larger scale, space-spray treatments with foggers, misters or high-pressure aerosols may be used for indoor or outdoor control of mosquitoes. Insecticides used in this way are mostly non-residual materials. Effective contact with the target insects can, in some cases, be difficult to achieve.

In summary, the killing of adults alone can do little in any serious attempt at mosquito control. Breeding sites must be dealt with, and in order to carry this out in an environmentally compatible fashion, much organisation, funding, and public awareness and co-operation are prerequisites.

FLEAS

Fleas are small, very specialised parasitic insects that belong to the Order Siphonaptera. This insect order is fairly small, having some 2380 species known worldwide and only about 90 species represented in Australia. Adult fleas are blood suckers, the majority feeding on mammals (eg dogs, cats, pigs) and some feeding on birds.

Some flea species are very widespread and as a result of their biting habit, which may cause severe irritation, and their role in disease transmission, the group has justly earned a reputation of being extremely important in the medical and public health context. When conditions favour flea growth and development, populations can be so great that references to a 'flea plague' are not uncommon. The interactions between flea populations and humans and their animals can be quite complex. In some instances, control may be difficult to achieve without the assistance and co-operation of the occupants of the building concerned. A sound understanding of the biology of fleas is an important prerequisite to effective control.

Structure

Adult fleas are small (1.5–4.0 mm long), usually brownish, strongly sclerotised, laterally compressed (facilitating fast movement through dense hair or fur), and equipped with piercing and sucking mouthparts. In the course of insect evolution, it appears that fleas have become wingless (again a condition that suits their parasitic lifestyle). Their well-developed hindlegs facilitate very powerful jumping, and claws on their legs ensure that they grapple onto the host animal. Some species have a transverse row of spines above the mouthparts, called the genal comb. The pronotal comb, when present, is a row of transverse spines on the pronotum. Such structures can be important in flea identification.

Flea larvae are small, legless, worm-like creatures with short antennae, chewing mouthparts and rigid hairs along the body.

Life cycle

Fleas undergo a complete metamorphosis. The adult female usually lays 4–8 eggs after each blood meal. In her lifetime she may lay several hundred. Most eggs are laid on the host; and as these usually fall off, they can be distributed in virtually any areas visited by the host animal. High concentrations of flea eggs are often associated with animal sleeping quarters. Eggs usually hatch in 2–14 days. Larvae feed on available organic material, in the form of crumbs, human skin scales and other debris that may accumulate in carpets, furniture, pets' bedding, cracks between floorboards, lawns, gardens and subfloor soil. Adult fleas often excrete almost undigested blood, which may dry into dark granules and serve as an important feeding supplement for larvae. The feeding period for flea larvae is usually 15 days, but it may be as long as several months in adverse conditions. When feeding is complete, the larva usually spins a silken cocoon, to which it will adhere particles of dust, soil, and the like, so as to camouflage and protect itself. The larva pupates within the cocoon, and the pupal stage may last for 7–14 days, or up to a year in some cases. The entire life cycle may take as little as 18 days or more than a year in less favourable conditions. Adult males and females, both blood suckers, may live 100–500 days and can endure long periods (up to 4 months) without food.

Habits

Fleas prefer warm, humid conditions and hence are often a pest during summer. High humidity favours the development of larvae, which may be populous both indoors and outdoors, where sandy soils (particularly if under cover from rain) are favoured. When climatic conditions are favourable, the development of larvae outdoors can be very widespread.

Insects can slow and almost halt their growth and development at various stages in order to make the most of more favourable conditions when they occur. Flea pupae may remain as pupae for long periods, being stimulated to emerge as adults by vibrations. Energy costs as a pupa are minimal, certainly less than those of an adult flea, which moves more, consumes more oxygen and so on. As vibrations may be caused by a larger animal that is likely to be a suitable host from which to obtain a blood meal, it is more efficient, from the viewpoint of the flea's well-being and inclination to produce the next generation, to wait until its first blood meal declares its presence by causing vibrations. Hence the emergence of adult fleas often relies on warmth, pressure and/or vibrations (as may be caused by a large animal that may well serve as a suitable first host).

Buildings unoccupied for long periods may suddenly seem to come alive with fleas immediately the occupants return. Host detection probably relies largely on temperature, carbon dioxide and possibly the detection of certain odours, as seems likely in the case of rodent hosts. Adult fleas spend a considerable time on the host (but not to the extent of some lice, which remain on their hosts all the time).

Fleas as pests

The significant pest status that fleas have achieved is largely attributable to their 'biting' (piercing and sucking) habit, which may cause mild to severe irritation or serve to transmit diseases.

Where a flea infestation is troublesome in domestic residences, most flea bites occur around the ankles and lower legs. Great variations in the degree of irritation exist between individuals. The irritation, which can persist for days, is due to the injection of saliva, which acts as an anticoagulant. Typically, a cluster of bites may occur, and these usually develop into a small red spot, surrounded by a reddish halo but seldom with any swelling. In Australia it is the frequency of bites, which may occur indoors or outdoors, that can annoy and irritate to the extent where control measures are sought.

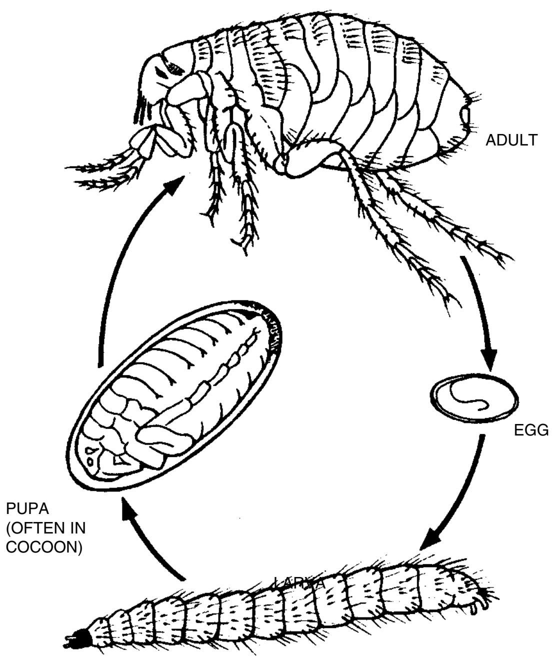


Figure 11.10 The life cycle of a flea

The role of fleas in disease transmission and human welfare has been profoundly important, because any flea bite allows the possibility of infection at the wound site, and because a number of diseases, some devastating, are transmitted by fleas:

Plague Historically, bubonic plague (the 'Black Death' that occurred during the Middle Ages) has claimed untold millions of human lives. The disease is caused by a bacterium called *Yersinia pestis*, normally carried by rats. The bacterium is transmitted from one rat to another by fleas, when an infected flea regurgitates while feeding on an uninfected new host. The principal vector of plague is the oriental rat flea (*Xenopsylla cheopis*) but many other flea species are thought to be quite capable of carrying the dreadful disease. Instances of plague still occur, but Australia has fortunately avoided its attentions for many years.

Murine or endemic typhus Murine typhus is another disease that is principally associated with rats and may be occasionally transmitted to humans. The oriental rat flea again is the main vector, and the cause of the disease is a micro-organism called *Rickettsia typhi*. Murine typhus is transmitted when infected flea droppings are scratched into the wounds made by feeding fleas.

Intestinal worm parasites It is likely that fleas play some role in the transmission of dog tapeworm (*Dipylidium caninum*) and rodent tapeworm (*Hymenolepsis diminuta*). Occasional infection of children by these organisms is known.

Important pest species

Flea species that are important as pests include:

Cat flea (*Ctenocephalides felis*) This is perhaps the most common pest flea in many regions. In addition to cats, it is known to attack dogs, rats, humans and other mammals.

Dog flea (*Ctenocephalides canis*) This is very similar in appearance to the cat flea but seems to be less commonly encountered. It also attacks a wide range of mammals.

Human flea (*Pulex irritans*) This is becoming much less associated with humans since the advent of the vacuum cleaner and other aids to better housekeeping. It also attacks dogs, pigs, rats and mice. It is often encountered in piggeries.

Oriental rat flea (*Xenopsylla cheopis*) Favoured host is the rat. This is the principal vector of bubonic plague and murine typhus.

Flea control

Effective flea control often relies on the well-directed application of chemical insecticides and/or insect growth regulators, backed up by procedures that the client undertakes to help make the environment less suitable for the development of fleas. Where pet animals are concerned, their role as carriers of adult fleas should not be overlooked.

Non-chemical methods of prevention and control

Cleanliness is an important prerequisite to flea control. All floor areas should be thoroughly and frequently washed, swept or, in the case of carpets, vacuumed or steam cleaned. Particular attention should be paid to less disturbed areas (eg carpet edges and under furniture). As well, other areas that may harbour eggs, larvae, pupae or adults should be thoroughly cleaned, including upholstered furniture and, in particular, areas favoured by pets for resting or sleeping. Vacuumings should be incinerated or sprayed with an aerosol insecticide. Keeping pets outside may reduce flea problems indoors, but their presence may still be obvious out of doors. Subfloor areas should, where possible, be made inaccessible to pets and other animals, as they often offer a very suitable environment for flea-breeding. As well, the exclusion of rats from premises may reduce the likelihood of flea problems.

Chemical control

Any serious attempt at flea control must take into account the complexity of the problem. By inspecting the premises and/or questioning the occupants, the pest control operator should gain some idea of the extent of the infestation. Attention to outdoor and subfloor areas may be required.

Where pet animals are involved, their role in carrying fleas must be considered. If possible, pets should be treated at the same time as the premises, to reduce the likelihood of reinfestation from adults carried on pets. Treatment of pets should not be carried out by the pest control operator. The pet owner may perform the treatment, or the animal may be taken to a vet for de-fleaing. In any case, only products specifically registered for flea control on pets should be used. These may be powder formulations or washes. Even if the treatment is entirely successful in killing all the adult fleas on the animal, reinfestation is usually only a matter of a short time. Some pet owners seek longer term protection of pets from adult fleas with insecticidal collars or with a program of ingestion of a systemic insecticide (eg cythioate). Pet owners should consult their vet about matters dealing with the direct treatment of their pets. Improvements in the treatment of pets against fleas have seen a significant reduction in the amount of flea control work undertaken by pest control operators.

Where possible, thorough vacuuming of the premises, prior to treatment with insecticides, can be advantageous. If the client willingly does this, it is advisable that the contents of the vacuum cleaner be incinerated or sprayed with an appropriate insecticide.

Once the operator has organised:

1 an understanding of the extent of the problem (including questioning the client);
2 treatment of pets for adult fleas; and
3 thorough vacuuming and cleaning of the premises,

then treatment with insecticides may be undertaken.

Appendix VI outlines some of the insecticides that are used in the control of fleas at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

Broadly, some types of insecticide formulations and methods of application are summarised as follows:

Surface-spraying The types of insecticides most commonly used in flea control are organophosphorus, carbamate, synthetic pyrethroids and IGRs as emulsifiable concentrates, wettable powders or suspension concentrates. These materials may have a residual life of up to a few months, depending on conditions. As many surfaces (eg carpets and rugs) must be treated indoors, the choice of an insecticide with low mammalian toxicity is clearly desirable. Indoors, surfaces treated should, within safety constraints, include all surfaces that may harbour eggs, larvae, pupae or adults. Typically, carpets, rugs, areas under rugs, crevices in upholstered furniture, floorboard cracks and wall-floor joints may all require attention. In some extreme cases, outdoor areas and subfloor areas may require attention. It is sometimes advisable to wet such areas with a hose prior to insecticide application as this may help the spray to penetrate.

Space-spraying Where the premises can be vacated for some hours, space-spraying, usually with a non-residual insecticide, can be a useful back-up to the treatment of surfaces.

Dusting Dusts, though not often used in flea control, can be useful for the treatment of areas where spraying is difficult or dangerous. The treatment of ceiling or wall voids and basements can, if necessary/appropriate, be carried out using dust formulations.

In summary, flea infestations in buildings can present a complex problem and effective treatment may rely on the cooperation of the occupants. Steps to consider include:

1 determining the extent of flea activity;
2 arranging treatment of pets (for adult flea control);
3 advising thorough vacuuming and cleaning;
4 applying insecticides carefully, aiming at all the possible habitats that larvae or other stages may infest; and
5 advising occupants on the importance of regular attention to pets and the importance of cleanliness in the home.

BEDBUGS

Bedbugs are one of the true 'bugs'; that is, they are insects belonging to Order Hemiptera. Hemipterans all have piercing and sucking mouthparts, and the vast majority of them suck sap from plants. A small proportion of the bugs are ectoparasites of animals, including those belonging to Family Cimicidae, one of which is the bedbug (*Cimex lectularius*).

Although they do not seem to be involved with any serious disease transmission, the bites of bedbugs at night can prove very irritating, even unbearable at times. They are blood suckers at all stages of their development, so a substantial infestation can lead to much biting and annoyance. Historically, they are associated with the sleeping quarters of hotels, taverns, inns, hostels and other dormitory-type facilities. In domestic residences, an infestation is usually located mainly in bedrooms.

The bedbug is of widespread distribution around the world, but in earlier times it was much more frequently encountered than is the case nowadays. The decrease in its abundance is largely attributable to an increase in standards of hygiene and the use of insecticides (particularly DDT soon after the Second World War).

Structure

Adult bedbugs are usually 4–5 mm long, rusty red-brown coloured, wingless and oval-shaped. Their piercing and sucking mouthparts are normally present as a proboscis that projects along the ventral part of head and thorax. During feeding, the proboscis is swung forward and downward, impaling the skin of the victim. Body shape is normally quite flattened, but it can be rather expanded and ovoid after blood-sucking. Nymphs resemble adults in general appearance.

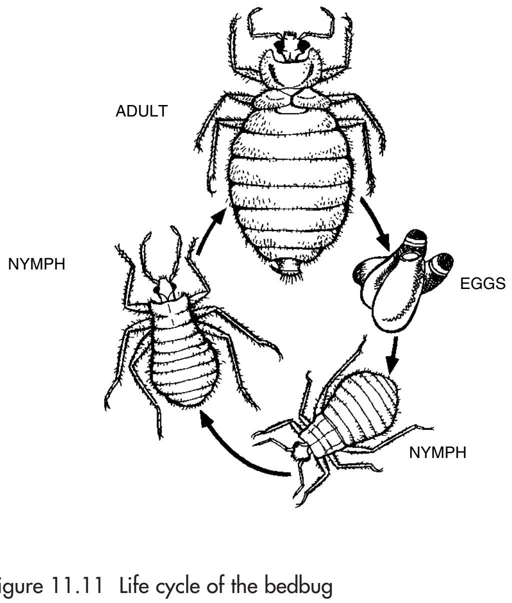


Figure 11.11 Life cycle of the bedbug

Life cycle

Bedbugs undergo a gradual metamorphosis. The adult female must have a blood meal before egg-laying. Eggs are cemented to surfaces in batches of up to 10 or more, and sites chosen for egg-laying usually include cracks and crevices (eg in furniture) that are within close proximity to the host's sleeping area. Typically, most cracks and crevices in an infested bedroom are suitable. In her lifetime a female may lay 200–500 eggs. Eggs usually hatch in 7–30 days, and the nymphs must have at least one blood meal between moults. Typically, bedbug nymphs undergo about 5 moults before reaching adulthood. The life cycle of bedbugs can be as short as 45 days but may be as long as a year or more in less favourable conditions. Adults may live for 50 days to over a year, depending on conditions. They can survive several months without a blood meal.

Figure 11.12 Adult bedbug (*Cimex lectularius*)

Habits

Males, females and nymphs are all obligate blood suckers. Most of their time is spent hiding in cracks and crevices in fairly close proximity to their sleeping host. Temperature is very important in host location, and they usually visit their host briefly in the few hours just before dawn. After taking a blood meal they return to their hiding places, where they are somewhat gregarious and may be found closely grouped together. Their most important host is humans, but in some cases bats, cats and other animals may serve for feeding.

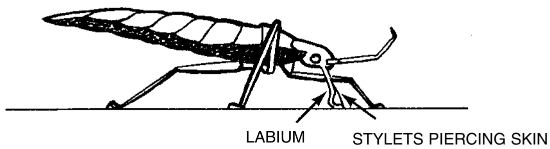


Figure 11.13 Lateral view of bedbug feeding

Bedbugs as pests

The activity of bedbugs in premises is usually detected by the irritation caused to sleepers. In infested premises, evidence of activity can include: live bugs hiding in cracks and crevices in furniture, behind skirting and architraves, among books, behind wallpaper, in bedding (especially under mattress buttons) and in other harbourages; eggs cemented to similar surfaces, hatched or unhatched; cast skins; small dark-brown marks on sheets, walls and other surfaces on which they may excrete; and, in the case of heavy infestation, an apparently sickly sweet 'buggy odour'. This odour is caused by body secretions, but it is often masked by other odours prevalent in unclean premises.

Bedbugs disperse largely by being carried by humans in furniture, luggage, clothes and so on. Well established infestations are usually associated with poor housekeeping and low standards of hygiene. When brought into even the cleanest premises, however, they may find suitable hiding places and hosts and thus commence an infestation. Although their mobility is restricted to crawling within buildings, they may infest adjacent rooms or apartments, and even neighbouring houses can be infested by their crawling habit.

When the bedbug bites its victim, saliva with anticoagulant properties is injected. The bugs have a tendency to 'test bite', which often results in a line of bites. For some people the bite is painless and there is no allergic reaction. However, many people react with local swelling at the site of the bites, followed by mild to severe irritation. Movements of the bugs or scratching may facilitate infection of wounds. In severe infestations, sleeplessness may result; and in India, cases of iron deficiency have resulted from severe attacks.

To date, the bedbug has not been implicated with any serious disease transmission.

Bedbug control

Where a well-established bedbug infestation is troublesome, it is likely that improvement in standards of hygiene will be a necessary back-up to any chemical treatment. Where normally hygienic premises have become infested by the importation of bugs in second-hand furniture or by some other means, it is likely that a thorough treatment of the premises with careful attention to cracks and crevices will give total eradication, which may last until any future importation.

An essential first step in the control of bedbugs in buildings is to determine the extent of infestation. By questioning occupants and, more importantly, by carefully inspecting the premises, the operator can establish the extent of the infestation and thus be more certain that potential sources of reinfestation are not overlooked during treatment. All possible hiding places should be inspected, including furniture, wall linings, skirtings, architraves, curtain rods, light fittings, picture frames, picture railings, shelves, appliances and bedding, including the mattress.

Non-chemical methods for prevention and control

Thoroughness in housekeeping is likely to make rooms less favourable for bedbug infestation. As well, a reduction in potential harbourage areas (eg cracks behind skirtings, loose wallpaper) may help to make premises less suitable. Thorough inspection of second-hand furniture before it is brought into the house may avert potential infestation. This particularly applies to bedroom furniture such as wardrobes and beds, and especially mattresses. An infested mattress may be treated by being wrapped in black plastic and placed in the sun for several hours on a hot day.

Chemical control

The proper and effective application of insecticides to control bedbugs relies on prior inspection and knowledge of harbourage areas. Thus equipped, the operator can ensure contact of the insects with the insecticides. Careful application to cracks and crevices is usually necessary. Broadly, the methods of application involved may be surface spraying, space spraying and, where appropriate, dusting.

Appendix VI outlines some of the insecticides that are used in the control of bedbugs at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

Where possible, particularly in conditions of poor hygiene, a clean-up prior to insecticide application can be most beneficial. Broadly, some types of insecticide formulations and methods of application are summarised below.

Surface-spraying The chemicals mostly used for surface-spraying are organophosphorus, carbamate and synthetic pyrethroid types. These are available mostly as emulsifiable concentrates, wettable powders and suspension concentrates and they may have a residual action of up to a few months, depending on conditions. Where possible, premises should be thoroughly cleaned before insecticide application. Surface-sprays should be applied to bed bug harbourage areas, and this often necessitates much crack and crevice treatment. Barrier treatments around bed frames (away from possible human contact), skirtings and heavy furniture may be appropriate. Where the bed itself is heavily infested, the mattress should be removed and the bed frame carefully treated. If the mattress itself is infested, this should be treated with a light spray of insecticide registered specifically for this purpose (see product labels), followed by a thorough airing. Alternatively some kind of heat treatment (as described above) may be attempted. All harbourage areas in a given building should be treated.

Space-spraying In instances where the premises can be vacated for a period, the application of space sprays can provide a useful back-up to surface-spray treatments. Space sprays can also be useful when fast knockdown and kill are needed for quick relief. Typically, non-residual insecticides are used. Surface-spray treatment should precede space-spray treatment when both techniques are employed. Where possible, the premises should be prepared for effective space-spraying by exposing harbourage areas as much as possible. Closets and wardrobes should be opened, and mattresses removed from beds. Once treated, the premises should be enclosed for the recommended exposure time, and instructions should be given to ensure that the area is properly ventilated prior to reoccupation.

Dusting The use of dusts can help in bedbug control. Where treatment of harbourage areas cannot be carried out with wet sprays (eg in wall voids or appliances), light dusting can give reasonable residual control.

In summary, effective bedbug control relies on:

1 inspection/analysis to determine the extent of the problem;
2 careful application of insecticides so as to make likely their contact with the insects; and
3 high standards of sanitation and hygiene to back up the insecticidal action.

LICE

Lice are highly specialised external parasites of birds and mammals. They belong to Order Phthiraptera, which comprises some 3000 different species worldwide, of which about 200 are represented in Australia. Within this order, there are four distinct suborders:

1 Amblycera
2 Ischnocera
3 Rhyncophthirina (these lice were, in the main, previously known as Mallophaga and represent those lice that have mandibulate [chewing-type] mouthparts and are mostly parasitic on birds and mammals, feeding on feathers and skin surface detritus)
4 Anoplura (representing those lice that have piercing and sucking mouthparts and are mostly parasitic on mammals, from which they suck blood).

The remainder of this section deals with certain Anopluran lice that are blood-sucking parasites of humans: the head louse, the body louse and the crab louse. These lice are of very widespread distribution, and the condition known as pediculosis (louse infestation of humans) is a serious problem in some countries.

Human-infesting lice have played a very significant role in the transmission of disease. Many would suggest that the transmission of epidemic typhus by the body louse has, during the history of humankind, had an unspeakably significant impact on human health. At times the ravages of typhus have changed the course of wars and battles. In Australia, the body louse is largely absent at present. The head louse and crab louse, however, are of reasonably common occurrence, and treatment for such infestations is usually under the direction of state health authorities or other medical personnel.

Structure

Adult lice are usually 1.5–3.5 mm long, wingless, and have a flattened body shape. Antennae are usually short, compound eyes are small or absent, and legs usually carry rather conspicuous claws, which facilitate movement among hair.

Developing nymphs resemble adults.

Life cycle

Lice undergo a gradual metamorphosis. Eggs, sometimes called 'nits', are usually glued to the host's hair or, in the case of the body louse, to clothing seams that are in close contact with the body. The eggs usually hatch in 5–10 days, and nymphs feed on blood from the host, usually passing through 3 instars before reaching maturity. Typically, the life cycle may take 3–4 weeks. Adults live for about a month, in which time the female may lay up to 200 eggs. The survival time of lice separated from their host is usually short, perhaps a matter of a few days.

Habits

Lice spend their entire life history on the host, surviving only a short time if separated from it. Both sexes and all developmental stages are obligate blood suckers and may feed intermittently throughout the day or night. Particular lice species tend to occupy certain regions of the host's body. The head louse is mostly associated with the hair of the head, while the crab louse is most often found infesting the pubic region. Lice are very sensitive to temperature and tend to leave a dead or dying host to seek another. Temperature and smell probably play an important role in host detection. The spread of lice infestations is largely effected by close contact between hosts and potential hosts.

Lice as pests

Pediculosis (infestation of the human body by lice) is, in Australia, mostly associated with the head louse and crab louse. Fortunately, these lice have not, to date, been involved with any serious disease transmission. Their feeding activities involve breaking the skin and injecting saliva. This may cause irritation and scratching, which can, in severe cases, lead to local infection of bite wounds. As well, the continuous injec-

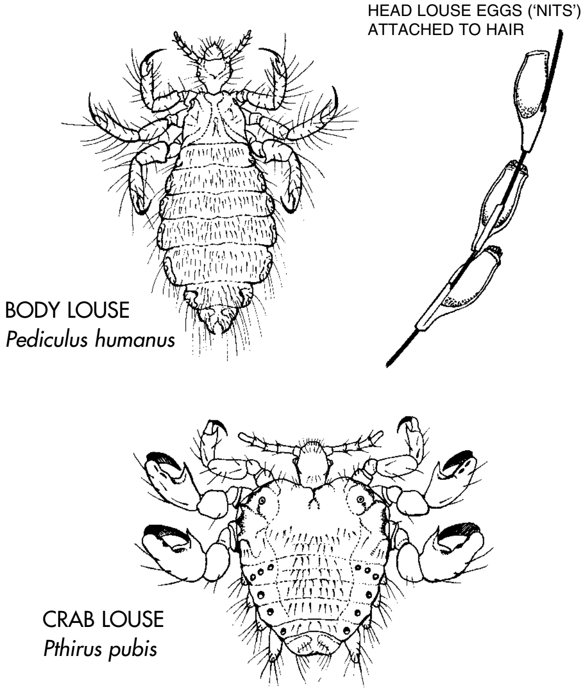


Figure 11.14 Body louse, crab louse and 'nits'

tion of saliva in severe infestations can lead to weariness and irritability — the human host feels 'lousy'.

The body louse has been responsible for much disease transmission and loss of human life. Severe body louse infestations are usually associated with crowded, unhygienic conditions, as may prevail in wartime or poorly managed prisons. Situations where humans seldom wash themselves and their clothes provide very favourable conditions for the development of body lice. Diseases associated with the body louse include:

Epidemic typhus This is a highly fatal disease during epidemics, and during the history of humankind it has been responsible for much loss of human life. The louse feeds on an infected host, and the disease-causing organism (*Rickettsia prowazeki*) then develops in its body. Disease transmission is usually effected when the human host scratches the bite wound, contaminating it with disease organisms from infected louse faeces or the crushed louse body. The bite of the louse is not directly involved in disease transmission. Fortunately, epidemic typhus has been absent from Australia since early settlement times, and generally high standards of personal hygiene continue to make conditions unfavourable for the development of body lice.

Trench fever This relatively uncommon and mostly non-fatal disease is caused by *Rechalimaea quintana*. As with typhus, distribution of the disease relies mainly on large populations of body lice associated with crowded, unhygienic conditions. Transmission again depends on the louse taking an infected blood meal, after which it or its faeces are crushed and scratched into the bite wound.

Relapsing fever Historically, relapsing fever has been a disease much associated with wars. Fatalities from the disease are relatively few, except in cases where the human hosts are undernourished. The louse becomes infected by the disease-causing spirochaete organism when it feeds on an infected host. Transmission to a new host is effected only when the body of the infected louse is crushed and allowed to contaminate broken skin.

Some characteristics of the important human-infesting louse species are summarised in Table 11.6.

Louse control

The development of synthetic insecticides has played a significant role in louse control since the Second World War. As well, increases in standards of personal hygiene have made the human body a less favourable habitat for lice. Where a louse infestation is discovered, persons that may associate with the infested person should immediately be checked, as this may limit the spread.

Non-chemical methods of prevention and control

Where possible, avoidance of contact with louse infested persons, their bedding and clothes is advisable. Frequent bathing, or washing with soap and water, and frequent changing of underwear, create conditions unfavourable to louse infestation. Where an infestation has been controlled with the use of appropriate insecticidal formulations, clothing, towels, bedding and so on should be thoroughly washed in hot water and then ironed. Specially designed fine-toothed metal combs can give partial control of head lice by physical removal.

Chemical control

Persons with a louse infestation should seek advice from state health authorities or other health professionals. A range of effective products for the treatment of human-infesting lice is currently available. Label directions may indicate one or more than one treatment. Such products should be used only in accordance with label directions and in consultation with appropriate medical personnel.

In summary, where a louse infestation is suspected, it should be quickly diagnosed; if it is confirmed, action should be taken to arrest the activity. Consultation with health authorities and proper use of available insecticidal formulations should give effective control. High standards of personal hygiene help in making infestation less likely.

PESTS OF FABRIC AND PAPER

The insects most commonly associated with damage to fabric and paper products include clothes moths, carpet beetles, silverfish and booklice. These groups are discussed in separate sections below, and the appearance and characteristics of some pest species are given in Table 11.7 and Figure 11.17.

Clothes moths and carpet beetles can be serious pests,

TABLE 11.6
Important human-infesting lice

Species	Head louse *Pediculus capitis*	Body louse *Pediculus humanus*	Crab louse *Pthirus pubis*
Description	Body length about 2.0–3.0 mm (on average slightly smaller than body louse). 3 pairs of legs clawed and of similar proportions.	Body length about 3.0–3.5 mm (on average slightly larger than head louse) 3 pairs of legs clawed and of similar proportions.	Body length about 1.25–2.0 mm. Little differentiation between thorax and abdomen. Body oval and broad. Front legs more slender than others and have small claws. Large claws on middle and hind legs. Crab-like in appearance.
	The head louse and body louse differ little in structure. The more important differences between the two relate to their habits.		
Habits	Typically infests hair on the head. Eggs are glued to hairs close to the scalp. Feeding occurs mainly on the scalp, particularly at the back of the head and behind the ears.	Occurs mainly on the insides of clothing, feeding from adjacent skin. Eggs are mostly glued to the seams of clothing in close contact with the body. Feeding occurs mostly where skin is soft or folded (eg around joints).	Typically infests the widely spaced hair of the pubic and perianal regions, occasionally eyebrows, beards and eyelashes also. Feeding mostly occurs around the pubic region.
Means of spread and infestation	Spread by personal contact, contact with items such as combs, brushes, hats, ribbons, pillow cases, scarves etc.	Associated with crowded unhygienic conditions. Spread by personal contact, contact with louse-infested persons and their clothes and bedding.	Spread mainly by sexual contact. Occasionally may be picked up from toilets, crowded locker rooms, bedding etc.
Role in disease transmission	No significant role in disease transmission.	Important in the transmission of epidemic typhus, trench fever and relapsing fever.	No significant role in disease transmission.

damaging a variety of materials, mainly of animal origin. In nature these insects perform an important 'clean-up' function, whereby certain parts of dead animals (eg feathers, furs, hides, horns, beaks) are recycled. While some materials of animal origin (eg woollen carpets) may be 'treated' or 'proofed' against such insects during manufacture, many materials are not. Within buildings, clothes moths and carpet beetles feed on and exploit a wide range of animal origin materials, including wool in carpets, clothing and furnishings, silk, fur, underfelt, and sometimes food products of animal origin, such as fishmeal. Even synthetic fabrics may be attacked if they are made attractive by contaminants such as urine, perspiration and food or drink stains. In some instances, infestations in a dwelling arise from activity associated with rodent or bird-nesting areas, or their carcasses in roof cavities, disused chimneys etc.

Silverfish have a preference for starchy materials, and in dwellings they may cause damage to cotton, linen, books, paper, wallpaper and other materials incorporating starch, sizing or glues.

Booklice, although often associated with stored papers, books, files and the like are usually more of a nuisance pest than a cause of serious or costly damage. They feed on the microscopic moulds that grow on such materials when they are stored in poor conditions.

CLOTHES MOTHS

Clothes moths belong to Family Tineidae (Order Lepidoptera) and are widely known for the damage they may cause to woollens, fur, felts and other materials of animal origin. In Australia, the casemaking clothes moth and webbing clothes moth are the more prevalent species, and they tend to be more frequently encountered in coastal regions, where the humidity is more appropriate for their requirements. Of the various developmental stages, only the larval stage is directly responsible for damage to materials. Adult moths are relatively short-lived, and with their siphoning-type sucking mouthparts tend only to feed on available liquids if at all.

Structure

In general, adult clothes moths are small (up to about 10 mm long) and often yellow or gold to buff, with narrow wings that are distinctly fringed and siphoning-type sucking mouthparts. Larvae are usually caterpillar-like, with a creamy-white body, dark head and mandibulate mouthparts. The larva of the casemaking clothes moth constructs a cocoon-like case inside which it carries out its larval development, dragging the case wherever it goes. The case is made basically of silk but may have, incorporated in it, fibres from the larval feeding medium. The colour of the case may give some indication of the feeding material in instances where the larvae have migrated away from the feeding site.

Life cycle

Female clothes moths usually lay eggs on or in materials that will provide a suitable food source for larval development. Eggs usually hatch in 5–10 days. The caterpillar-like larvae tend to feed in dark, undisturbed places. They may be protected in a case (eg casemaking clothes moth) or naked, feeding in silken tubes constructed throughout the feeding medium (eg webbing clothes moth). Larval feeding may be completed in 2–6 months. depending on temperature and other factors. When fully fed, larvae pupate. The webbing clothes moth usually does this within the feeding material, while the casemaking clothes moth usually crawls upward to the ceiling, picture rails or tops of wardrobes. The pupal phase usually takes about 8–12 days. Adults are usually short-lived, often surviving less than 14 days. They probably feed on available liquids (eg condensation, nectar), if at all.

Habits

Feeding clothes-moth larvae produce droppings that are similar to coarse sand. Their activity is usually restricted to dark, undisturbed areas, where the sand-like droppings and sometimes cast skins may accumulate. Adults tend to fly when disturbed and shun light.

Clothes moths as pests

With their preference for materials of animal origin, the range of materials attacked and damaged by clothes moths includes clothing, rugs, carpets, fabrics, furs, blankets, upholstered furniture, underfelt and felting such as that found in pianos. Usually, attack is confined to dark, undisturbed areas (eg carpet under heavy furniture, clothes stored for long periods in trunks). Adult clothes moths flying around in a room may indicate the presence of an infestation. Sighting of damaged fabric (or other material), sand-like larval droppings, cast skins and perhaps live larvae will confirm their activity.

Clothes moth control

Control methods are similar to those for carpet beetles and are discussed with those for carpet beetles below.

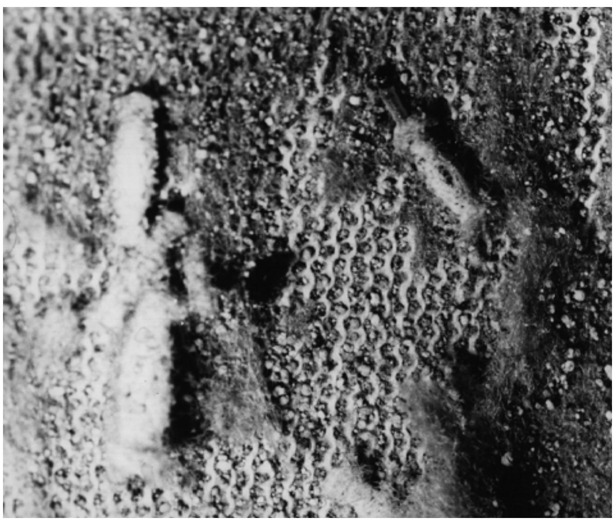


Figure 11.15 Larvae of casemaking clothes moth (*Tinea pellionella*)

CARPET BEETLES

Carpet beetles belong to Family Dermestidae (Order Coleoptera) and are widely known for the damage they may cause to a variety of materials of animal origin. A number of species are active in Australia, but the more commonly encountered ones are the variegated carpet beetle and the black carpet beetle. The distribution of carpet beetles is more widespread than that of clothes moths, probably owing to their higher tolerance of lower humidities, as may be prevalent in inland locations. Only the larval stage is destructive to various materials.

Structure

Adult carpet beetles are typically small (up to 5 mm long) and oval or elongate-oval in shape. Larvae are usually red-brown in colour and endowed with stiff bristles over the body surface.

Life cycle

Females lay their eggs in dark, undisturbed areas that will provide food for the developing larvae. Eggs usually hatch in 14–28 days. Larvae often feed for up to 9 months, after which they pupate. The pupal stage usually takes about 14–21 days. Overall, the life cycle of the carpet beetle is usually considerably longer than that of most clothes moths. Adults usually live for about 20–40 days.

Habits

Feeding carpet beetle larvae produce droppings that are similar to coarse sand. Their activity is usually restricted to dark, undisturbed areas, where feeding may lead to the accumulation of droppings and cast skins. Adults are mostly pollen and nectar feeders. They are often found around windows, probably migrating out to find flowers. Their habit of feeding on flowers may facilitate their transport into houses by 'hitch-hiking' on cut flowers and, once indoors, they may look for an egg-laying site.

Figure 11.16 Variegated carpet beetles (*Anthrenus verbasci*)

Carpet beetles as pests

Like clothes moths, carpet beetles have a marked preference for materials of animal origin, but they do seem to attack a wider range of materials than clothes moths. Carpet beetle larvae may feed on or in wool, fur, hair, silk, clothes, fabrics, carpets, rugs, underfelts, felts, fibre-type insulating material, dried insect specimens, animal carcasses, bee and wasp nests, and stored foods including dried meats, seeds, grains and

TABLE 11.7
Pests of fabrics and paper: clothes moths, carpet beetles, silverfish and booklice

Insect	Description of adult	Description of immature form	Life cycle	General remarks
Clothes moths				
Casemaking clothes moth *Tinea pellionella*	7–10 mm long. Forewings silvery-buff with 3 dark spots, sometimes indistinct. Wings fringed. Wingspan usually about 12 mm.	Larva up to 10 mm long when full grown. Creamy white with dark head. Usually protected in case made of silk and fibres of feeding material.	3–8 months	Very widespread and destructive pest of woollens, felts, upholstered furniture, clothes etc. Case of larva is often conspicuous, as it may incorporate fibres of the material being attacked.
Webbing clothes moth *Tineola bisselliella*	8–10 mm long. Golden buff. Wings without markings and fringed. Wingspan about 12 mm.	Larva up to 12 mm long when full grown. Creamy white with dark head. Often found in a network of silken tubing.	3–8 months	A widespread and destructive pest that attacks a variety of animal products, including wool, fur, skins, clothing, carpets, upholstered furniture, and felt. Larvae construct a network of silken tubing through the feeding medium, and this may obscure their presence.
Tapestry moth *Trichophaga tapetzella*	Forewings dark at base, outer parts creamy white.Wingspan about 19 mm.	Larva may grow to about 15 mm long. Prefers coarse materials and constructs silk-lined galleries.	3–6 months	Rare. Typically attacks old carpets, feltings and the fur and feathers of stuffed animals.
Carpet beetles				
Variegated carpet beetle *Anthrenus verbasci*	2–3 mm long. Mottled yellow, white and black. No cleft where elytra meet at end of abdomen. Oval shape similar to ladybird.	Larva up to 4–5 mm long when fully fed. Reddish brown to dark brown, with stiff, dark brown bristles. Of stout build, broadest at rear end.	9–12 months	Very widespread and destructive. Attacks carpets, underfelt, woollens, skin, fur, feathers, horn, and other materials (eg cereals, meat products, dead preserved insects).
Black carpet beetle *Attagenus unicolor*	3–5 mm long. Shiny black to dark brown, with brownish legs. Elongate oval shape.	Larva up to 7 mm long when fully fed. Reddish brown covered with stiff bristles. Tapers towards rear and has tuft of long hair from tip of abdomen.	6–12 months	Relatively widespread and destructive. Often associated with bird-nesting in roof cavities. May attack woollens, silk, carpet, felt, furs, skins, upholstered furniture, meat products, leather and various stored foods.
Australian carpet beetle *Anthrenocerus australis*	2–3 mm long. Basically black or dark with lighter markings. Oval	Larva reddish brown, covered with bristles. Elongate oval shaped, with some long hairs trailing from tip of abdomen.	9–12 months	Not as destructive as black and variegated carpet beetles. Attacks woollens, carpet, felt and underfelt, as well as stored food (eg meat products).
Furniture carpet beetle *Anthrenus flavipes*	2–3.5 mm long. Mottled yellow, white and black markings. Cleft where elytra meet at end of abdomen. Oval.	Larva up to 5 mm long when fully fed. Dark. Wide at front, narrow towards the rear.	9–12 months	Not as destructive as black and variegated carpet beetles. Often attacks upholstered furniture, carpets and some stored foods.
Silverfish *Ctenolepisma longicaudata*	Up to 15 mm long. Often silver. Body flattened, slender, scale-covered and tapering towards rear end (fish-like appearance). Antennae long and slender. 3 long appendages from rear of abdomen.	Young similar to adults but smaller.	6–36 months	Widespread pest that affects human foods, stored books and papers, wallpapers, starchy cotton and linen, glues, pastes and sizing. Fast moving. Nocturnal.
Booklice *Liposcelis bostrychophila*	1–2 mm long. Creamy white or greyish. Prominent head with narrow thorax. Wingless and soft bodied.	Nymphs similar to adults but smaller.	1–4 months	Mainly a nuisance pest. Fast moving. Found feeding on microscopic moulds on stored foods, paper, books, fabrics and leather. Usually associated with poor storage conditions that promote excess moisture.

cereals. The presence of flying or crawling adult carpet beetles may indicate the presence of an infestation. Sighting of damaged materials, sand-like larval droppings, bristly cast skins and perhaps live larvae will confirm their activity.

Control of clothes moths and carpet beetles

Where an infestation of clothes moths or carpet beetles requires treatment, it is important that a thorough and extensive inspection be carried out throughout the premises. If treatment is directed merely towards localised and obvious feeding areas, less obvious feeding areas may continue to supply adults to the rest of the premises after treatment; for instance, where carpet beetle larvae might be feeding on a rat carcass, bird nest or hot water insulation lagging in the ceiling or some other obscure location. Some 'good housekeeping' procedures can help to reduce the likelihood of infestation.

Non-chemical methods of prevention and control

Hygiene plays an important role in the prevention of fabric pests. The vacuuming or cleaning of carpets, rugs, soft furnishings and upholstered furniture should be thorough and frequent. Particular attention should be paid to carpet edges (adjacent to skirting) and areas covered by furniture. Such areas are often neglected, and with the subsequent build-up of hair, dust, skin scales, pet fur and the like, they are often sites of infestation. Rodent and bird nesting should be excluded from premises, and pet bedding should be regularly and frequently cleaned. As well, cut flowers brought into the house should be checked for the presence of carpet beetles.

When clothes are to be stored for some time, they should be thoroughly cleaned and wrapped up tightly in plastic before storage. Soiled clothes should never be stored in that condition for any length of time. Articles of clothing supporting an infestation of fabric pests may be freed of pests by placing the infested material in a black plastic bag, which is then tightly closed and hung in the hot sun for about three hours.

Chemical control

The use of insecticides in the control of clothes moths and carpet beetles mostly relies on surface spraying, space spraying or often a combination of both techniques.

Appendix VI outlines some of the insecticides that are used in the control of clothes moths and carpet beetles at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

Where possible, particularly in conditions of poor hygiene, a clean-up prior to insecticide application can be most beneficial. Before treatment, the entire premises should be inspected to ensure that potential sources of reinfestation do not escape attention. Where accessible, the roof cavity should be checked. Furniture should be moved, so that carpet or rugs underneath can be inspected and treated if appropriate. A thorough vacuuming of all carpet areas, especially edges and areas normally covered by furniture, should precede treatment. The contents of the vacuum cleaner should be sprayed or otherwise appropriately discarded. Broadly, some types of insecticide formulations and methods of application are summarised as follows:

Surface-sprays A number of insecticides, mostly organophosphorus, carbamate and synthetic pyrethroid, are registered for, and employed as, surface-sprays for the control of clothes moths and carpet beetles. Formulations are mostly emulsifiable concentrates and wettable powders. Wettable powders leave a dust-like residue that is easily removed by subsequent vacuuming. Emulsifiable concentrates are not so readily moved by vacuuming and may pose a staining problem, so spot-testing or checking with manufacturers may be worthwhile. Usually, surface-spray treatments are directed to feeding sites as well as adjacent areas, carpet edging, and areas of carpet normally hidden under heavy furniture.

Space-sprays Where premises can be vacated for some hours, space-spray treatments may serve as a useful back-up to direct surface-spraying. Typically, non-residual insecticides are used. Applied properly, these should move around in all the spaces within the premises, killing larvae or adults that have migrated away from feeding sites. Having wardrobes, closets, trunks and so on open during space-spraying (safety implications permitting) can be advantageous, because minor infestations in such places may be controlled. The choice of space-spraying technique should exclude methods that produce oily droplets that may stain.

Dusts Where dusts are applied to sites of infestation such as carpet edges, they should be brushed carefully into the pile, to ensure some penetration. Where much larval feeding in the roof cavity has occurred because of the presence of bird nesting, the nesting should be removed and the ceiling space treated with an insecticidal dust, which may be applied efficiently with a compressed-gas dust applicator. Proofing against future entry of birds will probably be necessary.

Other methods Stored goods that are susceptible to attack by fabric pests should be thoroughly cleaned before storage and, sometimes, attempts at further protection may be made with the use of insecticidal formulations that give off toxic vapours. The more common products used for this purpose are camphor/naphthalene (in the form of balls or flakes) and dichlorvos (in impregnated resin strips). These insecticides require a relatively enclosed space that will facilitate an adequate build-up of toxic vapours and occupants should first consider the toxicity/safety implications.

In summary, the proper control of clothes moths and carpet beetles in premises relies on:

1. thorough inspection to determine the extent of the infestation in the building;
2. careful application of insecticide(s) so as to make likely contact with the pest insects (areas that are dark and relatively undisturbed will probably require attention); and
3. a back-up of high standards of hygiene and sanitation.

SILVERFISH

Silverfish are very primitive insects that constitute the Order Thysanura. In Australia, this rather small insect order is represented by only 28 described species. These are agile, fast-running, scale-covered insects that are primitively wingless. About 5 species of silverfish have successfully invaded buildings. These pest species restrict their activities to relatively undisturbed areas (eg bookcases, storage rooms), where they may damage paper, fabrics and other materials.

Structure

Silverfish are primitively wingless and have a flattened, slender, scale-covered body. Most have a silvery appearance and, because the body tapers to the rear, they are often said to have a fish-like appearance. Antennae are usually long and slender, and three long appendages from the rear of the abdomen are very conspicuous. The structure of the young is similar to that of the adult.

Life cycle

Silverfish undergo a primitive metamorphosis (sometimes referred to as 'no metamorphosis'). Females lay eggs singly or in small batches, and these usually hatch in 2–8 weeks. The hatchlings closely resemble the adult form and undergo a number of moults. Usually, sexual maturity is attained after about 3–24 months. Silverfish continue to moult periodically throughout their adult life, which may be as long as 4 years.

Habits

Silverfish are agile, fast-running, nocturnal insects that generally shun light. They are usually found in dark, undisturbed places but may range fairly widely throughout a given dwelling. Their inability to climb smooth surfaces often results in their being trapped in bathtubs and basins.

Silverfish as pests

Within buildings, silverfish may be found almost anywhere. While frequently found in roof cavities, they may also occur in wall voids, subfloor areas and many places within the dwelling parts of premises. They feed on most types of human food but seem to prefer starchy materials. When paper or photographs are attacked, it is often the outer, shiny layer that is most damaged. As well, book bindings, cottons, linens and wallpaper are often damaged. Any sources of glue, starch or sizing are likely to be attractive.

Control of silverfish

Silverfish can be quite widespread within a given dwelling. Inspection is an important prerequisite to treatment. Thorough inspection should involve moving stored articles to reveal disturbed silverfish, and in some cases the use of an aerosol flushing agent can help to locate activity. The possibility of populations residing in wall cavities can make control more complex and demanding.

Non-chemical methods of prevention and control

Inspecting incoming goods that may harbour silverfish (eg second-hand books) may help to avoid infestation. As well, books, papers, files and so on should, where possible, be stored in light and airy conditions. Books hidden away in closed cabinets, particularly if infrequently opened, can provide very suitable conditions for silverfish development. In kitchen areas, tight containment of foods and frequent cleaning of scraps and crumbs helps to reduce the suitability of that environment to silverfish.

Chemical control

Owing to the often widespread distribution of silverfish within premises, it is usually necessary to use a combination of treatments to achieve effective levels of control.

Appendix VI outlines some of the insecticides that are used in the control of silverfish at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

Where possible, particularly in conditions of poor hygiene, a clean-up prior to insecticide application can be most beneficial. Broadly, some types of insecticide formulations and methods of application are summarised as follows:

Surface-sprays A variety of surface-sprays, mostly organophosphorus, carbamate and synthetic pyrethroid types, are registered for use in silverfish control. Where it is possible and safe to do so, these residual surface-sprays should be applied to surfaces on which the silverfish rest or travel.

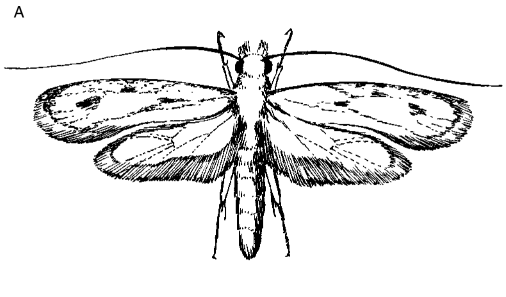
Space-sprays The application of space-sprays, in the form of mists, fogs or high-pressure aerosols, can be a useful back-up to surface-spray applications. Applied properly, non-residual insecticides can be distributed in the spaces of a building to control silverfish that may escape contact with treated surfaces.

Dusts Dry dust formulations can be useful in silverfish control. Often, the areas in which silverfish dwell are not suited to wet sprays (eg certain parts of libraries, archives, roof voids etc.). Dusts applied to surfaces tend to leave a very fine layer, which can give good residual control. Ceiling voids, which often serve for silverfish harbourage, can be safely and efficiently treated with dusts.

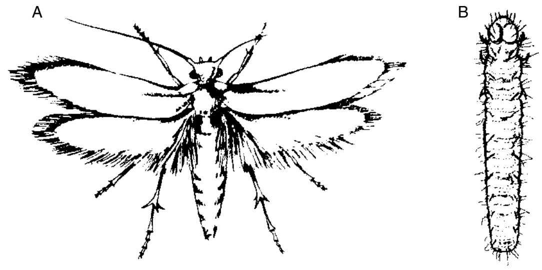
Baits Some silverfish control may be achieved by placing insecticidal baits in appropriate locations. Placement is very important, and competition from other food sources can limit their effectiveness.

In summary, silverfish control often relies on:

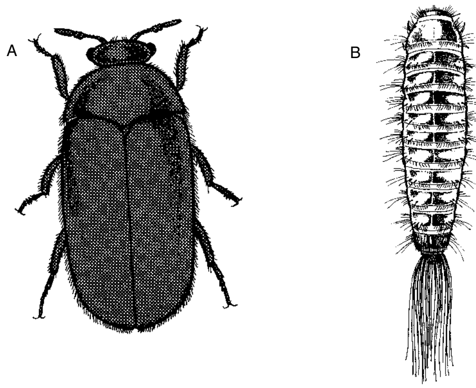
1 thorough and extensive inspection/survey of the premises;
2 careful application of insecticides so as to make likely their contact with the insect pests;
3 avoidance of unnecessary longer-term storage of paper, books and so on in closed-up boxes and bookshelves; and
4 thorough hygiene and sanitation.



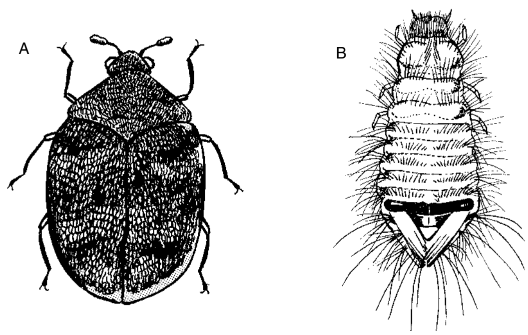
Casemaking clothes moth *Tinea pellionella*
A. Adult moth B. Larva in case



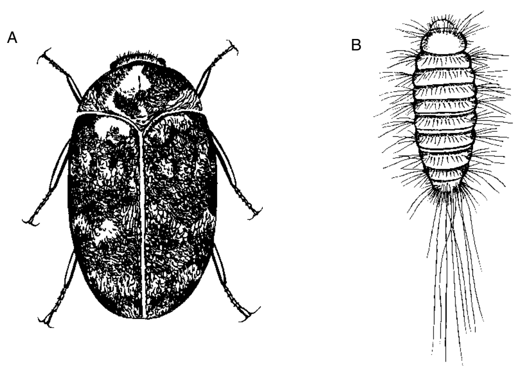
Webbing clothes moth *Tineola bisselliella*
A. Adult moth B. Larva



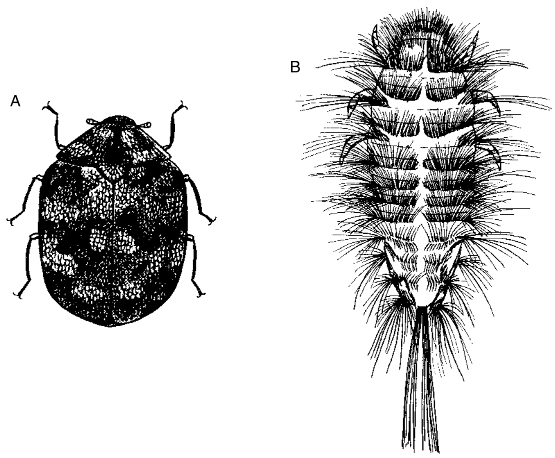
Black carpet beetle *Attagenus unicolor*
A. Adult B. Larva



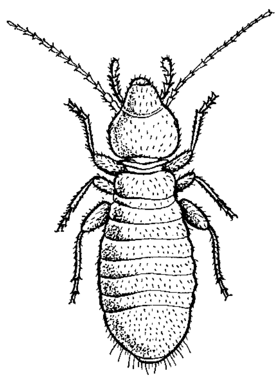
Variegated carpet beetle *Anthrenus verbasci*
A. Adult B. Larva



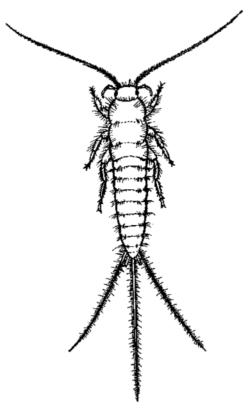
Australian carpet beetle *Anthrenocerus australis*
A. Adult B. Larva



Furniture carpet beetle *Anthrenus flavipes*
A. Adult B. Larva



Booklouse adult



Silverfish adult

Figure 11.17 Pests of fabrics and paper: clothes moths, carpet beetles, silverfish and booklice

BOOKLICE

Booklice (or psocids) are very small insects that constitute the Order Psocoptera. This order is relatively small, being represented in Australia by only about 300 species. Most of these are scavengers in leaf litter, under bark and in other such places. A few species are regarded as pests when they occur in stored foods or among books in buildings. Their presence is usually secondary to poor storage methods that facilitate the growth of moulds, on which they feed. Even though their numbers can be large within buildings, they are usually little more than a nuisance pest that is indicative of some other problem.

Structure

The more common booklice are small (1–2 mm in length), soft-bodied insects with chewing mouthparts. Some species are winged, but those found infesting buildings are wingless. Typically, they have a large head with medium to long antennae, and a rather narrow thorax. Immature forms usually resemble adults.

Life cycle

Booklice undergo a gradual metamorphosis. The female lays eggs in a suitable location and, after hatching, the nymphs undergo about 3–4 moults and mature in 3–4 weeks.

Habits

Booklice are more numerous towards the end of summer. When present, their small size may make detection difficult. Their distribution is usually determined by their need for relatively high humidity. They are very agile and fast moving.

Booklice as pests

The activities of booklice in buildings seldom cause any serious damage. They are nuisance pests that feed on microscopic moulds that grow on materials such as paper, leather, straw, carpet and certain stored foods when not stored properly. They frequent damp, undisturbed locations. Sometimes, recently constructed buildings have areas that remain moist for some time (eg recently plastered walls). Such situations may support temporary infestations of booklice. As well, damp darkrooms without adequate ventilation can support their activity. Booklice are most unlikely to bite humans.

Control of booklice

The presence of booklice is usually indicative of poor storage methods. Some infested materials can be dealt with by placing them in the sun, so that the insects die of desiccation. Where entire rooms are concerned, proper aeration and ventilation that prevents mould growth are likely to exclude booklice. If chemical control is required, a variety of surface-spray and space-spray products are likely to be effective, but few, if any, are registered specifically for booklouse control. In such cases it may be necessary to obtain a permit from insecticide registration authorities.

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CHAPTER 12

PESTS OF STORED FOODS

Insect pests of stored food products such as grains and cereals are ubiquitous and troublesome. Worldwide, the storage and handling of such foodstuffs requires considerable attention to protecting these goods from the many species of small beetles and moths that would otherwise attack and destroy them. This chapter looks at the kinds of problems associated with these pests, the more important species and, in broad terms, some of the methods of prevention and control.

Ever since humans began to grow amounts of food that were in excess of their immediate needs and that required storage for a period before use, they have had to defend that stored food against the ravages of insects and other organisms. At present, the costs of protecting stored grains and other foods are enormous. In some more unfortunate countries (mostly located in the tropics or subtropics), estimates of losses of grain in store may be as high as 50% of total production.

A wide range of organisms are pests of stored foods. Scavengers such as rodents and cockroaches are often problematic in food storage facilities. This chapter, however, is more concerned with those insects (mostly small beetles and moths) and mites that have exploited stored products as both a food source and a habitat in which they undergo most or all of their life history. Tables 12.1 (beetles), 12.2 (moths) and 12.3 (mites) identify and describe the appearance and life history of a number of these pests.

'Stored product pests' can be, and often are, troublesome at all points of food handling, from the farm where the food is harvested, through the various processing facilities to the end user. As such, infestations of stored product pests can be problematic in on-farm silos, regional silos, mills, warehouses, food-processing plants, bakeries, stores, restaurants, canteens and homes.

Most stored product pests are tropical or subtropical in origin, so they prefer warm, relatively humid conditions in which to develop. Storing grain and other foods in cooler conditions can slow down the development of stored product pests. Storage conditions below 15°C can severely hinder or halt reproduction of many species. In bulk grain, localised heating of the grain may result from grain respiration, insect activity and, where moisture content is high, from the respiration of moulds.

The control of pests of stored products can present certain difficulties that are peculiar to that type of pest control. Stored product pests often live within food for human consumption. In order to control insects within food, the food must be removed and destroyed, or treated in a way that presents no hazard in its end use. Most urban pest control operators are not themselves equipped to treat infested foods; and where removal and subsequent destruction are not feasible, the matter should be referred to qualified fumigators. Because fumigation techniques can allow for penetration into food materials with effective kill of all stages of insect life and minimal problems with toxic residues, they play a very important role in controlling pests of stored foods.

PROBLEMS CAUSED BY STORED PRODUCT PESTS

The small beetles and moths that infest stored grains and other such products cause severe losses both directly and indirectly. The problems that they may create include the following:

1 *Direct damage, where the kernels are hollowed or otherwise damaged.* Typically, the 'primary' pests of grain (the lesser grain borer, the rice weevil, the granary weevil, the maize weevil and the Angoumois grain moth) are responsible for severe grain damage, as larval feeding occurs within the kernel. As well, a variety of other stored-product pests can cause conspicuous direct damage to stored products.

2 *Contamination of stored products with live or dead insects (at all stages of growth), cast skins and droppings.* Repulsive and persistent odours may develop; these typically occur with flour beetle and lesser grain borer infestations. Where moths are active, unsightly accumulations of webbing typically result.

3 *Damage to wooden structures and various types of food packaging.* Some beetle species, at the completion of larval feeding, may tunnel into nearby wooden structures to pupate. The cadelle and various Dermestid (skin and hide) beetles may, in this way, cause severe damage to timbers adjacent to their feeding areas. As well, beetle activity in packaged foods is often betrayed by the small round exit holes made by emerging adults.

4 *Moulding and caking of stored products.* Insect activity in grain may produce heat and moisture, which can facilitate the growth of moulds and lead to caking. Such conditions can adversely affect germination.

Where the storage conditions favour the development of stored product insect pests, populations may grow very rapidly. Infestations are dispersed mainly by the crawling or flying adult insects and by the habits of those involved with the handling of stored products. Where poor sanitation and clean-up practices allow accumulations of food materials in equipment, cracks and crevices in storage facilities, sacking and other types of containers, it is likely that such accumulations will become sites of infestation, which may then serve to contaminate otherwise uninfested incoming grain. In warehouses, stores and homes, old unattended grain-based rat baits may become infested with insect pests, which can, as adults, disperse within the building to attack stored foods.

Figure 12.1 *Left top:* Lesser grain borer (*Rhyzopertha dominica*)

Figure 12.2 *Left:* Rice weevil (*Sitophilus oryzae*)

PREVENTION AND CONTROL

The control and prevention of insect pests of stored products usually requires an integration of:

- regular inspection and monitoring;
- high standards of sanitation and hygiene (including stock rotation); and
- judicious use of chemical methods of control.

Diligence and care at all points of food handling, from harvest, through storage and processing to end use, does much to reduce instances of infestation. Establishments that handle food materials prone to infestation should carry out regular extensive inspections at frequent intervals, so that incipient infestations are dealt with prior to wider dispersal of the adults.

Inspection and monitoring

The intimate association between stored product pests and the foods that they infest often makes inspection and control difficult. In most of the situations in which pest control operators are called upon to deal with problems associated with stored product pests, it is essential that an extensive survey/inspection of all areas be carried out, to ascertain all the infestation sites.

Typically, in domestic premises, infestations may be found in food packages in the kitchen/pantry or in old rat baits in the ceiling or subfloor areas. In some cases, accumulations of crumbs and other food materials under cupboards and even within lounge chairs can sustain a population of stored product pests.

In commercial premises, the task of finding the source(s) of infestation can be difficult. In a stored food facility that is normally well managed (with regular monitoring and inspections and high standard of sanitation and hygiene), the source of infestation may be very localised — perhaps only one bag of product is infested. On the other hand, if the management of stored product pests has been poor or non-existent, the infestation may be very extensive, with much of the stored product infested throughout the storage facility.

In either case, the use of traps (mostly pheromone based and in many cases species specific), can be a very useful tool for general monitoring, for helping to locate infestation sites (or so-called 'hot spots') and for mass trapping. Traps/lures typically last from a few weeks to a few months and, used effectively, can generate very useful information about the severity, extent and location of infestations. They may also be a very useful tool for 'before and after' trials of various approaches to stored product pest control.

Feedback from on-site employees is very important in avoiding major setbacks in the management of stored product pests. Setting up a workable and effective system of communication with the site management can facilitate early warning of increased levels of pest activity.

The operator who has determined all the sites of infestation has, broadly speaking, two options:

1. Remove the infested material and dispose of it in a manner that will not disperse the infestation. Infestations in food packages in the pantry are dealt with in this manner, as are infestations associated with poor sanitation and old rat baits.
2. Organise to have the food material treated in an acceptable manner. Unless techniques utilising controlled atmospheres, high temperatures (or microwave oven treatments) are employed, the material will probably need to be fumigated by specially qualified personnel.

Having dealt with the infested material, the operator may employ surface-spray or space-spray techniques in order to control any surviving adults, which may otherwise commence new infestations. Clients in charge of food-handling premises should be educated about the importance of high standards of hygiene and sanitation and about other non-chemical methods of prevention and control of stored product pests.

Non-chemical methods of prevention and control

Food-handling industries

The adoption of sound work habits by those employed in food-handling industries can do much to limit the activities of stored product pests.

- High standards of hygiene and sanitation must be an integral component of any control program. All excess foods in the form of spillages, accumulations of dust and so on must be cleaned up regularly and frequently. Where feasible, vacuuming can be effective. Premises, equipment, containers and transport vehicles must be kept clean, especially prior to the intake of new (uninfested) stock.
- Where feasible, cracks and crevices that accumulate grains, dusts and the like should be filled to avoid future contamination.
- Where feasible, goods should be stored away from walls and off the ground, to facilitate more thorough cleaning and inspection.
- New incoming stock should be received in an area remote from the main storage area, and inspection should be carried out prior to further handling, processing or storage. Material found to be infested should be rejected or fumigated.
- Stock should be rotated as often as possible.
- Equipment or machinery that may accumulate food particles should be cleaned out regularly.
- Where grains are stored, temperature and moisture levels should be kept low, to discourage insect activity.
- Regular and extensive inspection and monitoring (with the use of traps/lures) throughout the entire food-handling premises should be on-going, to ensure that infestations are not allowed to proceed unchecked.
- Where small amounts of infested material are not adversely affected by heat, all stages of all insects are usually killed by heating the material to 60°C for 30 minutes.

Domestic premises

In domestic premises, problems associated with stored products may be reduced or prevented by several means:

- Where packaging permits, foods should be checked for any tell-tale signs of infestation prior to purchase – the produce should be rejected if there are insects present, if there are signs of webbing or if there are holes in the packaging.
- The suspicious appearance of small beetles or moths around the kitchen/pantry should be followed up immediately. All foods should be checked, and any infested materials incinerated.
- High standards of hygiene and sanitation should prevent the build-up of food materials in places such as corners of cupboards and under furniture.
- Foods should be purchased in amounts that will be consumed in a short time.
- Foods should be stored in airtight containers that will not allow the entry of adult females for egg laying.
- Foods should be discarded if unused for long periods of time.
- Old rat baits in ceilings and subfloor areas should be removed.

Chemical control

Chemical methods of prevention and control include the use of surface sprays, space sprays and dusts (and the direct treatment of stored food materials). Research into safer and more efficient methods for dealing with insect pests of stored products is constantly being carried out. Better control of these pests will always rely on diligence in sanitation and hygiene, at all points of handling from harvest to end use. For the present, however, some reliance on the use of insecticides is, in many cases, unavoidable.

Surface-sprays

The application of surface sprays for the control of stored-product insect pests should:

1. be carried out only after the site of infestation has been determined and dealt with appropriately;
2. be carried out only after the areas to be treated have been thoroughly cleaned;
3. be directed to those surfaces on which it is likely that the target insects will make contact with the insecticide — for example, in cracks and crevices, between equipment and floor, in wall-floor joints, in corners of shelving and on shelves (where shelf paper will protect against contamination of foods or people); and
4. be carried out in a manner that presents no risk of contamination of foods, food preparation surfaces, utensils or humans.

Operators wishing to carry out a treatment of this type should select an appropriate surface-spray insecticide product that is registered for use in food-handling areas for pest situations of this kind.

Space-sprays

The application of space sprays for the control of stored-product insect pests should be carried out:

1. only after the site of infestation has been determined and dealt with appropriately;
2. only after the areas to be treated have been thoroughly cleaned;
3. to control wandering adults, not immature stages and adults within food materials;
4. only in premises that can be vacated for a suitable duration and closed up to contain the insecticide; and
5. in a manner that presents no risk of direct contamination of foods, food preparation surfaces or utensils (and consistent with label directions).

Insecticides often used as space-sprays (eg high-pressure aerosols, mists or fogs) for the control of stored product pests are generally non-residual type insecticides.

Dusts

Insecticidal dusts may be useful for short-term residual control of stored product pests in areas where wet surface sprays cannot be tolerated. Some crack and crevice treatments are best carried out with dust formulations. Dusts should be avoided in areas where flour and similar food products are handled.

Direct treatment of stored food materials

Urban pest control operators are seldom involved with techniques in which grain or other stored foods are treated directly in order to control active insects or to protect against future attack. Principally, there are two types of treatment.

Grain protectants The use of grain protectants involves the application, directly to grain, of insecticidal sprays or dusts. Such a procedure can give relatively long-term protection against insect infestation, while the grain is in storage or in transit. Ideally, protectants are applied to grain with a maximum moisture content of 12% and a maximum temperature of 25°C. Most grain treated in this way is destined for human consumption, so very strict guidelines control the use of grain protectants. Registration of appropriate application rates is based on the natural decline of residues to low levels during storage of the grain and subsequent processing into edible foods. Increasing concerns about pesticide residues in food may see a general move away from the use of protectants in favour of methods of fumigation that are residue free.

Some grain insects have developed resistance to particular insecticides but the insects and types of resistance vary between regions and states. Consequently, users of grain protectants should liaise with state agriculture authorities regarding appropriate products.

Insecticides are often applied as surface sprays for the control of grain pests in empty silos. grain handling machinery, sheds and warehouses. Appendix VI outlines some of the insecticides used for control of stored product pests at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose)

Fumigation Where stored products (eg grain) become infested with insects, fumigation offers a means of controlling the insect activity without giving any residual protection. Fumigants are usually applied to products under gastight sheeting or within sealed bins. The handling of fumigants can be hazardous and usually requires special training and licensing. Fumigants include:

Phosphine from:

1. Metallic phosphides (ie from tablets, pellets or bag chains containing aluminium phosphide, for example Phostoxin™, Gas-ex P™ from Detia Degesch or from tablets, plates or strips containing magnesium phosphide for example Magtoxin™ from Detia Degesch); or
2. Gaseous phosphine dispensed from industrial gas cylinders as a non-flammable mixture of phosphine and carbon dioxide (ECO_2fume® from BOC Gases). SIROFLO® is an innovative fumigation technique, developed by the CSIRO, which essentially mixes small amounts of the phosphine/carbon dioxide mixture into an air stream at the base of a storage facility. This creates a small pressure in the storage area that causes the gas to spread evenly through the grain mass showing good efficacy even in storage bins that are not fully sealed.

Carbon disulphide is used in some regions for treatment of farm stored stock feed grain.

Methyl bromide the use of which will decline owing to its listing under the Montreal Protocol due to its likely ozone depleting activity.

Carbonyl sulphide, developed as a fumigant by the CSIRO, shows considerable promise as a possible alternative for some of the traditional applications of methyl bromide.

Controlled atmospheres An interesting approach to 'fumigation' involves the use of controlled atmospheres, whereby grain is stored in a relatively airtight storage facility with a high concentration of carbon dioxide or nitrogen. The commercial application of this method of stored-product pest control would offer very attractive implications, not the least of which include a reduction in the handling of very toxic materials and a reduction in the problems associated with insecticide/fumigant residues in treated grain. This method of insect control is probably well suited to the growing market for so called 'organic' food products (considerable amounts of this type of grain product are currently treated with carbon dioxide), however bins/silos need to be very well sealed and exposure times need to be relatively long.

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TABLE 12.1
Beetle pests of stored products

Insect	Adult description	Larval description	Life cycle, foods and habits
Family Anobiidae			
Drugstore beetle *Stegobium paniceum*	2.0–3.5 mm long. Reddish brown. Longitudinal lines of fine hairs on elytra. Antennae with 3 enlarged segments on tip. Head usually not visible from above.	Small (up to 3.5 mm). White. Curled grub with 3 pairs of legs.	Life cycle usually 1–6 months. A very common and widespread pantry pest, attacking a vast range of foodstuffs, including biscuits, flour, fruits, nuts, spaghetti, spices, woollens, leather, grain-based rodent baits, dried animal specimens and a range of other organic materials. Adults do not feed.
Cigarette beetle *Lasioderma serricorne*	2.0–3.5 mm long. Light brown. Oval, with smooth pubescent elytra and serrate antennae. Head usually not visible from above.	Small (up to 4.0 mm). White. Curled grub with 3 pairs of legs.	Life cycle usually 1–4 months. A major pest of tobacco and allied products. Also, has perhaps the widest range of foods of any of the stored-product pests and is a very common and widespread 'pantry pest'. Attacks tobacco, grains, seeds, dried fruit and vegetables, herbs, spices, nuts, bamboo, biscuits, dried animal specimens, fish and meat meals, and grain-based rodent baits. Adults feed on same food as larvae.
Black spider beetle *Mezium americanum*	1.5–3.5 mm long. Shiny black. Bulbous body and relatively long legs.	Small (up to 4.0 mm). White. Curled grub. 3 pairs of small thoracic legs.	Life cycle usually 6–12 months. Typically attacks various dried animal products, seeds, woollen carpets, furs, rodent carcasses, rodent droppings, tobacco, out-of-condition grain and old grain-based rodent baits.
Smooth spider beetle *Gibbium psylloides*	2.0–3.5 mm long. Dark brown to black. Bulbous body and relatively long legs.	Small (up to 4.0 mm). White. Curled grub. 3 pairs of small thoracic legs.	Life cycle usually 6–12 months. Typically attacks decaying moist foodstuffs, seeds, woollens, furs, rodent carcasses, rodent droppings, out-of-condition grain and old grain-based rodent baits.
Australian spider beetle *Ptinus tectus*	2.5–4.0 mm long. Dull reddish brown with light brown hair covering elytra. Pubescent wing covers, bulbous body, long legs.	Small (up to 4.0 mm). White. Curled grub. 3 pairs of small thoracic legs.	Life cycle usually 3–12 months. Typically attacks decaying foodstuffs, seeds, woollens, furs, rodent carcasses, rodent droppings, old grain-based rodent baits, bird-nesting, accumulation of grain, and a range of other organic materials.
Family Anthribidae			
Coffee bean weevil *Araecerus fasciculatus*	Up to 4.0 mm long. Mottled brown. Antennae with 3-segmented club.	Small (up to 5.0 mm). White. Curled legless grub with wrinkled appearance.	Life cycle usually 1–4 months. Mostly not of serious economic importance. Attacks coffee beans, cocoa beans, nutmeg, dried ginger and dried fruits.

Family Bostrichidae			
Lesser grain borer *Rhyzopertha dominica*	2.5–3.0 mm long. Reddish brown. Cylindrical body with head usually concealed beneath thorax. Antennae clubbed with 3 segments.	Small (up to 3.0 mm). White. 3 pairs of small thoracic legs.	Life cycle usually about 8 weeks. Adults may live 1–2 months. A primary pest of grain. Females produce over 300 eggs, usually laid loosely in the grain. After hatching, larva usually enters the grain kernel and completes its larval life there. A major pest of wheat and other stored cereal grains. As well may attack processed cereals, spaghetti, biscuits etc. Adults can fly.
Family Chrysomelidae			
Bean weevil *Acanthoscelides obtectus*	2.0–3.0 mm long. Mottled brown. Saw-tooth-like antennae and elytra that do not cover entire abdomen.	Small (up to 4.0 mm). White. Curled legless grub.	Life cycle usually 2–4 months. Larvae feed mostly inside beans. Attacks all legumes, including kidney beans, peas and lentils.
Family Cleridae			
Redlegged ham beetle *Necrobia rufipes*	4.0–6.5 mm long. Shiny greenish-blue body with red legs and antennal bases.	Medium (up to 10 mm). Purplish. Slender, tapering towards head.	Life cycle usually 1–3 months. Adults may live up to 12 months. Adults and larvae feed on a variety of animal products, including dried and smoked meat, cheese, bones, hides and animal carcasses. As well, may attack chocolate and copra. Adults and larvae may be predacious. Often associated with Dermestid beetles.
Redshouldered ham beetle *Necrobia ruficollis*	4.0–6.5 mm long. Mostly metallic blue, with red-brown thorax, base of elytra and legs.	Medium (up to 10 mm). Slender, tapering to head.	Life cycle usually 1–3 months. Adults may live up to 12 months Adults and larvae feed on a variety of animal products, including dried and smoked meats, cheese, bones, hides and animal carcasses. Adults and larvae may be predacious.
Family Curculionidae			
Rice weevil *Sitophilus oryzae*	2.5–3.5 mm long. Reddish brown with four paler spots on elytra. Pronotum pitted. Head with long slender snout.	Small (up to 4.0 mm). White with dark head. Legless.	Life cycle usually 4–6 weeks. Adults may live up to 6 months. A primary pest of grain and probably the most destructive pest of stored products. Female usually bores a hole in grain kernel and lays an egg in it. Larvae develop within the kernel.Adults and larvae feed mostly on grains (eg wheat, rice, maize, barley, oats). Occasionally attacks other stored foods (eg spaghetti). Adults can fly. Females lay up to 400 eggs
Granary weevil *Sitophilus granarius*	2.5–4.0 mm long. Dark brown to black. Elongate pits on pronotum. Head with long slender snout.	Small (up to 4.0 mm). White with dark head. Legless.	Life cycle usually 4–6 weeks. Adults may live up to 8 months. A primary pest of grain. Female usually bores a hole in grain kernel and lays an egg in it. Larvae develop within the kernel. Adults and larvae feed mostly on grains (eg wheat, barley, oats, maize, rye). Occasionally attacks other stored foods (eg beans, nuts). Adults cannot fly. Life history similar to that of rice weevil, but seems to prefer cooler regions.
Maize weevil *Sitophilus zeamais*	2.5–4.0 mm long. Reddish brown with four paler spots on elytra. Pronotum pitted. Head with long slender snout. Resembles rice weevil.	Small (up to 4.0 mm). White with dark head. Legless.	Life cycle usually 4–6 weeks. Adults may live up to 6 months. A primary pest of grain. Attacks mostly maize but may damage other cereal grains. Life history similar to that of rice weevil. Adults can fly.
Family Dermestidae			
Common hide beetle *Dermestes maculatus*	6–10 mm long. Uniformly grey-brown. Pointed tips on elytra.	Large (up to 15 mm). Brown. Very hairy with light line along dorsal surface. 3 pairs of legs.	Life cycle usually 2–9 months. Larvae and adults feed on various animal products, including furs, leathers, smoked meats, animal skins, fish and meat meals, and bone. Larvae may bore into timber for pupation site.
Hide beetle *Dermestes ater*	7–9 mm long. Uniformly dark. 3-segmented clubbed antennae.	Large (up to 18 mm). Brown. Very hairy. 3 pairs of legs.	Life cycle usually 2–9 months. Larvae and adults feed on animal products, including animal skins, fish and meat meals, furs, leather, bone and various dried foods. Larvae may bore into timber for pupation site. Often a pest in skin and hide stores.
Larder beetle *Dermestes lardarius*	7–9 mm long. Dark, almost black, with striking yellow-brown band across front part of elytra.	Large (up to 15 mm). Brown. Very hairy. Tip of abdomen with two curved processes. 3 pairs of legs.	Life cycle usually 2–9 months. Larvae and adults feed on animal products, including animal skins, hides, leather, smoked meats, fish and meat meals, bone, cheese, feather and various dried foods. Occasionally attacks chocolate, copra and cocoa beans. Larvae may bore into timber for pupation site.
Dermestes frischii	7–9 mm long. Brown with border of pale yellow around thorax. 3-segmented clubbed antennae.	Large (up to 15 mm). Brown. Very hairy. 3 pairs of legs.	Life cycle usually 2–9 months. Larvae and adults feed on animal products, including animal skins, hides, leather, smoked meats, fish and meat meals, bone and various dried foods. Larvae may bore into timber for pupation site.
Warehouse beetle *Trogoderma variabile*	1.5–4.0 mm long. Mostly dark brown, with mottled lighter	Medium (up to 10 mm). Pale cream, with indistinct	Life cycle usually 1.5–6 months. A serious and persistent economic pest of stored products that has only relatively

	brown markings. Oval.	to dark brown markings. Very bristly. 3 pairs of legs.	recently been introduced into Australia. May be found breeding in seeds, grains, most types of packaged foods, dog biscuits, old rodent baits, snail baits, stock feeds, grain remnants in sacks, cracks and crevices, bee and wasp nests, rodent carcasses, dead insects, animal droppings, and many other organic materials. Hairs shed by larvae may cause asthma, skin problems or gastric disorders.
Family Laemophloeidae			
Flat grain beetle *Cryptolestes* spp.	1.5–2.0 mm long. Light brown. Rather long antennae.	Small. Whitish. Elongate with 3 pairs of legs and appendages on end of abdomen.	Life cycle usually 7–9 weeks. Adults may live up to 1 year. Of relatively widespread occurrence. Does not attack sound uninjured grain. Can be very numerous in weather-damaged and moist grain. Fast moving. Attacks grains, grain products, seeds and various processed cereal products.
Family Nitidulidae			
Dried fruit beetles *Carpophilus* spp.	2.5–3.0 mm long. Variegated brown, yellow and black. Wing covers do not cover abdomen.	Small (up to 7.0 mm). Yellow. Rounded projections on end of abdomen.	Life cycle usually 1–2 months. Typically prefers damaged or fermenting fruits (eg figs, dates, raisins). Sound fruit rarely attacked.
Family Silvanidae			
Sawtoothed grain beetle *Oryzaephilus surinamensis*	3.0–3.5 mm long. Dark brown. Slender and flattened with 6 'saw-tooth'-like projections on each side of the thorax.	Small (up to 4.0 mm). White. Elongate with 3 pairs of legs.	Life cycle usually 3–6 weeks. Adults may live up to 3 years. Does not attack sound kernels. Usually follows attack by another pest of stored grain. Very common pantry pest. Females lay up to 300 eggs loosely among broken grain or other foods. Larvae and adults feed on a variety of grains, cereals, seeds and other foods (eg biscuits, nuts, dried meats, spaghetti, dried fruits). Adults are very active but do not fly.
Family Tenebrionidae			
Rust-red flour beetle *Tribolium castaneum*	3.0–4.0 mm long. Reddish brown. Grooved wing covers. Antennae ending in distinct 3-segmented club.	Small (up to 6.0 mm). White with a dark head. Elongate with 3 pairs of legs.	Life cycle usually 4–8 weeks. Adults may live 15–21 months. Does not attack sound kernels. Common pest on farms and in mills, stores and homes. Females lay about 400 eggs loosely among food materials. Larvae and adults feed on fragments of food. May be found feeding in stored cereals, grains, cereal products, stockfeed, seeds, peanuts, dried fruits, spices, chocolate and other stored foodstuffs. Adults are strong fliers. In many regions is the most common flour beetle.
Confused flour beetle *Tribolium confusum*	3.0–4.0 mm long. Resembles rust-red flour beetle, but antennae thicken gradually towards the tip.	Small (up to 6.0 mm). White with a dark head. Elongate with 3 pairs of legs.	Life cycle usually 4–8 weeks. Adults may live 3 years. Diet and habits similar to those of rust-red flour beetle, but cannot fly.
Broadhorned flour beetle *Gnatocerus cornutus*	4.0–4.5 mm long. Light reddish brown. Smooth wing covers. Male has mandibular appendages.	Small (up to 8.0 mm). White-yellow with brown bands towards rear of body. Elongate with 3 pairs of legs.	Life cycle usually 8–10 weeks. Adults may live 4–6 months. Not a major pest. Feeds mostly on flour and other processed grain products.
Longheaded flour beetle *Latheticus oryzae*	2.5–3.0 mm long. Pale yellow-brown. Slender and flattened.	Small. Whitish. Elongate with 3 pairs of legs.	Life cycle usually 4–6 weeks. Usually considered only a minor pest. Attacks mostly flour and processed grains.
Yellow mealworm *Tenebrio molitor*	12–15 mm long. Dark brown to black.	Small (up to 25 mm). Shiny yellow with brown bands.	Life cycle usually 9–12 months. Adults may live 2–3 months. Eggs laid loosely in food materials. Typically found in discarded grain sacks and in grain remnants in sheds and machinery. Favours damp out-of-condition grain. Often found in litter of chicken houses, among feathers, droppings and grain feeds.
Lesser mealworm *Alphitobius diaperinus*	6–7 mm long. Shiny black.	Large (up to 20 mm). Dark yellow with brown bands, shiny.	Life cycle usually 9–12 months. Adults may live 2–3 months. Typically prefers moist or out-of-condition grain. Often associated with litter in chicken houses.
Small-eyed flour beetle *Palorus ratzeburgii*	2.5 mm long. Reddish brown. Flattened.	Small (up to 3.5 mm). Whitish. Elongate with 3 pairs of legs.	Life cycle usually 4–6 weeks. Usually considered only a minor pest. Found in farm stored grain and various processed stored foods.
Family Trogossitidae			
Cadelle *Tenebroides mauritanicus*	6.0–10.0 mm long. Shiny black. Elongate and flattened. Shield-like prothorax distinctly separated from rest of body.	Large (up to 19 mm). Grey-white with darkened head and 'neck' area. Appendages on tip of abdomen and 3 pairs of legs.	Life cycle usually 4–12 months. Adults may live 1–2 years and may hibernate in low temperatures. Attacks sound, broken and out-of-condition grain. Eggs laid loosely among grain, flour etc. Adults and larvae feed on a variety of foods (eg grains, flour, cereal, nuts, seeds, grain products). May be predacious, attacking larvae of other pests of stored products. Fully fed larvae may bore into timber before pupating.

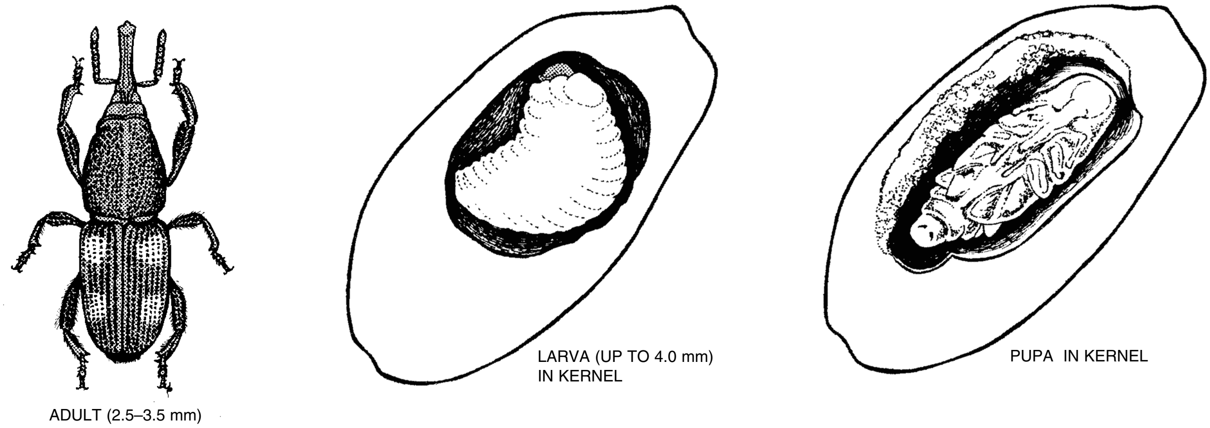


Figure 12.3 Rice weevil (*Sitophilus oryzae*)

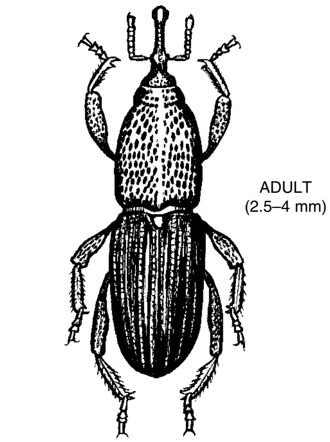


Figure 12.4 Granary weevil (*Sitophilus granarius*)

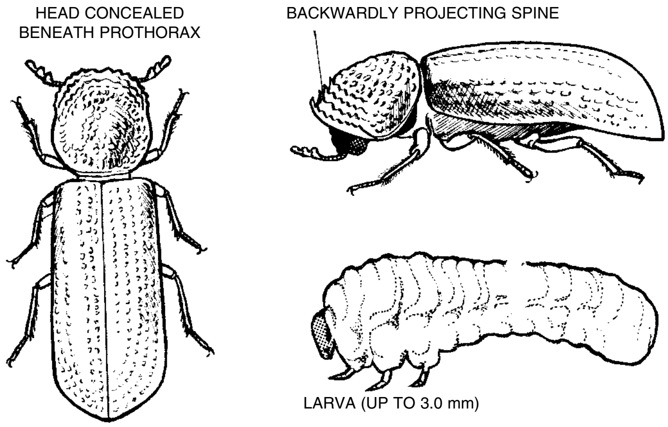


Figure 12.5 Lesser grain borer (*Rhyzopertha dominica*)

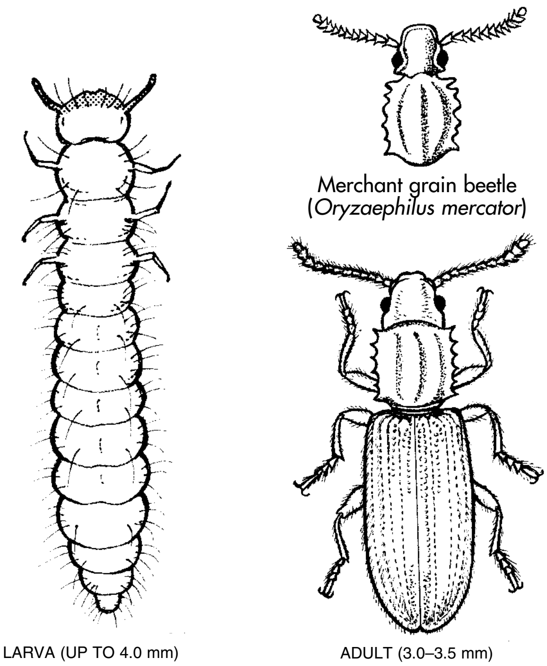


Figure 12.6 Sawtoothed grain beetle (*Oryzaephilus surinamensis*)

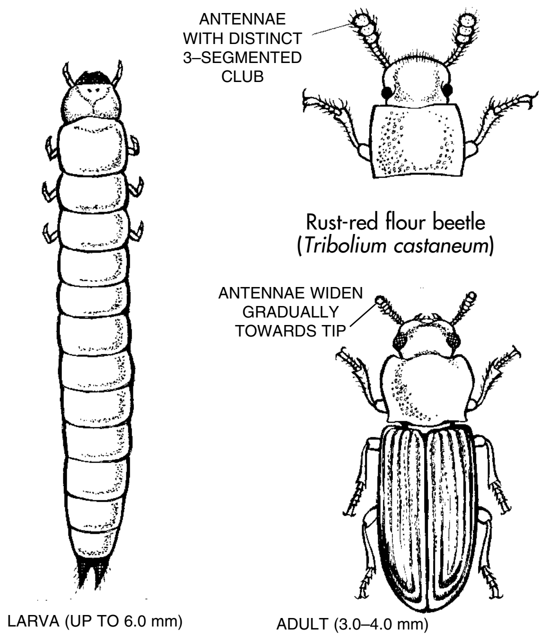
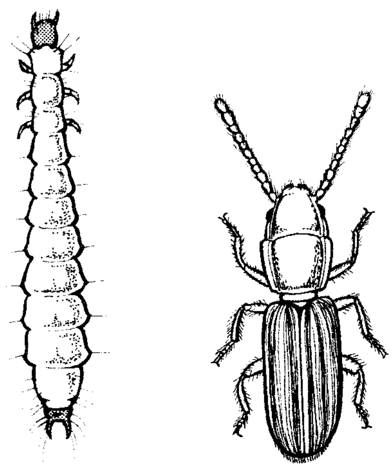
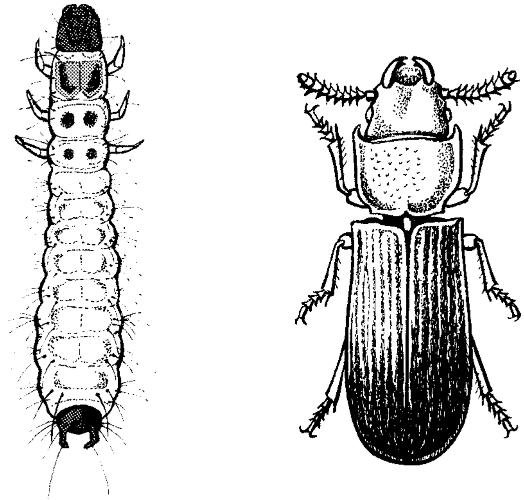


Figure 12.7 Confused flour beetle (*Tribolium confusum*)



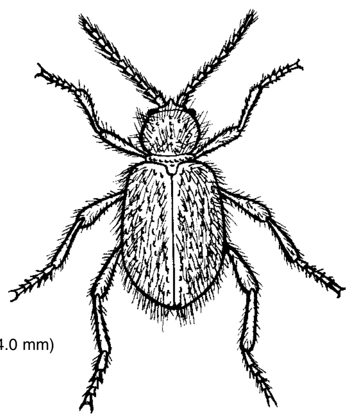
LARVA ADULT (1.5–2.0 mm)

Figure 12.8 Flat grain beetle (*Cryptolestes* sp.)



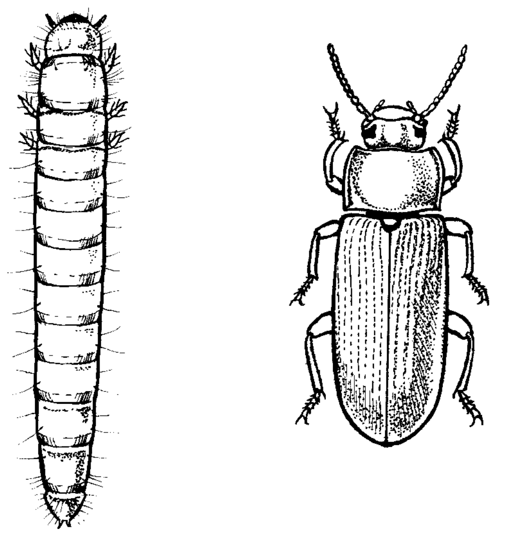
LARVA (UP TO 19 mm) ADULT (6.0–10.0 mm)

Figure 12.9 Cadelle (*Tenebroides mauritanicus*)



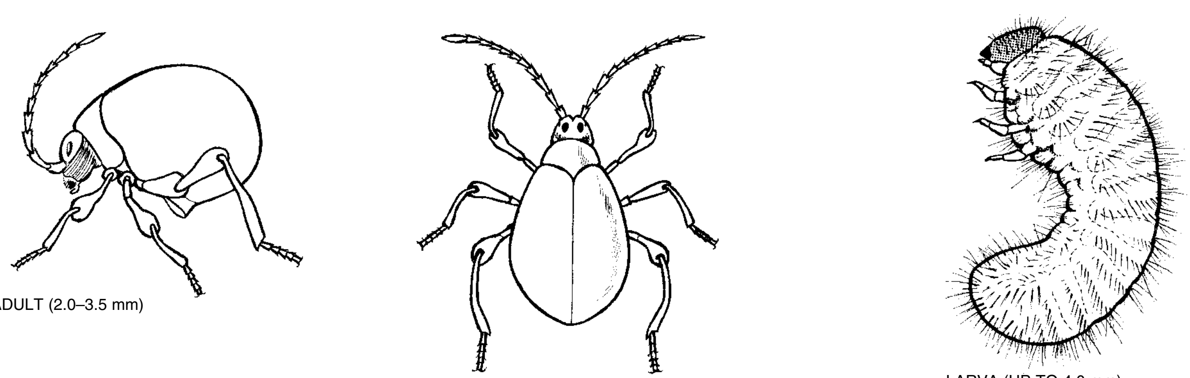
ADULT (2.5–4.0 mm)

Figure 12.10 Australian spider beetle (*Ptinus tectus*)



LARVA (UP TO 25 mm) ADULT (12.0–15.0 mm)

Figure 12.11 Yellow meal worm (*Tenebrio molitor*)



ADULT (2.0–3.5 mm)

LARVA (UP TO 4.0 mm)

Figure 12.12 Smooth spider beetle (*Gibbium psylloides*)

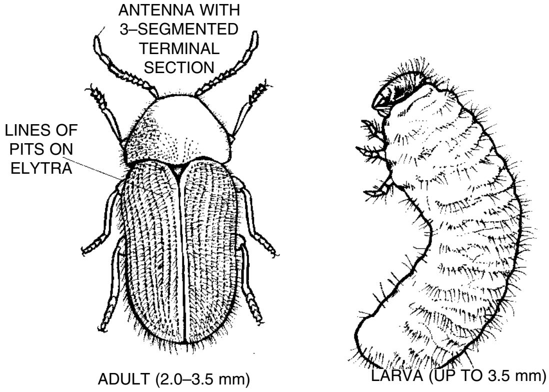


Figure 12.13 Drugstore beetle (*Stegobium paniceum*)

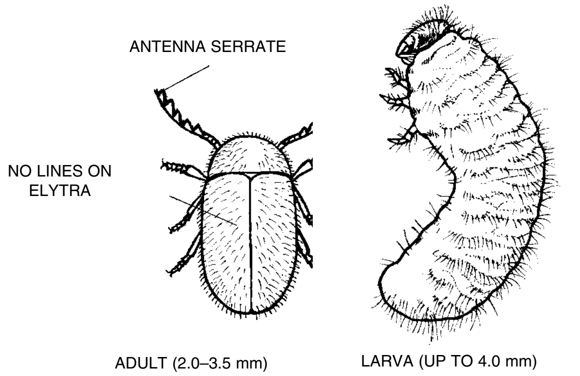


Figure 12.14 Cigarette beetle (*Lasioderma serricorne*)

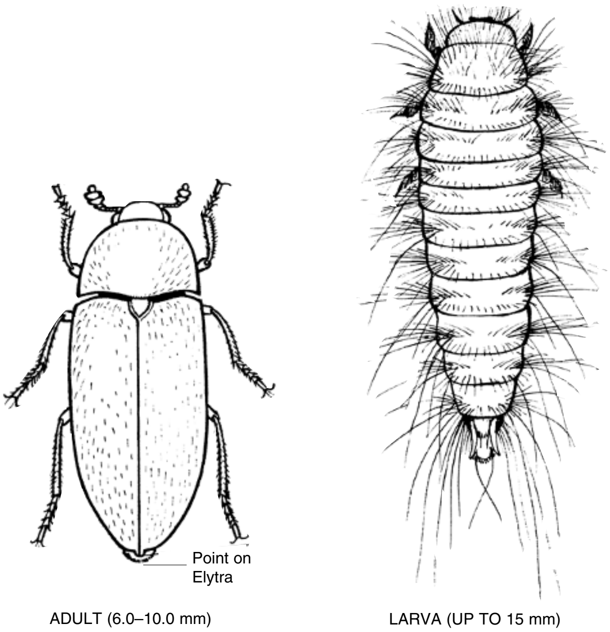


Figure 12.15 Common hide beetle (*Dermestes maculatus*)

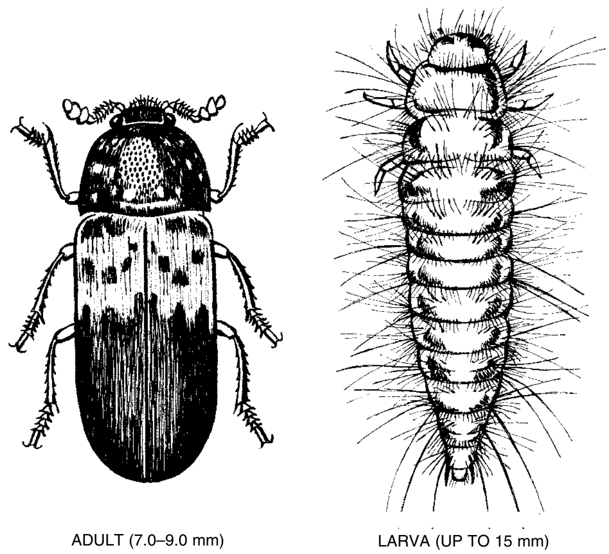


Figure 12.16 Larder beetle (*Dermestes lardarius*)

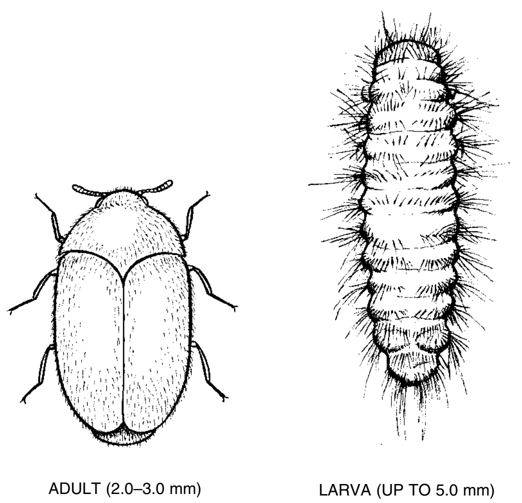


Figure 12.17 Khapra beetle (*Trogoderma granarium*)

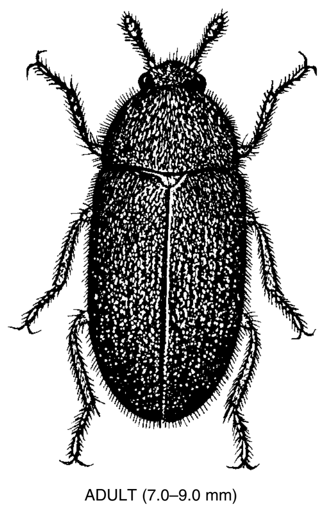


Figure 12.18 Hide beetle (*Dermestes ater*)

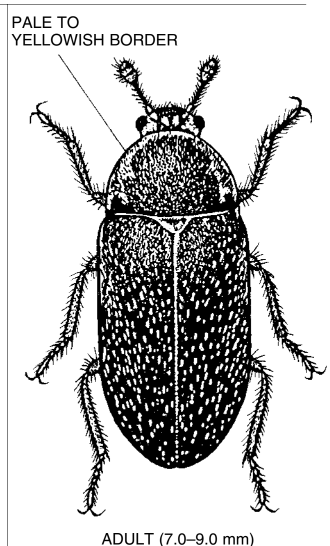


Figure 12.19 *Dermestes frischii*

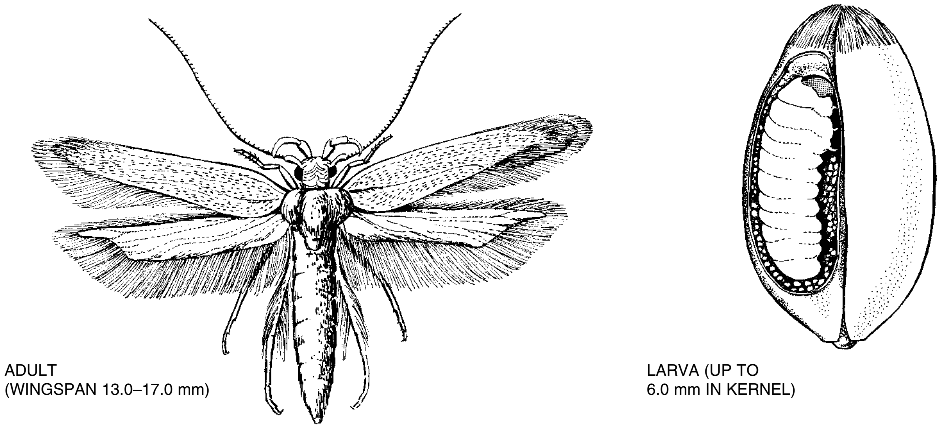


Figure 12.20 Angoumois grain moth (*Sitotroga cerealella*)

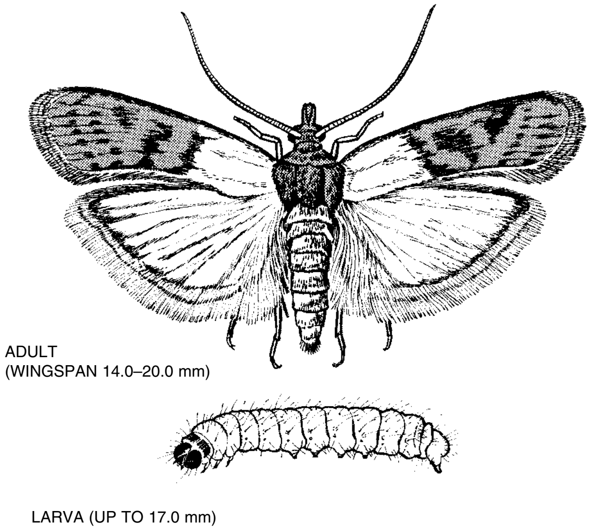


Figure 12.21 Indian meal moth (*Plodia interpunctella*)

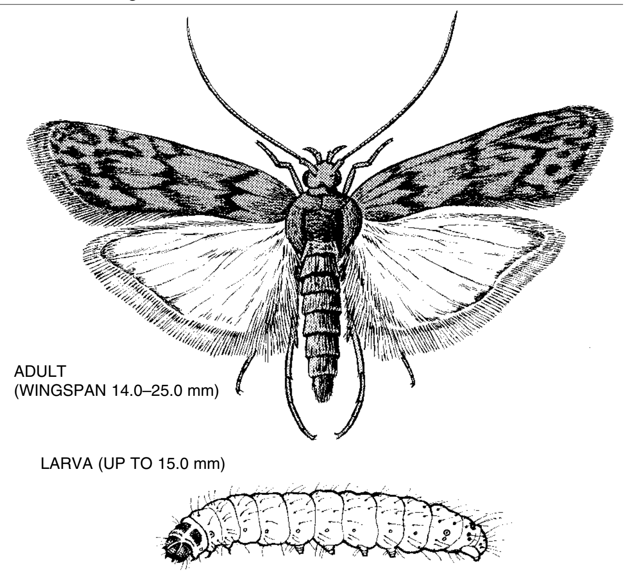


Figure 12.22 Mediterranean flour moth (*Ephestia kuehniella*)

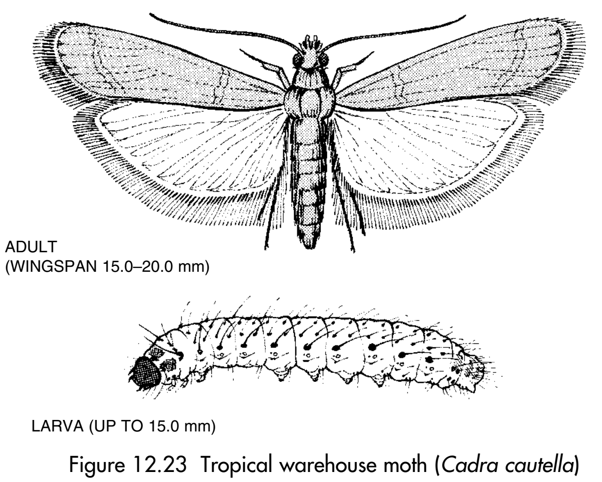


Figure 12.23 Tropical warehouse moth (*Cadra cautella*)

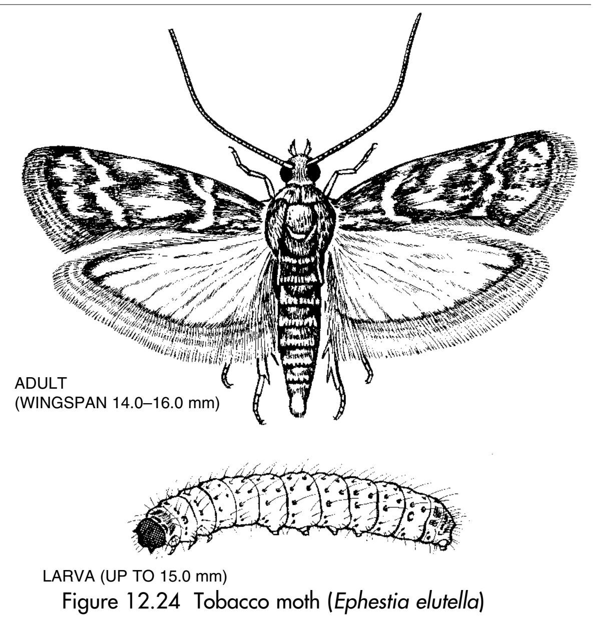


Figure 12.24 Tobacco moth (*Ephestia elutella*)

TABLE 12.2
Moth pests of stored products

Insect	Adult description	Larval description	Life cycle, foods and habits
Family Gelechiidae			
Angoumois grain moth *Sitotroga cerealella*	Wingspan 13–17 mm.Wings buff to yellow-brown and heavily fringed with long hairs. Hindwings pointed at tips.	Up to 6 mm long. Pale yellowish. 3 pairs of legs and poorly developed abdominal prolegs.	Life cycle usually 1–3 months. A diapause period of 2–9 months is common in the life of many moth pests of stored products. Only sound grain is attacked. Females lay eggs among grain, and larvae bore into kernels. Attacks wheat, rice, barley, maize and oats. A relatively important pest of stored grain.
Family Pyralidae			
Indian meal moth *Plodia interpunctella*	Wingspan 14–20 mm. Wings pale fawn colour with outer portions of forewings reddish brown.	Up to 17 mm long. Dirty white but sometimes slightly coloured depending on diet. Head capsule dark. 3 pairs of legs plus prolegs.	Life cycle usually 1–3 months. Adults live less than 2 weeks and do not feed. Females lay about 200 eggs on appropriate foodstuffs. Larvae may feed on flours, corn, broken grains, dried fruits, biscuits, seeds, nuts, powdered milk, chocolate, dog foods, cereals and other such foods. During feeding, larvae cover food with webbing. Larvae pupate, either within the feeding medium or in adjacent areas. Very common commercial and pantry pest.
Mediterranean flour moth *Ephestia kuehniella*	Wingspan 14–25 mm. Forewings bluish-grey, transversely marked with dark zigzagging. Hindwings fawn coloured.	Up to 15 mm long. Dirty white (perhaps pinkish) with dark spots at base of hairs. 3 pairs of legs plus prolegs.	Life cycle usually 1–3 months. Females lay several hundred eggs on appropriate foodstuffs. Larvae may feed on flours, cereals, grains, seeds, chocolate, biscuits, dried fruits, nuts, dog foods, and grain-based rodent baits. Larval feeding produces mats of webbing over and in foodstuffs. Often pupate in cocoon in foodstuffs or remotely.
Tropical warehouse moth *Cadra cautella*	Wingspan 15–20 mm. Forewings brownish-grey with lighter transverse markings. Hindwings fawn coloured.	Up to 15 mm long. Yellowish-white with dark spots at base of hairs and dark head. capsule.	Life cycle usually 1–3 months. Females lay about 200 eggs in foodstuffs. Larvae may feed on flours, grains, nuts, seeds, cereals, chocolate, cocoa and dried fruits. Larvae contaminate food with webbing and usually pupate within a cocoon.
Raisin moth *Cadra figulilella*	Wingspan 12–15 mm. Forewings greyish, hindwings white, both with conspicuous fringing.	Up to 13 mm long. White with 4 rows of purple spots along the back. 3 pairs of legs plus prolegs.	Life cycle usually 1–3 months. Larvae feed mostly on dried fruits (particularly raisins), but cereals and nuts are occasionally attacked. Pellets and webbing contaminate food.
Tobacco moth *Ephestia elutella*	Wingspan 14–16 mm. Forewings brownish-grey crossed with lighter bands. Hindwings light buffy grey.	Up to 15 mm long. Creamy white. 3 pairs of legs plus prolegs.	Life cycle usually 1–3 months. Larvae feed mainly on stored tobacco but will attack cereals, seeds, dried fruits, nuts, spices and chocolate. Larvae produce masses of webbing in feeding material.
Meal moth *Pyralis farinalis*	Wingspan 20–25 mm. Base and apex of forewings reddish brown. Rest of wings mainly fawn.	Up to 24 mm long. Greyish white with dark head and prothorax. 3 pairs of legs plus prolegs.	Life cycle usually 2–3 months. Attacks mostly moist or out-of-condition grain and grain products. May also attack damp straw and other materials of vegetable origin. Larvae create manes of webbing.
Larger wax moth *Galleria mellonella*	Wingspan 20–25 mm. Wings grey to brownish, often with black markings.	White or yellowish white with dark head. 3 pairs of legs plus prolegs.	Life cycle usually 3–6 months. A common pest in apiaries. Larvae devour wax in storage and in combs wherever they may occur.

TABLE 12.3
Mite pests of stored products

Mite	Description	Life cycle	Habits and food
Family Acaridae			
Flour mite *Acarus siro*	Usually about 0.5 mm. Pearly white body with yellowish, sometimes pinkish, legs.	2–4 weeks	Feeds in flour, broken grain and other grain products, provided the immediate relative humidity is greater than 70%. Cast skins and droppings may accumulate to cause an unpleasant odour. Sometimes associated with bird nests. Presence can lead to dermatitis in sensitive people.
Seed mite *Tyrophagus longior*	Usually about 0.5 mm. Clear to white body with darker legs.	2–3 weeks	Tends to be associated with moist or mouldy straw, hay and grains. May also occur on cheese.
Cheese mite *Tyrolichus casei*	Usually about 0.5 mm. Pale, clear to white.	2–3 weeks	Largely associated with cheese in storage.
Family Pyemotidae			
Straw itch mite *Pyemotes herfsi*	Usually about 0.2 mm except for gravid female, which may be up to 2.0 mm.	3–4 weeks	Parasitic on various arthropods, including a number of insect pests of stored foods. Can cause dermatitis in people handling infected materials.

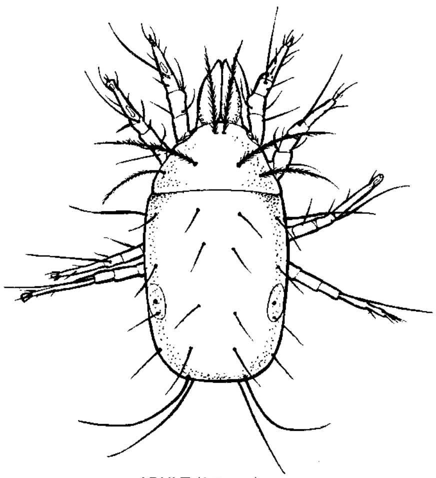


Figure 12.25 Flour mite (*Acarus siro*)

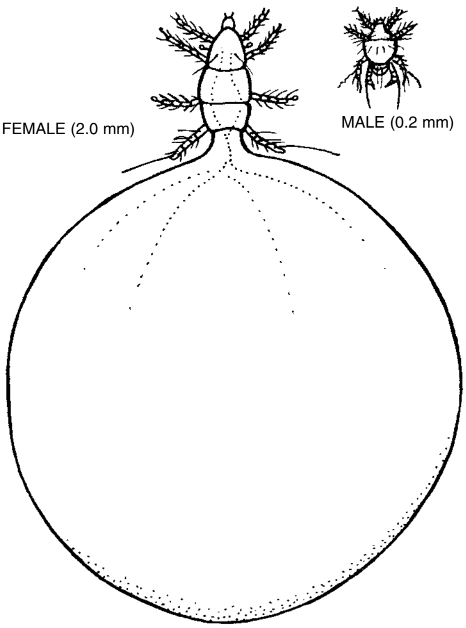


Figure 12.26 Straw itch mite (*Pyemotes herfsi*)

CHAPTER 13

SPIDERS, MITES, TICKS & RELATED ANIMALS

Spiders, ticks, mites, centipedes, millipedes, scorpions and insects are all animals and belong to Phylum Arthropoda. They differ in appearance and behaviour, and these characteristics are used in classification (see Figure 13.1, Table 13.1). Spiders, ticks, mites, scorpions and harvestmen belong to Class Arachnida, centipedes to Class Chilopoda, millipedes to Class Diplopoda, slaters to Class Malacostraca and insects to Class Insecta.

ARACHNID CHARACTERISTICS

Structure

Members of Class Arachnida may be separated from other arthropods on external features alone.

They have 8 jointed legs and their bodies are divided into 2 sections: cephalothorax and abdomen. The cephalothorax is a fused head and thorax region. Palps are located in the front and often mistaken for an extra pair of legs (pedipalps). Their function is sensory, and in the male they are also associated with reproduction. Legs and body may be heavily or sparsely clothed with hairs. Although the general appearance of arachnids varies, the basic structure remains the same. For instance, scorpions have a prominent pair of 'claws' at the end of their pedipalps, and harvestmen do not have a constriction between the cephalothorax and abdomen — a feature that characterises true spiders.

Identification of the sexes

Size and colour alone are not good enough features to identify any arachnid; they must only be considered as supplementary characteristics to structural features.

In determining the sex of spiders, the difference in size between adult males and females is usually so marked that it is a useful feature on its own. The male spider is usually smaller than the female of the same species, and its legs are longer than the female's. The palps, placed anteriorly, are larger in the male and are a satisfactory feature for separating the sexes of most spiders. In some spiders (eg Sydney brown trapdoor spider and the nephilas) the male palps are clearly swollen and are so characteristic that it is difficult to confuse the two sexes. The abdomen of the female is swollen for reproduction. Sometimes the young may be seen adhering to the body of the female (eg garden wolf spider), or she may be guarding an egg sac. Males do not usually spin webs, except in some cases during mating activities.

Morphological differences between the sexes of scorpions, harvestmen and mites are not obvious to pest controllers. However, male ticks usually have a full shield or scutellum over the dorsal surface of the abdomen, while the females have only a partial shield and mature females are much larger than male ticks.

Respiration (breathing)

The arthropods have no red blood cells, and although their blood may be capable of carrying oxygen to some extent, it cannot do this as well as the blood of higher animals. Insects have a series of minute openings (spiracles) on the sides of their bodies which allow air to be taken in and then conveyed, by means of small tubes known as tracheae and tracheoles, directly to the various internal structures. These tubes are bathed by the blood of the insect, and they also impinge on the various internal organs. The respiratory system of arachnids is similar in many respects to that of insects, although

TABLE 13.1
Some arthropod characteristics

Arthropod	Body	Legs	Antennae	Jaws	Breathing
Spiders	2 sections (cephalothorax and abdomen)	4 pairs	Absent	No true jaws. Fangs and chelicerae	Lung-books and/or spiracles
Ticks and mites	2 sections	4 pairs	Absent	No true jaws (modified chelicerae)	Spiracles
Scorpions	2 sections	4 pairs	Absent	No true jaws (chelicerae)	Lung-books and spiracles
Slaters	3 sections (head, thorax with 7 segments, and abdomen)	7 pairs	Present (short)	Modified jaws	Gills (under abdomen)
Centipedes	2 sections (head and many abdominal segments)	Numerous, 1 pair to each segment	Present (short)	Modified jaws	Trachea or breathing tubes
Millipedes	2 sections (head and many abdominal segments)	Numerous, 2 pairs to each segment except front 3 pairs	Present (short)	Modified jaws	Spiracles, trachea

there is some variability from one order to another. Spiders have lung-books, trachea or both. Lung-books consist of a sac filled with clusters of lamellae, which resemble leaves of a book. Always visible on the ventral surface of the abdomen, these lung-books may be seen on the Sydney funnelweb spider as prominent orange-red plates behind the junction of the legs with the body. The means of respiration in certain arachnid groups are summarised in Table 13.2.

Senses

Most spiders have 3 or 4 pairs of eyes, situated on the sides and top of the cephalothorax, although some have only 1 or 2 pairs. Each eye is a simple lens or ocellus. The arrangement of the eyes on the cephalothorax is constant for each species. This arrangement is referred to as the eye formula and is a useful supplementary feature in separating some families and genera. Sometimes very little remains of a spider for identification when someone has been bitten, and the eye formula may be useful when this part of the body remains comparatively intact. Variability in eye formula occurs between the sexes of the same species, so this feature must, as far as possible, be considered with other structural features. Scorpions and harvestmen have prominent functional eyes, and eyes may or may not be present in ticks and mites.

The bodies of spiders and other arachnids are covered with setae or spines, which appear to be associated with their sense of touch and taste. Acoustic setae, thought to aid in hearing, are located on the legs.

Life cycle

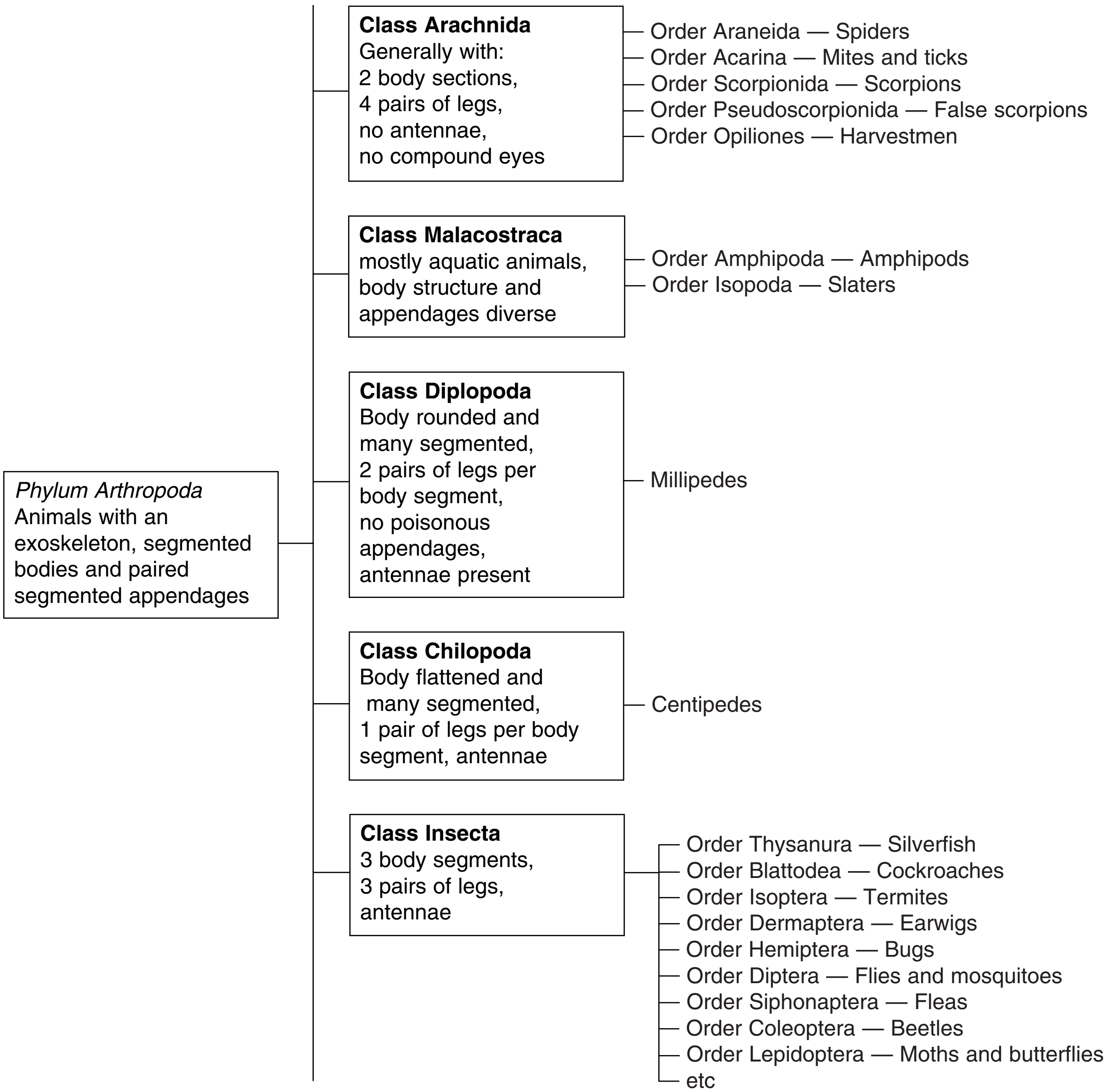
After fertilisation, the mature female spider produces an egg sac, which varies in size and shape depending on the species. The egg sac of all spiders (eg the nephilas) consists of a mass of silken threads enclosing many eggs. The egg sac is round and composed of tough web material in the case of redbacks. Some spiders leave their sacs near their habitats or in burrows. Unlike true spiders, scorpions produce their young alive.

The eggs hatch inside the egg sac, and the young moult (shed their skins) once before emerging. On emergence the young spiders are known as spiderlings, and in most cases they must obtain their own food. The spiderlings may disperse by ballooning on silken threads. They produce a thread, which is allowed to drift in the wind; and as the thread lengthens, the

TABLE 13.2
Arachnid respiration

Order	Animal	Structures for respiration
Araneida	Spiders	Lung-books and/or spiracles
Opiliones	Harvestmen	Spiracles (usually 2)
Scorpionida	Scorpions	Lung-books and spiracles
Pseudoscorpionida	False scorpions	Spiracles (usually 4)
Acarina	Ticks and mites	Spiracles (up to 8)

Figure 13.1
A broad classification of arthropods



spiderling becomes airborne and is carried some distance. This dispersal avoids competition by overpopulation in a small area.

By successive moults they reach the adult stage, but immediately after a moult the freshly emerged spider is paler and softer than in the stage before. Later the body hardens and darkens in colour. Sometimes limbs are lost in encounters with other spiders, or at the time of moulting, but a limb will be entirely or partially replaced, depending at what age it is lost. The younger the spider when the limb is lost, the more complete will be the replacement. If a limb is lost just prior to the adult stage, the replacement will not be identical with the other of the pair.

The life cycle of most web-spinning spiders is less than 12 months, but some ground-dwelling spiders (eg funnelwebs) develop more slowly and appear to have a life cycle of many years.

Habits

Most arachnids are nocturnal. During the day they are seldom seen, unless they are sought or disturbed in their natural environments. When the light fades, spiders become active.

Figure 13.2 Spider — ventral view showing the various structures

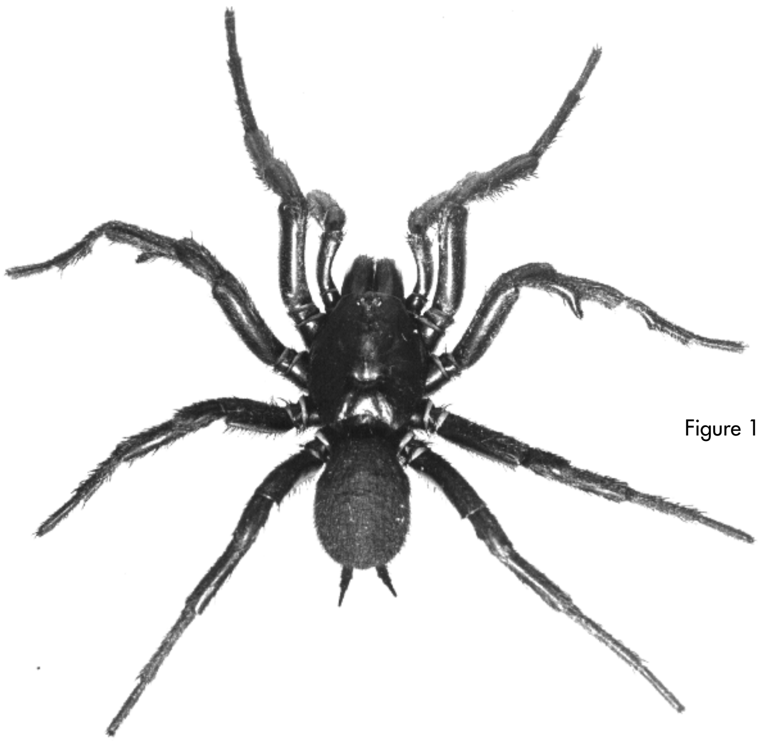


Figure 13.3 Male Sydney funnelweb spider (*Atrax robustus*)

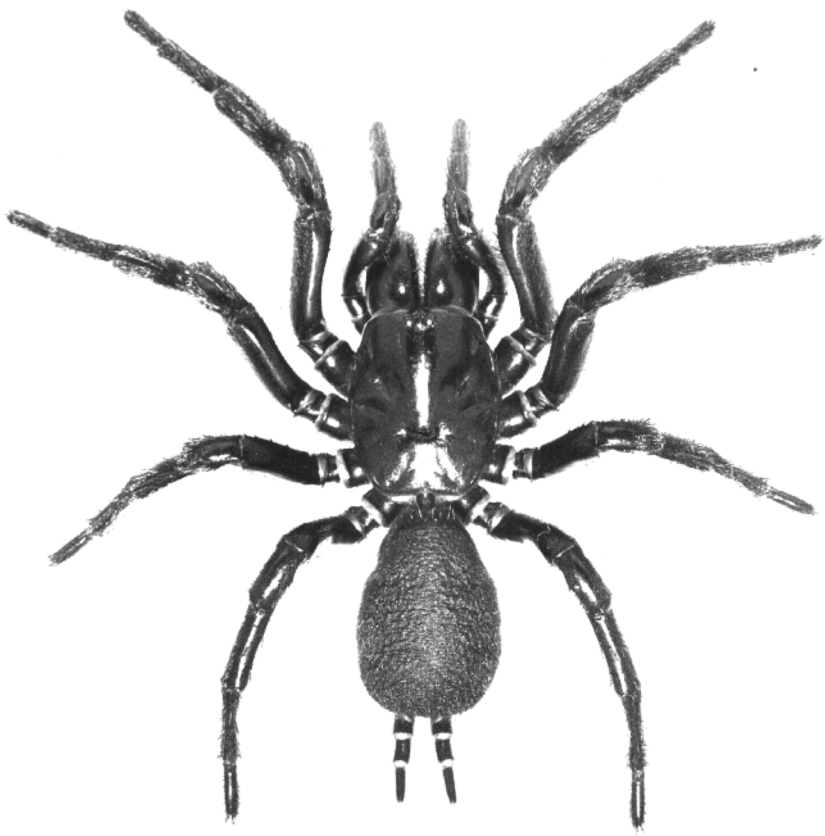


Figure 13.4 Female Sydney funnelweb spider (*Atrax robustus*)

They leave the protection of their burrows or shelters and go out in search of food or, in the case of web-spinning spiders, construct their webs to snare prey. As day breaks, most spiders seek the safety of their shelters again.

Reproduction

Courtship in the arachnids may be short or protracted. Scorpions engage in a type of dance, which involves an entwinement of their abdomens, and the female is led off in this manner to shelter. Courtship in spiders varies greatly, but usually there is considerable preparation, mostly by the male. This involves movements of the palps or a general stroking of the female when the male is at close range. The male of most web-spinning spiders drums on the threads of the web and gradually closes in on the female. The activity of the male during courtship appears to suppress the female's desire for food, since she becomes inactive and in an apparent state of hypnosis.

The mating of spiders is rather interesting in its departure from the generally accepted concept of this act. In true spiders the male reproductive organ is located in the pedipalpi. The male secretes his seminal fluid on either the ground, some bark or a web specially made for this purpose. He then picks up the seminal fluid on his palps and conveys this to the spermatheca of the female. After the female has been fertilised, the male is often caught and consumed by the female.

The mating habits of scorpions are more developed and involve the contact of the male and female genitalia. Harvestmen require contact, the male conveying spermatozoa directly into the female. The male false scorpion deposits spermatozoa on the ground and then draws the female over the sperms.

Food and feeding

Cannibalism is well established among arachnids. From a very early age, and more frequently when food is short, spiders kill and eat one another. If two spiders are placed in a container, one will usually kill the other. If a male is confined with a female of the same species, the female invariably kills the male, which puts up little resistance.

Arachnids are carnivorous, feeding on living or freshly killed animals (eg insects and other arthropods). Ground-dwelling spiders have been recorded as killing small lizards and other creatures, which then have their body fluids squeezed from them. The large nephilas have been recorded as feeding on very small animals other than insects, which become entangled in their strong webs. Some spiders (eg Sydney funnelweb) are able to survive many months without food, particularly during winter when food is scarce. Large ground-dwelling spiders have been kept in sealed jars with moist sand for 3 months without food during winter. In warmer months they do not survive for such periods.

True spiders render their prey immobile by injecting it with venom by means of their fangs, while scorpions sting with a structure on the tip of their abdomen. The body of the prey is then squeezed by means of the spider's fangs and the strong basal section known as the chelicerae. The mouth is a minute opening located in the region at the base of the palps; it connects with a tubular sucking organ, through which passes the body fluids of the prey being consumed. Ticks and some mites feed on blood, while scorpions and harvestmen, like spiders, are carnivorous.

Production of silk or web

Silk or web, so characteristic of the true spiders, is a complex albuminoid protein. Its chemical composition varies, depending on its function. Silk is produced from a set of structures, usually 4–6 in number, known as spinnerets. These are located on the end of the abdomen and connect with silk glands situated in the abdomen. They are not single tubes, but each one consists of many fine ducts, sometimes exceeding 100. Each duct produces an extremely fine thread, and these duct threads are drawn together to form a single thread. False scorpions produce silk from glands located in the cephalothorax, and the silk passes along fine tubes that terminate in the clasping structures of the pedipalpi.

In some spider species, silk is used for dispersal by newly emerged spiderlings. They spin a fine thread of silk and allow this to be taken up by the air until it is of sufficient length to lift the spiderling and carry it away, sometimes many kilometres. After its descent it frequently covers the foliage with gossamer silk; and when the spider population is large, the vegetation may be covered with many fine strands of silk, which is more apparent when covered with dew.

Orb-weaving spiders produce two main types of silk. The spiral of the orb-web or main snare structure is composed of an adhesive silk, while the guy ropes or radii are composed of a drier silk. The production of the silks appears to be related to particular spinnerets. Some ground-dwelling spiders line their burrows with silken thread, and frequently a snare of silk is laid on the ground to trap small creatures. Silk is also used to construct egg sacs and attach them to foliage or any selected object. Certain spinnerets seem to be specialised for this and not used for general web construction.

Arachnid venom

The venom of arachnids is not necessarily poisonous to warm-blooded animals. Some arachnids are capable of causing death by introducing an extremely toxic substance into the bloodstream of warm-blooded animals, including humans, but most arachnid bites result in no more than localised swelling or irritation. Rarely, a spider that inflicts a deep wound may introduce bacteria into the bloodstream, causing septicaemia.

TABLE 13.3
Commonly occurring spiders (Order Araneida)

Spider	Structural characteristics	Body size (mm) Female	Male	Colour	Life cycle	Habits	Toxicity
				GROUND-DWELLING SPIDERS			
Family Hexathelidae							
Sydney funnelweb *Atrax robustus*	Shiny cephalothorax. Spinnerets long; terminal segment longest. Male palps small; spur on 2nd pair of legs.	30	25	Black. Fine reddish hairs.	3–5 years. Large white egg sac.	Favours moist dark situations. Long silken tube through litter in or on ground. Active during late summer and autumn. Aggressive.	Very toxic. Male more toxic than female.
Northern Rivers funnelweb spider *Hadronyche formidabilis*	Similar to *A. robustus* but larger. Male — rounded protuberance covered with spines on 2nd front legs.	35	30	Black. Reddish hairs.	3–5 years.	Inhabits holes in trees. Occurs on northern coast of NSW. Aggressive.	Considered to be very toxic but there is little data available.
Family Idiopidae							
Sydney brown trapdoor *Misgolas rapax*	Cephalothorax dull. Spinnerets short, terminal segment shortest. Male — boxing gloves palps: 2 spines on inner surface of front legs.	25–30	20	Brown to dark brown. Heavily covered with fine hairs.	1–3 years. Not accurately known.	Inhabits drier situations in exposed areas. Lid not usually over hole but leaves or litter may cover it. Not aggressive.	Not toxic. Bites usually only painful.
Family Actinopodidae							
Mouse spiders *Missulena* spp.	Enlarged cephalothorax. Base of fangs enlarged. Eyes on front of cephalothorax. Male — long legs; palps only slightly swollen. Female short legs.	20–25	12–18	Black with reddish hairs. Male of *M. occatoria* has red cephalothorax and basal part of fangs.	1–3 years	Females live in holes (with double door) in the ground. Holes may be quite extensive. Adult male roams in search of female. Not aggressive.	Toxic. Fangs are strong and bite may be painful.
Family Lycosidae							
Wolf spiders *Lycosa* spp.	Posterior eyes large and mounted in square on front of cephalothorax. Male is leggy.	20–25	15–20	Mottled grey and brown. Union jack appearance on cephalothorax. Round egg sac. Carries young on its back.	1–2 years.	Inhabits garden, making holes in ground; covered by litter. Moves very rapidly when disturbed. Not aggressive.	Some may be toxic. Bite may be painful for a short while.
				ORB-WEAVING SPIDERS			
Family Araneidae							
Garden orb-weaving *Eriophora* spp.	Rather large abdomen. Abundant hairs over body surface. Male seldom encountered.	20–25	5–10	Dark to light brown with a pattern.	1 generation per year.	Orb-web; hides on foliage during day and constructs orb-web at night. Not aggressive.	Not toxic. Seldom bites.
St Andrew's cross *Argiope keyserlingii*	Long legs, small cephalothorax. Male — small and paler than female.	10–15	5–6	Brown cephalothorax. Abdomen striped yellow and brown.	1 generation per year.	Orb-web; hangs in web with legs in shape of a cross. Not aggressive.	Not toxic.
Leaf-curling *Phonognatha graeffei*	Long legs, small cephalothorax, large abdomen.	6–8	4	Brown with yellow markings; variability in colour.	1 generation per year.	Orb-web; hides in curled-up leaf or paper at the centre of the web. Not aggressive.	Not toxic.
Two-spined *Poecilopachys australasia*	2 dorsal protuberances on abdomen.	6–8	3	Brown and cream body with reddish legs.	1 generation per year.	Orb-web; hangs in web. Makes sac larger than its own body. Not aggressive.	Not toxic.
Tailed *Arachnura higginsii*	Long tail with star-shaped structure on its end. Male smaller, without the tail.	20	5	Cream coloured. Reddish tip on tail.	1 generation per year.	Orb-web without some supporting radii. Not aggressive.	Not toxic.
Golden orb weavers *Nephila* spp.	Small cephalothorax and large bulbous abdomen. Male — brown and very small.	35–40	5–6	Yellow cephalothorax. Purplish abdomen covered with fine hairs; velvety.	2 generations per year.	Orb-web; very strong strands often having a yellow sheen in sunlight. Not aggressive.	Not toxic.

Spider	Structural characteristics	Body size (mm) Female	Male	Colour	Life cycle	Habits	Toxicity
				SPIDER ANGLERS			
Magnificent *Ordgarius magnificus*	Bulbous abdomen with yellow tubercles. Cephalothorax is produced into a crown-like structure.	12	2–3	Cream colour; pink dots on surface and brown wavy lines.	1 generation per year.	Loose web on leaves, etc. Produces a thread with globule on end for catching prey. Called spider anglers.	Not toxic.
Hairy imperial *Ordgarius furcatus*	Bulbous body with 2 prominent tubercles on dorsal surface of abdomen.	10	2–3	Dull brown with light brown wavy lines.	1 generation per year.	As above.	Not toxic.
Bird-dropping *Celaenia kinbergii*	Angular and wrinkled body with banded legs. Resembles skull.	12	2–3	Brown and white.	1 generation per year.	No web, attacks and seizes moth prey.	Not toxic.
				OTHER SPIDERS			
Family Theridiidae							
Redback *Lacrodectus hasselti*	Long legs and large bulbous abdomen. Small cephalothorax. Male — much smaller and insignificant.	12–15	3–4	Black, velvety; red stripe on dorsal surface. This may be missing on some. Pale area on ventral surface.	1 generation per year.	Makes a loose web in rubbish; unsewered toilets; under houses. Most bites on male genitals. Not aggressive.	Very toxic. Female bites; male does not. Very painful.
Family Desidae							
Black house *Badumna insignis*	Large abdomen. Fangs are not obvious but move pincer-wise.	15–18	8–10	Dark brown to black; legs often black.	1 generation per year.	Makes a felted web at the centre of which is a tunnel. In sheds, toilets, windows, under guttering. Not aggressive.	Toxic. Produces pain, nausea, sweating. No fatalities.
Family Lamponidae							
Whitetailed spider *Lampona cylindrata*	Cigar-shaped body, Cephalothorax oval.	12–15	5–8	Grey to black. White mark on end of abdomen.	1 generation per year.	Found under bark of trees; often inside in bathrooms. Not aggressive.	Bites cause local pain and blistering, also tissue necrosis.
Family Sparassidae							
Huntsman *Isopeda immanis*	First 2 pairs of legs are longer than rear two. Flattened and hairy. Male — slightly smaller with enlarged palps.	35–40	15–25	Buff; dark patches on cephalothorax and abdomen.	1 generation per year.	Lives under bark during daytime and emerges at night; often enters houses. Very useful in that it feeds on insects. Not aggressive.	Not toxic. Bites may be painful but are very rare.
Family Deinopidae							
Net-casting *Deinopis subrufa*	Stick-like, having long legs and flattened cephalothorax.	Up to 20	Variable with species	Grey to brown. Often mottled.	1 generation per year.	Makes a net that it holds between four front legs to capture insects.	Not toxic.
Family Salticidae							
Jumping *Myrmarachne* sp.	Well-developed front legs and very large cephalothorax.	Up to 10	Variable	Variable from brown to black.	1 generation per year.	Characteristic jumping habit. Hunts during the day; no fixed abode.	Not toxic.

SPIDERS (ORDER ARANEIDA)

Commonly occurring spiders

The spiders most frequently encountered are given below under their family names, as this provides a quick reference to books etc that specifically describe and classify the many spider species. Spiders that belong to a particular family often have similar structural and behavioural characteristics. Table 13.3 summarises the characteristics of some common spiders.

Family Idiopidae

This family is important to pest controllers, since it contains the trapdoor spiders that belong to the genera *Arbanitis* and *Misgolas*.

Trapdoor spiders live in holes in the ground, but some species do not necessarily have the cover or trap over the hole that their name implies. *Arbanitis* spp. do. The most often encountered trapdoor spider around Sydney is the Sydney brown trapdoor, *Misgolas rapax*. However, some other species look similar; and where a positive identification is required, the specimen should be referred to a specialist, most often in a museum.

Family Lamponidae

The whitetailed spider, *Lampona cylindrata*, belongs to this family. It is a dark grey to black spider with a characteristic white spot on the end of its abdomen. Inside homes it may be found on walls, particularly in the bathroom. It is also found outdoors under loose bark of trees and in leaf litter. It is not an aggressive spider, but like many other spiders it will bite if touched or placed on the body inside clothing. The bites are painful causing localised pain and this may lead to ulceration in the area of the bite. It has been recorded that the bites may lead to necrosis of the tissue surrounding the bite.

Family Actinopodidae

Mouse spiders also live in holes in the ground, which may have lids. The male is a wanderer, even during the day. Mouse spiders are distributed throughout Australia. In the

Figure 13.5 Male redheaded mouse spider (*Missulena insignis*)

Figure 13.6 Female eastern mouse spider (*Missulena bradleyi*)

Figure 13.7 Whitetailed spider (*Lampona cylindrata*)

redheaded mouse spider, *Missulena insignis*, the forepart of the cephalothorax of the male is red — hence its name. The legs of the female are relatively short compared with those of the male. Female mouse spiders are often confused with funnelwebs. The eastern mouse spider, *M. bradleyi*, is often found in swimming pools on coastal New South Wales.

Family Hexathelidae

This family contains the funnelweb spiders and their relatives. Spiders in the genera *Bymainiella* and *Aname* may be confused with funnelwebs on casual examination.

Funnelwebs are well known for their toxic bites, particularly the male. There are many species in this group other than the Sydney funnelweb, *Atrax robustus*. *Hadronyche cerberea*, the tree funnelweb spider, and *Hadronyche formidabilis*, the Northern Rivers funnelweb spider, are well-known species and are considered toxic. The male of the Sydney funnelweb is often found wandering at certain times of the year, mainly in summer and autumn, when searching for the female. It leaves its burrow (funnelweb) when mature and at this stage may enter houses. The female spends its entire life in its funnel in the ground, leaving only to catch prey and mate. The male dies soon after mating, but the female usually lives for some time. Sustained wet weather or the use of insecticides often causes the male to enter houses and even hide in footwear or clothing.

Family Deinopidae

The net-casting spiders belong to this family. The most often encountered species is *Deinopis subrufa*, the common netcasting spider. They usually hang in vegetation, and when an insect passes in their range, they throw a net, held loosely between their two pairs of front legs, over it. Some species have nets that may expand to 50 mm. Their coloration and appearance blend with the vegetation where they occur, making them often difficult to see. They are of no concern to pest controllers, since they are entirely useful and their webs are located in vegetation and not on houses. However, pest controllers should be able to recognise them.

Family Scytodidae

This family contains the spitting spiders, *Scytodes* spp., so called because of their habit of producing a fluid that they squirt onto their prey.

Family Sicariidae

This family contains the fiddleback spider, *Loxosceles rufescens*. The fiddleback spider was introduced into Australia over 100 years ago, probably from Europe. It has been recorded in South Australia, but since it is rather timid and not obvious, it is likely to be well established all over Australia. It is about 6–8 mm long. Bites are rare because of its timid habit, but when bites do occur, there is illness and the area of the bite takes some time to heal.

Figure 13.8 Male Sydney brown trapdoor spider (*Misgolas rapax*)

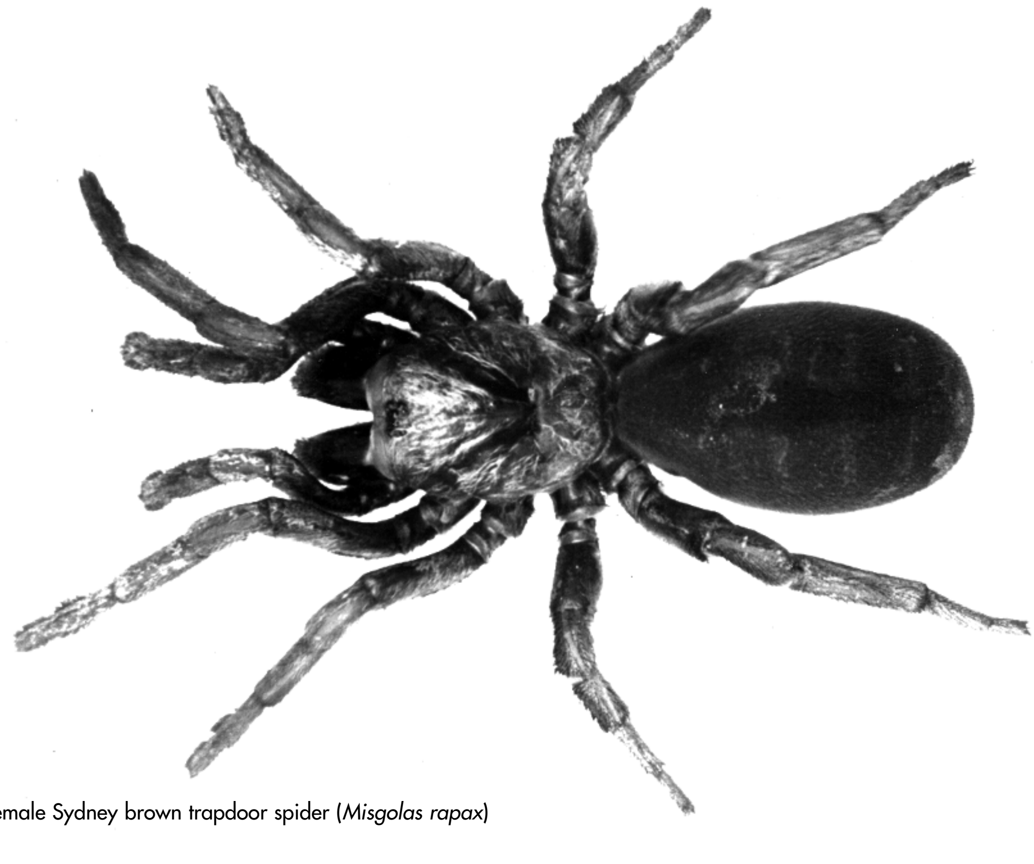


Figure 13.9 Female Sydney brown trapdoor spider (*Misgolas rapax*)

Figure 13.10 Female Northern Rivers funnelweb spider (*Hadronyche formidabilis*)

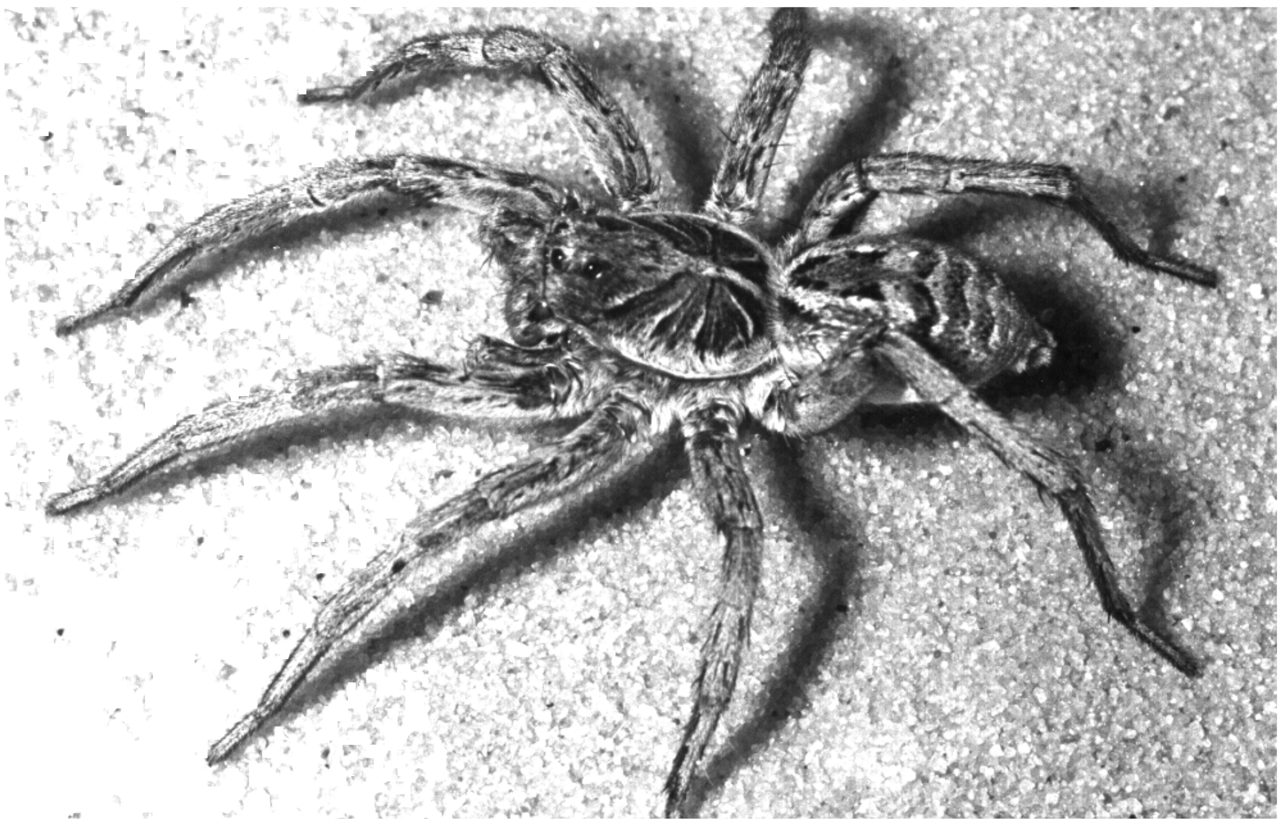
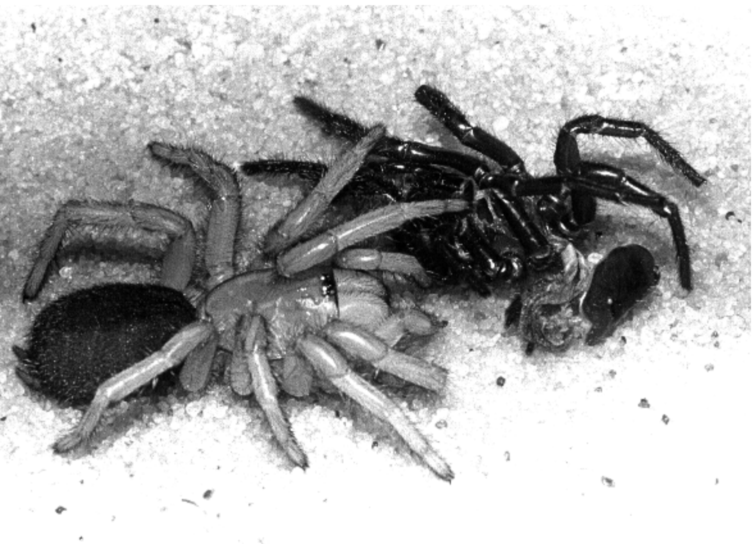


Figure 13.11 Female garden wolf spider (*Lycosa godeffroyi*)

Figure 13.12 Sydney funnelweb spider which has just shed its cuticle



Family Araneidae

Many often-encountered, web-spinning spiders belong to this family. The nephilas, known as golden orbweavers, are recognised by their strong golden webs. The female is about 20 mm long, has rather a bulbous abdomen and is often seen in bushland along Australia's eastern coast. The female of *Nephila maculata* which occurs in many other countries also (eg India and China), has a more elongate body, about 35–40 mm long. The male of all species is much smaller than the female, about 5–6 mm long. These males are often found at the edge of the female's web or near her. Quite large insects (eg cicadas) become caught in the webs of these spiders.

The scorpiontailed spider, *Arachnura higginsii*, also occurs in this family. It is characterised by its abdomen, which is drawn out into a tail and often has an obvious process of a different colour on the end of it.

The leafcurling spider, *Phonognatha graeffei,* lives in curled leaves or paper suspended in its webs. The species is often encountered in gardens, and the female is about 6–8 mm long.

Figure 13.13 Female Sydney funnelweb spider aroused at the entrance to her funnel

The St Andrew's cross spider, *Argiope keyserlingii,* belongs to this family. It is a colourful species that makes a cross or stabilimentum in its web. The spider hangs head downwards with its legs in pairs along the arms of the cross. The female spider is about 12 mm long and larger than the male. The species is considered harmless.

The garden spiders or garden orbweavers also belong to the Family Araneidae. There are several species of the genus *Eriophora,* the most often encountered being *E. transmarina.* They construct webs between buildings and shrubs and are the spiders that produce the unpleasant feeling when one walks into them. They are often colourful and are not considered to be toxic.

The two-spined spiders also belong to this family. The colourful species *Poecilopachys australasia* is often encountered in foliage.

The angling spiders or bolas spiders are placed in this family. These spiders do not make webs but produce a thread about 5–6 cm long with a sticky globule on the end. With this they catch small insects that pass in their range and draw the globule and insect in to them. They occur on foliage and are harmless. They belong to the genus *Ordgarius* and include the magnificent and hairy imperial spiders.

Family Araneidae also contains many other spiders belonging to several genera, some of which are beautifully camouflaged to blend in with their environment. However, these are harmless and of no relevance to pest controllers.

Family Thomisidae

This family contains the crab spiders and flower spiders and some ant-mimicking species. They are of no relevance to pest controllers.

Family Clubionidae

Other ant-mimicking spiders belong to this family. They resemble ants for protection against predators. Also known as sac spiders.

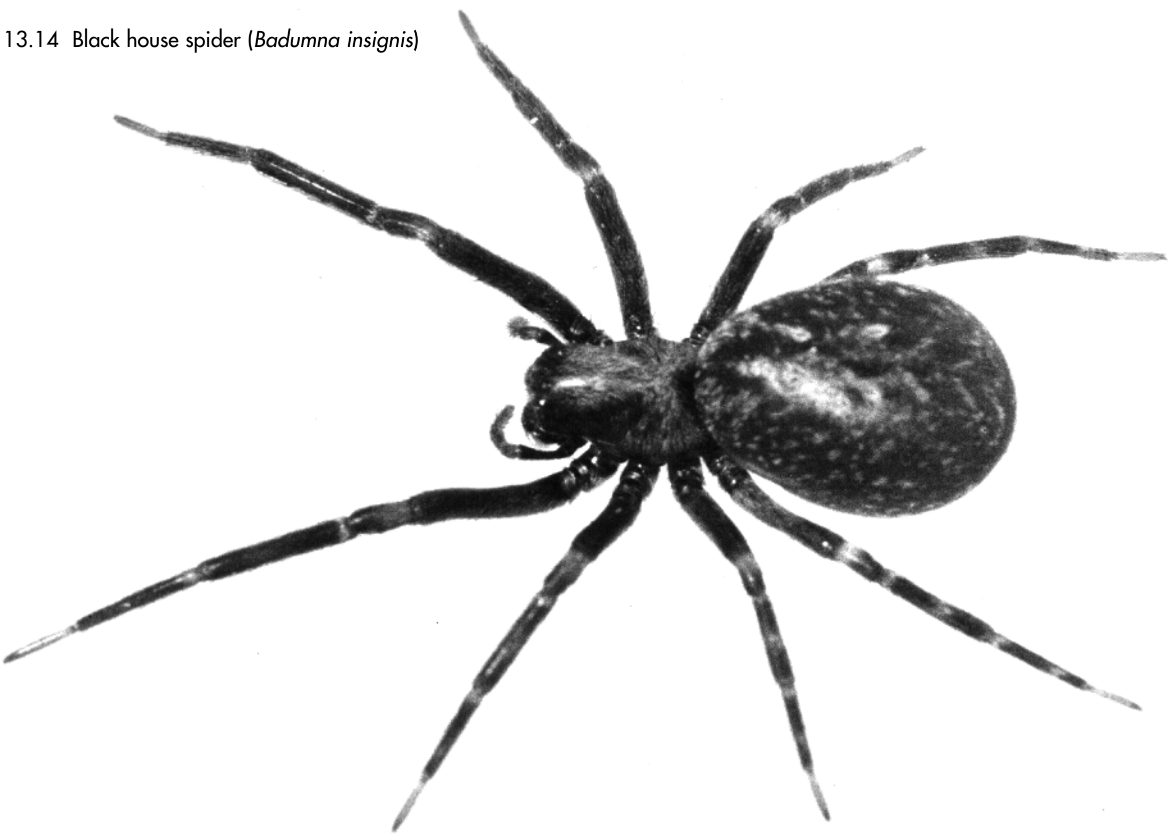
Family Theraphosidae

This family contains the very large spiders, *Selenocosmia* spp. the so-called birdcatching (eating) spiders, which occur in Queensland. They are also known as brushfooted trapdoor spiders. They live in the ground and catch quite large insects and lizards. They are often about 50–60 mm long.

Family Desidae

The well-known black house spider, *Badumna insignis,* belongs to this family. Much of the pest controller's work in country areas and even in cities involves the treatment of this spider. The female is dark brown to black and about 15–18 mm long, while the male is only 8–10 mm long. In the wild they construct their webs in the loose bark of trees, but around buildings they make their webs in window frames, in corners, under eaves — in fact, in any place where they have security. The web is a mat with an obvious, roughly round, entrance hole. Their bites cause some pain and swelling, but the patient soon recovers. Medical advice should always be sought as

Figure 13.14 Black house spider (*Badumna insignis*)



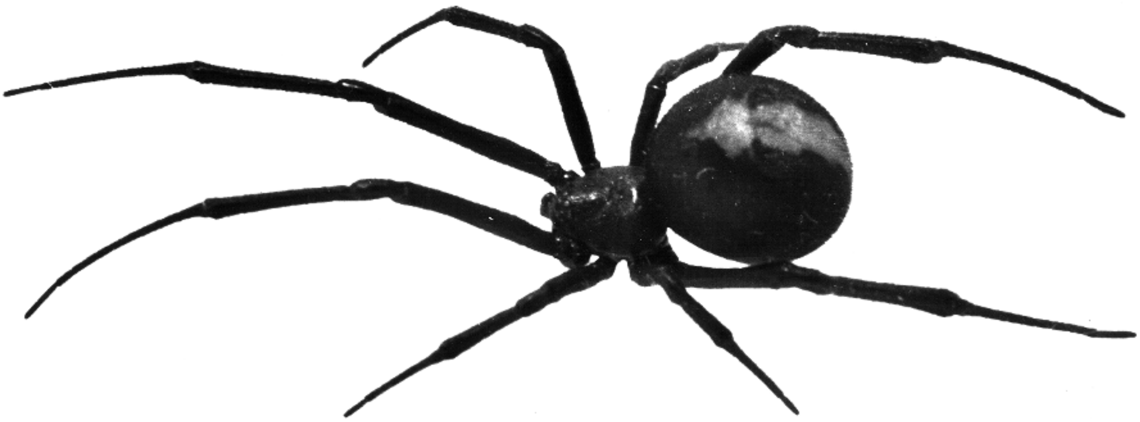


Figure 13.15 Redback spider (*Latrodectus hasselti*)

there could be an allergic reaction. Where insecticidal treatment is to be done, it is best to wait until late spring to early summer when all the young have emerged. There are several species of *Badumna*, and these vary in size, coloration and location of webs.

Family Pholcidae

This family contains the daddy-longlegs spiders. These can be confused with harvestmen, sometimes known as daddy-longlegs, which have no constriction between cephalothorax and abdomen. Harvestmen are not true spiders but belong to Order Opiliones.

The most often encountered daddy-longlegs spider is *Pholcus phalangioides* found in houses, cupboards and subfloor areas. Pest controllers are often called in to control these loose-web-spinning spiders. The female is about 7–9 mm long and is characterised by its very long legs. Apart from the nuisance value of their webs, they do no harm and are non-toxic.

Family Theridiidae

There are many species in this family, but the best known is the toxic redback, *Latrodectus hasselti*, the female of which has caused deaths and illness from its bite. Many bites occur on

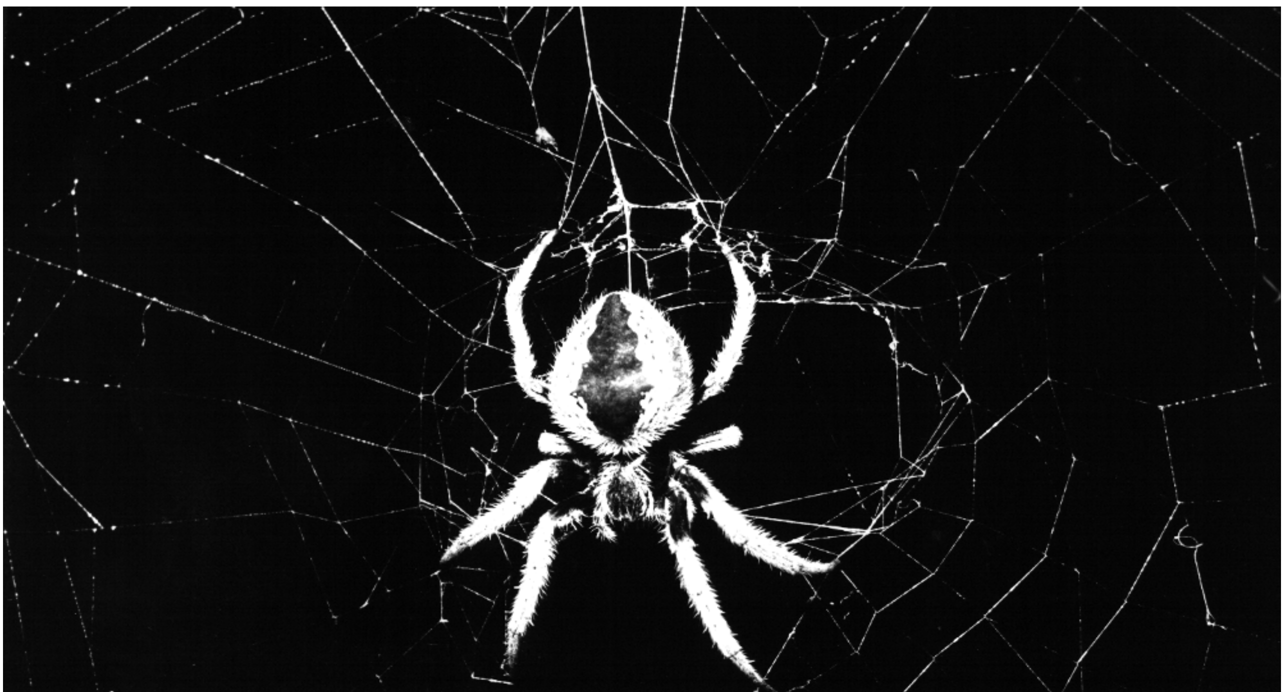
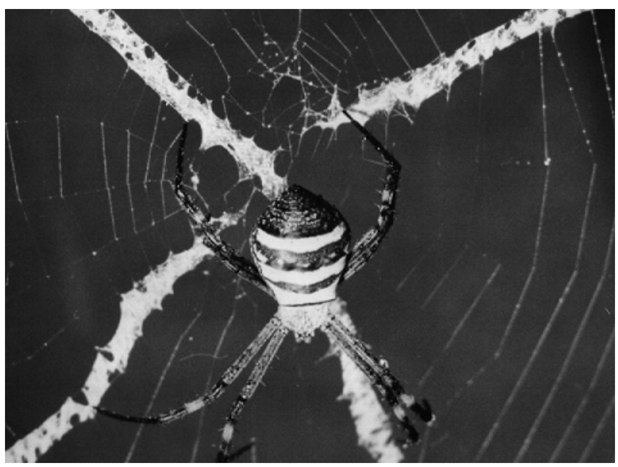


Figure 13.16 Garden orbweaving spider (*Eriophora* sp.)

Figure 13.17 *Top:* Female golden orbweaver spider (*Nephila* sp.)

Figure 13.18 *Above:* Female netcasting spider (*Deinopis subrufa*)

Figure 13.19 *Right:* Female St Andrew's cross spider (*Argiope keyserlingii*)



male genitals, as these spiders construct their webs across the seats of outside and often unsewered toilets. This species is found all over Australia, but the female is the sex most often encountered. It hides in stacked articles and rubbish during the day. Males occur in numbers around the female's web usually in late summer and autumn. The male is small, about 3–4 mm, and does not bite. The female is about 12–15 mm, black, velvety and has a bright red or orange stripe on the upper surface and a pale or red area on the underside. Sometimes the female may be entirely black and be mistaken for another species. The deadly American black widow is the same species as Australia's redback, but is considered to be a geographic variant. The New Zealand 'katipo' or night stinger is also a related species.

An antivenene is available for the treatment of bites of this spider.

Family Lycosidae

This family contains the wolf spiders, which are mostly in the genus *Lycosa.* All species are ground dwellers, making their holes in the ground or living in the leaf-litter layer. Most species have a mottled appearance, the male being of lighter build than the female and having more obvious and swollen palps.

The most frequently encountered species in coastal New South Wales is the garden wolf spider, *Lycosa godeffroyi.* The size of the wolf spiders varies, but *L. godeffroyi* female is about 20–25 mm long and the male 15–20 mm.

Figure 13.20 Jumping spider

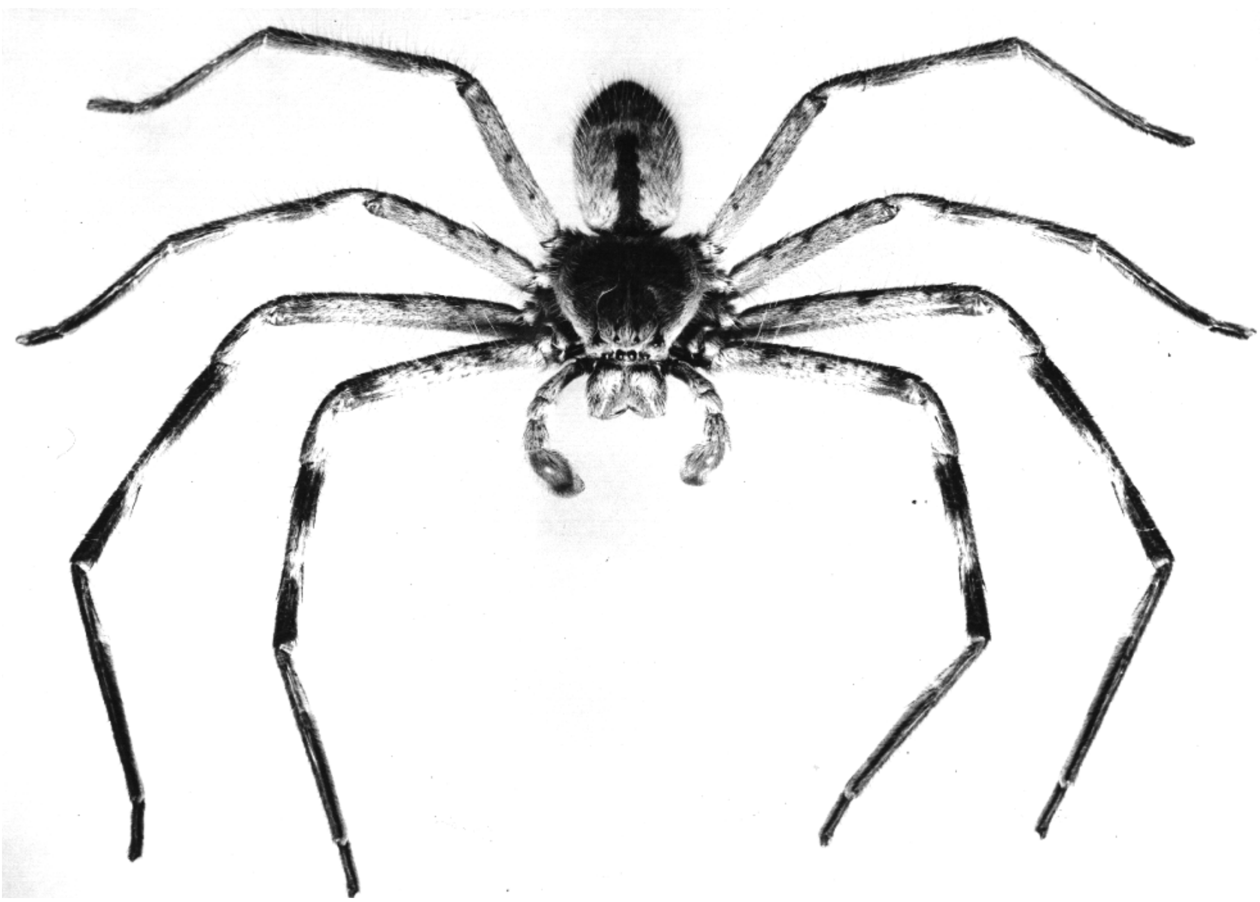


Figure 13.21 Huntsman spider (*Isopeda* sp.)

Family Heteropodidae

This family contains the huntsman spiders, which are also, and erroneously, known as triantelopes. These spiders often enter houses and may be found on walls. Their natural habitat is under damaged or loose bark of trees. They feed on insects and other arthropods. Some species of the genus *Isopeda* are quite large, the female being about 40–45 mm long and the male only slightly less. Their front two pairs of legs are longer than their rear two pairs of legs. They are hairy and flattened and able to move sideways very rapidly. They are not known to be toxic and seldom bite, despite their fearsome appearance. There are many species belonging to such genera as *Delena*.

Family Salticidae

This family contains mostly small spiders whose front legs, often the front two pairs, are more robustly developed for jumping. They spin mats of web, but they often stray in search of food and are encountered in many different places. They are harmless, mostly shy, and some species are colourful. Some species mimic ants.

SPIDER CONTROL AND AVOIDANCE OF BITES

Within the broad range of urban pest control activities, the control of ground-dwelling spiders (eg funnelwebs) has involved serious misuse of pesticides. This has been largely manifest in the 'blanket-spraying' treatment, using very stable, sometimes very toxic, organochlorine insecticides. However, these insecticides are no longer approved for spider control and their use has been banned in many countries of the world.

Control of ground-dwelling spiders relies on direct contact of the spider with the insecticide. Treatments that attempt such direct contact are likely to be time consuming and may miss less obvious burrows and spiders.This procedure is preferable to complete coverage of the area as many useful creatures will be preserved.

Because pest controllers are often employed in ground-dwelling spider control and in order to afford the client some 'peace of mind', it is essential that some advice be given in relation to the prevention of bites. Advice given may include:

1 Wear gloves when gardening and handling soil or rubbish.
2 Wear sensible footwear when walking outside, particularly at night, when most ground-dwelling spiders are active.
3 Where extensive excavations, landscaping, digging or gardening has occurred nearby, be alert for disturbed ground–dwelling spiders, which may enter buildings.
4 Don't leave toys, clothes and other such articles on the ground, particularly overnight. Wandering spiders may use them as a temporary resting site.
5 Be particularly alert for wandering male funnelwebs during the warmer months, (January to March). It is their mating season, and they may wander into yards and buildings in search of a mate.
6 Be alert for wandering ground-dwelling spiders after long periods of very wet weather. Burrowing spiders have particular preferences so extremes of weather may cause them to wander more than usual.
7 Be alert for wandering ground-dwelling spiders following the widespread application of insecticides. Where spiders are not directly contacted (and 'wetted') by the insecticide, they may be disturbed and wander more than usual.

Symptoms and treatment of spider bites

If, despite control measures and precautionary activity, a funnelweb or redback spider bite does happen it may be treated as shown in Table 13.4.

TICKS

Order Acarina

Ticks have their heads and bodies fused into one region and in this way may be distinguished from spiders. They have 4 pairs of legs in the adult stage, although, like mites, the immature forms have 3 pairs. Ticks may cause the death of warm-blooded animals by introducing toxins into the bloodstream, or cause non-fatal infections.

There are many species of ticks, and their identification is usually a task for the specialist. General entomologists mostly refer ticks to a specialist, except in cases of better-known species.

The brown dog tick, *Rhipicephalus sanguineus,* is an introduced species that has become established in Queensland and northern New South Wales. In these areas it is the usual tick on dogs, but it can also be found on cats, sheep, cattle, horses and humans. In Queensland it is blamed for transmitting 'Q fever' — a typhus disease.

The Australian paralysis tick is often encountered on animals, and its life cycle is considered here in detail.

Australian paralysis tick *Ixodes holocyclus*

The Australian paralysis tick (Table 13.5) is distributed mainly along the eastern coast of Australia, from Queensland to Victoria. The species seems to be most abundant on the central coastal plain, from Kempsey to Wollongong.

As a result of the presence of the paralysis tick, poisoning kills many domestic animals, particularly cats and dogs, as well as causing discomfort and illness. Infrequently, this tick causes death to humans. Humans showing tick-poisoning symptoms should be referred to a doctor, and for animals suffering from tick poisoning the services of a veterinary surgeon should be enlisted.

Developmental stages

The length of the life cycle of the Australian paralysis tick varies and may, in some stages, be very protracted. There are

TABLE 13.4
Symptoms and treatment of arachnid bites

Funnelweb spider	Redback spider	Australian paralysis tick	Scabies mite
Symptoms			
1. Pain in area of bite; numbness. 2. Nausea and vomiting. 3. Profuse sweating and collapse. 4. Frothing at the mouth, because of excess salivation. 5. Patient may turn blue because of breathing difficulty. 6. Cramps and pain in limbs and abdomen. 7. Patient may become delirious. 8. Twitching of facial muscles, contractions of limbs, reflexes sluggish, eyes fail to respond to light; coma.	1. Stinging sensation at bite although no sign may be evident. 2. Swelling around bite and paleness; pain and tenderness. 3. Stiffness around bite area. 4. Pain in lower limbs due to absorption of venom in lymphatic system. 5. Patient shows shock symptoms: pallor, weakness, profuse sweating, nausea and vomiting. 6. Some cases show paralysis of lower limbs.	1. Headache, particularly when tick is in the scalp. 2. Inability to read or focus. 3. General malaise. 4. Blurring of vision and weakness in limbs, increasing to paralysis after four days. 5. Muscles of respiration become involved, with breathing difficulty.	1. Itching under skin at night; mites mine in upper epidermis of skin.
First aid treatment			
1. Remove any tight clothing and make patient comfortable. 2. Apply firm pressure over area of bite using a broad roller bandage. Cover bite site, and extend bandage to both the extremity of the limb and as high up the limb as possible and keep movement of that part of the body to a minimum. 3. Remove patient to hospital as soon as possible. 4. Avoid stimulants; no liquids taken orally. 5. Warmth to wound reduces pain.	1. Remove tight clothing and make patient comfortable. 2. Apply a cold pack to the bite being careful not to freeze tissue. 3. Seek medical assistance promptly.	1. Remove the tick with a fine pair of forceps — no chemicals. 2. Do not press the tick body. Merely grasp the head and mouthparts; move sideways. 3. If symptoms are advanced or tick is in auditory meotus or any other inaccessible position, refer to a hospital.	1. Attention to personal hygiene. 2. Patient to wash; hexachlorophene soap. Seek medical advice. 3. Wash clothing by boiling, and iron creases. 4. Local application of sulphur ointment.

four distinct developmental stages in this species — egg, larva, nymph and adult — and these are much the same for other species. Continuity of growth depends on the tick's obtaining a blood meal to enable it to pass from one stage to another, and the adult female must have a blood meal before it can produce eggs.

The adult male does not feed on blood and therefore does not become attached to an animal host and cause it distress. It may be distinguished from the female by the large shield or plate that covers its entire upper body surface. In the adult female, in both the larval and nymphal stages, this plate covers only about one-third of the upper body surface.

The egg Eggs are laid in very moist situations, such as under bark and debris, which may be in contact with the ground. A female may lay up to 3000 eggs, which hatch in 40–60 days, but this depends entirely on temperature and humidity.

The larva The larvae are often referred to as seed ticks. They are about 1 mm long and have 6 legs. After a short time, during which their skins harden, they climb onto the foliage of plants, from where animals, brushing past, pick them up.

Figure 13.22 Australian paralysis tick (*Ixodes holocyclus*)

They insert their mouthparts into the tissue of selected hosts and commence to withdraw blood. It appears that the larval stage requires a native host (eg a bandicoot, kangaroo or possum) for its blood meal. However, the later stages are not so host-specific. After feeding for a period of 4–6 days, the larva falls to the ground, where it moults (sheds its skin) before re-ascending the vegetation as a nymph.

The nymph The nymph may remain in the moist vegetation for some time (14–40 days) before being picked up by a warm-blooded animal. It measures about 2 mm and has 8 legs. Having established a position on the animal, it feeds for about 4–7 days and then drops to the ground, where it moults and then re-ascends the vegetation as an adult tick.

The adult The adult female tick, after a short period in the moist vegetation, again attaches itself to an animal and commences to feed. The period of engorgement is variable, usually 6–20 days.

Tick poisoning

The tick becomes attached to its host by inserting its sharp mouthparts, which bear backward-projecting barbs, thus ensuring that it is held in place during feeding. At the same time a material is injected from the salivary glands of the tick, and this prevents the coagulation of blood, which would cause the fine mouthparts to become clogged. It is this anticoagulant, and perhaps other materials, that is toxic to animals. Fatal paralysis in mice has been produced experimentally by injecting them with fluid from the salivary glands of ticks. The tick does not burrow into the skin; but because there is localised reaction to the presence of the tick, which causes swelling of the skin, the tick appears to be embedded deeply. Once a tick bite has been detected, it should be treated immediately (Table 13.4).

Symptoms and treatment of tick bites

The following symptoms start to appear about 3–7 days after the tick has attached itself to an animal:

1. Loss of appetite, lassitude and depression occur.
2. Discharge from the eyes may be present.
3. Paralysis is first evident in the hindlimbs, when the animal finds difficulty in walking and coordinating its movements.
4. Vomiting may be evident, followed by grunting and wheezing.
5. Paralysis extends to the forequarters, with accompanying difficulty in swallowing.
6. Eyes may show distress, and the pupils become dilated.
7. Death may be caused by respiratory failure brought about by paralysis of the throat region, or heart failure may occur.

Any animal that has picked up a tick should be referred to a veterinary surgeon as soon as possible, even after the tick has been located. The tick should be removed, and this may be done by grasping the tick head area with the finger and thumb nails (or fine forceps if available) and snapping it sideways and then withdrawing it. Do not use kerosene, and do not squeeze the tick's body. After the tick has been removed, the site may be washed with a mild antiseptic. If the animal cannot be taken to a vet, seek the vet's guidance in some other way.

Control of ticks

The number of ticks in an area may be reduced and the hazard minimised by several means:

1. Exclusion of bandicoots. These are protected animals and must not be killed. However, if they are trapped and released elsewhere, the problem is reduced.
2. Removal of excess vegetation, particularly above grass height, and elimination of moist areas.
3. Chemical spraying of foliage and areas suspected of harbouring ticks, using materials such as diazinon, bendiocarb, carbaryl, maldison and chlorpyrifos. Read the label for acceptance in problem areas.
4. Washing the animal in a recommended and approved pesticide. Information appears on the label of suitable pesticide containers. Dusts also have some value.
5. Searching animals at least every second day. This is the most satisfactory procedure. Pesticides, although effective for a time, are likely to give animal owners a sense of false security that the ticks have all been killed or repelled. Any small ticks found may be removed as described previously. Fully engorged or 'bluebottle' ticks must be removed carefully, preferably with forceps.

Some general details about ticks

Paralysis in animals The adult tick is the most dangerous stage in the life cycle of the tick, although younger stages may cause paralysis when present in large numbers.

Veterinary treatment The advantages of seeking advice from a veterinary surgeon are stressed. The vet is able to administer tick serum and either minimise or prevent distressing vomiting. When a tick is removed, the peak symptoms may not be evident until some time later.

Tick serum The serum is produced by allowing large numbers of ticks to feed on laboratory-held animals. Some animals do not produce this serum.

Susceptibility Bandicoots, kangaroos and wallabies appear to be susceptible until they acquire immunity, probably by exposure to the immature stages of the tick.

Recovery Recovery appears to be higher in cats and goats than in dogs. Animals do recover from tick poisoning with proper treatment.

Immunity After an infestation from ticks, an animal that has recovered usually retains immunity for about 3–4 weeks, particularly if serum has been administered. Ticks must constantly feed on an animal for immunity to be retained.

Location of ticks Ticks are found mostly on the forequarters, especially the head and neck region. Some difficult, yet favoured, areas for attachment are the mouth, ears, eye surrounds, base of tail and anus. The animal can usually remove them itself from other parts of its body.

Seasonal abundance Ticks are usually more abundant in the November–December period, but weather conditions play an important role. Although numbers decline in winter, animal inspection must not be neglected at this time.

Tick dispersal Ticks may be transferred from vegetation on such things as clothing and picnic rugs, as well as animal fur. Ticks do not jump; they merely adhere to the body of a passing animal.

Figure 13.23 A mite-infested huntsman spider

MITES

Order Acarina

Mites are minute creatures, 0.1–2.0 mm in length, which have unsegmented abdomens and 4 pairs of legs in the adult stage. They obtain air through their body surfaces by means of spiracles or small breathing apertures. Mouthparts may be piercing and sucking, in the case of predatory and parasitic mites and mites that feed on plant sap. A modified type of mandibulate mouthpart is possessed by mites that feed on grain and other food products. Many mites having a mandibulate mouthpart feed on fungi, which, like the mites themselves, are favoured by moist conditions.

Mites are mostly associated with moist or humid conditions, and for this reason they are seldom pests in air-conditioned buildings. Even if they are brought in on paper and other articles, they do not continue long in the dry atmosphere.

The development of a mite involves an egg, larval, nymphal and adult stage. Some species form a hypopal stage, which may, depending on the species, be able to move. The hypopal stage is really a type of nymph that has no mouthparts and its legs are reduced in size. As it is able to resist dryness, it can survive short periods of adversity. The larvae have only 3 pairs of legs, the nymphs and adults 4 pairs. The life cycle usually occupies 2–4 weeks, but this depends on the species and weather conditions.

Mites are annoying. They attack various foodstuffs, and some species may attack humans, causing scabies, skin irritation and inflammation. Some mite species attack animals (eg a mite that causes mange in dogs). Some mites are beneficial, attacking insect pests.

Common mites

The food mites (Family Acaridae) may occur in houses, but they have their origin in stored food.

The starling mite, *Ornithonyssus bursa* (Family Macronyssidae), may be brought inside or occur in houses where birds are kept. When a nest is removed in a roof cavity and the area is not treated, these mites often cause temporary irritation to the occupants of the house.

The poultry red mite, *Dermanyssus gallinae* (Family Dermanyssidae), may be carried inside on clothing and cause some irritation and discomfort to the wearer or contacts. May occur in bird nesting material.

The bryobia mite, *Bryobia rubrioculus* (Family Tetranychidae), which is usually reddish brown, may migrate indoors from vegetation, particularly fruit trees and clover.

The straw itch mite, *Pyemotes herfsi* (Family Pyemotidae),

TABLE 13.5
Miscellaneous arthropods

Arthropod	Structural	Body size	Colour	Life cycle	Habits	Toxicity
Class Arachnida						
Australian paralysis tick *Ixodes holocyclus* (Order Acarina)	Female — partial plate over body; sharp mouthparts with barbs. Male — plate covers abdomen completely.	3–5 mm for adult	Pale brown, but female becomes grey-blue after feeding.	2–3 months. Several generations per year.	Female — feeds on blood; lays eggs in vegetation. Egg–larva – nymph–adult. Larva =. seed ticks. Nymph = nymphal ticks. Male — feeds on old skin tissue, not blood.	Toxic. Adult kills dogs. Children have died from tick poisoning. Adults may become sick.
Scorpions (Order Scorpionida)	Long tail leading to a 'stinger' Pedipalpi modified to form claspers.	Mostly 25–50 mm	Mottled to brown depending on species.	2–4 years approx	Lives under rocks, bark etc. and feeds on insects. Young born alive; carried on female's back for a time.	Toxic. Some are not, but if bitten medical attention should be sought.
Class Diplopoda						
Millipedes	Long bodies. 2 pairs of short legs to each body segment. Rounded body.	45–50 mm usual, up to 150 mm	Variable. Black with cream and yellow etc.	Probably 1 generation per year.	Damp situations required. Eats decaying vegetable matter. Produces a repellent fluid.	Not toxic. Fluid may cause irritation.
Class Chilopoda						
House centipede *Allothereua maculata*	Long slender antennae. Long fragile legs. 15 pairs of legs; 1 pair to each segment.	20–25 mm	Pale brown with dark markings.	Probably 1 generation per year.	Frequents fernhouses, damp rockeries. When found in houses indicates dampness and poor ventilation.	Generally harmless.
Giant Centipede *Ethmostigmus rubripes*	Long body with 1 pair of legs to each segment. Usually odd number of pairs.	Up to 250 mm	Green, yellow, brown depending on species.	2–3 years approx	Found under litter, stones, rotting wood etc., usually in moist situations. Bites with jaws under head.	Toxic, producing pain but no fatalities.

is a pest in straw in storage and occurs often in straw mattresses. It also occurs on the bodies of many insects, particularly those attacking timber and grain in storage. It does not cause discomfort on the human body for long, as it prefers other environments. Fair people are more sensitive to this mite, and a rash may develop. Removal from the area for a short time is sufficient for the marks to disappear.

The scabies mite, *Sarcoptes scabiei* (Family Sarcoptidae), tunnels in the upper epidermis of human skin, and intense itching occurs mostly at night when the infected person is in bed. This mite is found where there is overcrowding and hygiene is poor. It is conveyed by contact and from infected clothing. The female lays her eggs close to the skin, and the young bore into the skin. The life cycle is usually completed in 4–6 weeks.

The grass itch mite, *Odontacarus australiensis* (Family Trombiculidae), is bright red and less than 0.5 mm long. It occurs in Sydney and surrounding areas during the summer months, and also in other areas along the coast. It is better known for its presence, in clusters, in the ears of cats. When feeding it attaches itself to the skin of its host, and in humans it causes inflamed swellings that itch for some days.

Control of mites

Avoidance of infestations is the most satisfactory control measure. Once mites have attacked humans, they become a medical problem, since the reaction to their bites must be treated, particularly in sensitive or allergic people. Scabies is not a pest control problem, since hygiene and the use of medical creams resolve the condition (see Table 13.4).

Treatment of areas infested by mites to eliminate them quickly from offices is often necessary using an insecticide approved for this use. They are only temporary pests of humans and mostly enter houses or offices from vegetation, from birds abandoning their nests in roof voids and leaving mites without their normal hosts, from paper and other stationery brought from bulk storage, and from food products infested while in storage. Organophosphorus and carbamate insecticides are used for the control of mites. The label data should be read carefully to determine whether the insecticide is approved under state legislation for the control of mites.

SCORPIONS

Order Scorpionida

Scorpions (Table 13.5) have 4 pairs of functional legs and a pair of palpi modified to form grasping or seizing organs. These palpi are similar to the claws of a lobster and are called pedipalpi. The posterior segments of the abdomen terminate in a stinger provided with poison glands. The cephalothorax carries the eyes, pedipalpi and mouthparts and is protected on the upper surface by a hardened plate giving it an armoured appearance. Eyes are arranged around the sides, and the legs terminate in claws. Four pairs of lung-books are present on the undersurface of the abdomen. These are hollow sacs filled with leaves or lamellae and constitute the respiratory organs of scorpions.

Scorpions grasp their prey or enemies with their pedipalpi and strike with the stinger, thus immobilising the animal. With the aid of the pedipalpi, the scorpion forces its prey to its mouth and consumes the body fluids, casting aside the outer covering and wings if present.

The female scorpion produces its young alive, and these are carried about on its back for some time. Scorpions appear to have a long life cycle, requiring some years to reach maturity, during which time they moult frequently. They endure lengthy periods without food and may be kept alive in jars of moist sand for some time.

Australia is fortunate in that only one death due to scorpion stings has been recorded, most species being relatively harmless. However, since stings have been recorded from Australian species and some species are toxic, scorpions should be regarded as potentially toxic until the species is known. Very little data is available on the nature of their venom.

The common brown scorpion, *Liocheles waigiensis,* is an often–encountered species found under bark or stones. It is about 25–35 mm long and mottled. Bites from its sting produce only some pain and swelling, but medical advice should be sought.

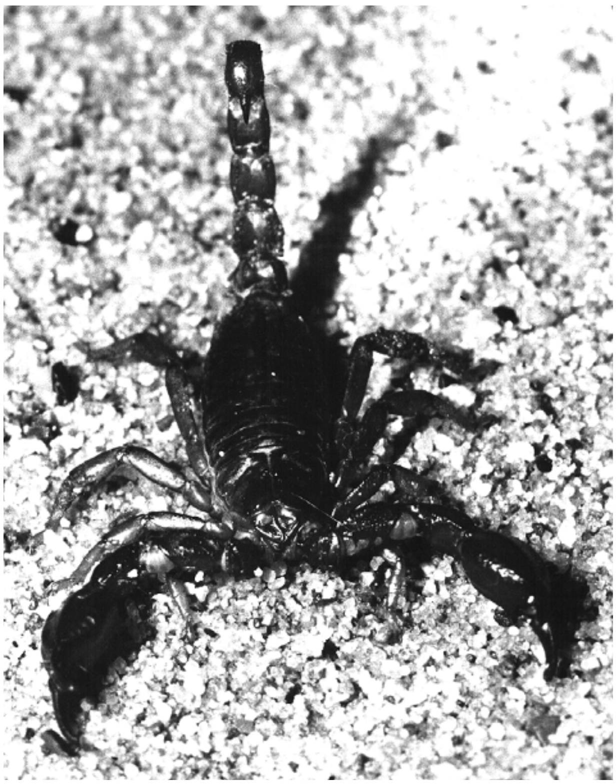


Figure 13.24 Common brown scorpion (*Liocheles waigiensis*)

FALSE SCORPIONS

Order Pseudoscorpionida

Also called bark scorpions.

These are minute arachnids that may be found under bark. They superficially resemble true scorpions but do not possess the characteristic sting. They have large claws on the pedipalpi and breathe by means of spiracles on the body segments.

They feed on very small insects and other arachnids and produce a small amount of silk to line the shelter in which they hibernate. Eggs are carried about on the underside of the female. They are harmless to humans.

The bark scorpion, *Conicochermes brevispinosus,* occurs around Sydney and measures about 7–12 mm.

Figure 13.25 False scorpion (*Conicochermes brevispinosus*)

HARVESTMEN

Order Opiliones

Also called daddy-longlegs.

Harvestmen are frequently encountered by pest controllers. On casual observation they may be considered to be spiders. They are distinguished from spiders by the absence of the constriction between cephalothorax and abdomen. Legs have well-defined segments, and the body is often slung between the legs so that it rocks to and fro. They obtain air through spiracles on their bodies. They are encountered under houses during inspections and treatment.

There is no record of bites, but some species produce an offensive odour.

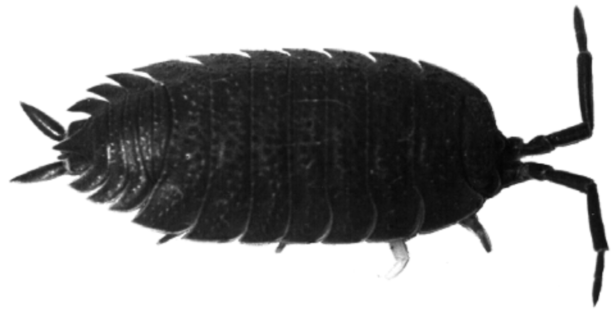


Figure 13.26 Common slater (*Porcellio scaber*)

OTHER ARTHROPODS

Slaters
Superclass Crustacea, Order Isopoda

Also called wood lice.

Slaters are encountered in most situations around the house and are well known. Their bodies are divided into three regions: head, thorax and abdomen. There are 7 thoracic segments, each bearing a pair of legs. The head has eyes and prominent segmented antennae. They depend on moisture to keep the oxygen-absorbing gills under their bodies moist.

Slaters feed at night and conceal themselves during the day. They eat mainly decaying vegetable matter but will at times damage young plant tissue. Damage of this kind is more frequent in fernhouses, where the moisture level is high. Young slaters resemble the parent and are carried beneath the body of the mother. They do not bite.

The common slater, *Porcellio scaber,* is pale brown to dull blue, about 12–15 mm long and appears armoured, particularly when mottled. It has paired processes at the end of its abdomen.

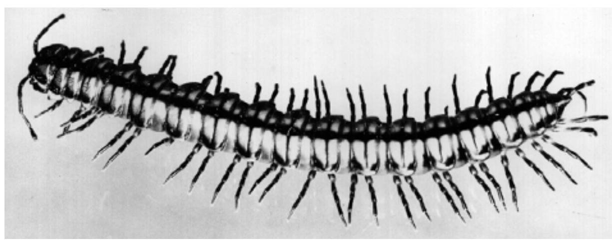


Figure 13.27 Millipede

MILLIPEDES

Class Diplopoda

Millipedes (Table 13.5) have short segmented antennae and 2 pairs of legs to each body segment, with the exception of the first 3 segments. Head bears the mouthparts, consisting of a pair of jaws, and a cluster of simple eyes on each side of the head. Body is round and not flattened as in the centipedes, and the outer casing is quite hard. Segments are telescoped and variable in number. Movement of the body appears to occur in waves, running from front to rear. Reproductive organs open towards the head and are not located posteriorly. Millipedes may attain a length of 20 cm.

Millipedes generally feed on organic matter, usually vegetable. They rear their young in a variety of situations, depending on the species, but usually require dampness. They do not inflict a wound, but produce a fluid that stains and has a repellent effect on other arachnids and insects.

CENTIPEDES

Class Chilopoda

Centipedes are somewhat flat and soft bodied, having one pair of bead-like antennae and eyes arranged in a cluster on either side of the head. They have a large number of short, jointed legs, one pair to each body segment. The name implies that they have 100 legs, but this is not so. The number of pairs of legs varies from 15 to 151, depending on the species, but is always an odd number. The first pair of legs are modified into poison claws or jaws and are located on the first segment behind the head. It is these structures that are used in attacking prey and inflicting wounds on other animals. Centipedes breathe by means of tracheae or breathing tubes.

Centipedes are generally found beneath damp and rotting wood, stones and garden litter, and it is here also that they rear their young. The bite of a centipede may be painful, but no fatality has been recorded. The processes on the end of the abdomen are not capable of inflicting a wound.

Three types of centipede are often encountered:

The house centipede, *Allothereua maculata* (Table 13.5), occurs in damp places and often indicates to pest controllers that there is a moisture problem — most likely insufficient ventilation in the subfloor area. It is also found in fernhouses, where it feeds on insects. The head bears a pair of long slender antennae, and the eyes are separate lens units. Eight body segments are obvious from above, but there are really 15, each bearing a pair of long legs, which are dropped if the creature is handled or hurt.

The giant centipede, *Ethmostigmus rubripes* (Table 13.5), is found under stones and in moist leaf litter. It travels at night in search of insects and other small creatures. It is reddish brown with short amber-coloured legs, and may measure up to 15 cm. Its bite can be painful and cause some localised swelling.

The ribbon centipede, *Schizoribaubtia aggregatum,* occurs in damp soil where it feeds on small insects and other animals. It is pale orange, with short thick antennae and a variable number of body segments. It appears to be unable to bite humans.

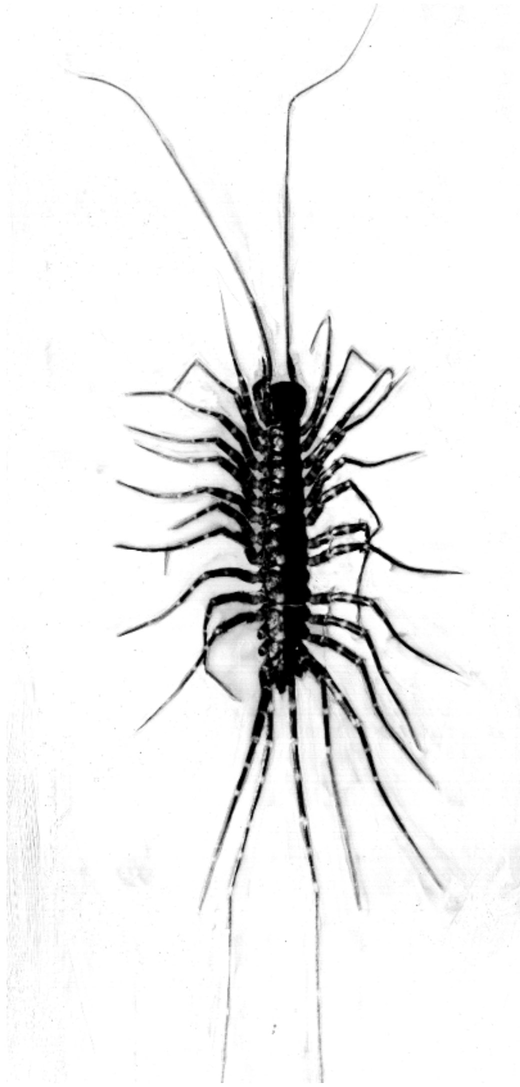


Figure 13.28 House centipede (*Allothereua maculata*)

EARWIGS

Class Insecta, Order Dermaptera

Earwigs are sometimes confused with centipedes. They have 6 legs and 3 body sections and are typical insects. The only reason for confusion is that they possess pincers on the end of their abdomens.

CONTROL OF POISONOUS ARACHNIDS

It is important that the arachnid is identified before any control measure is applied. Apart from the danger arising from the presence of the funnelweb, redback and at times the black

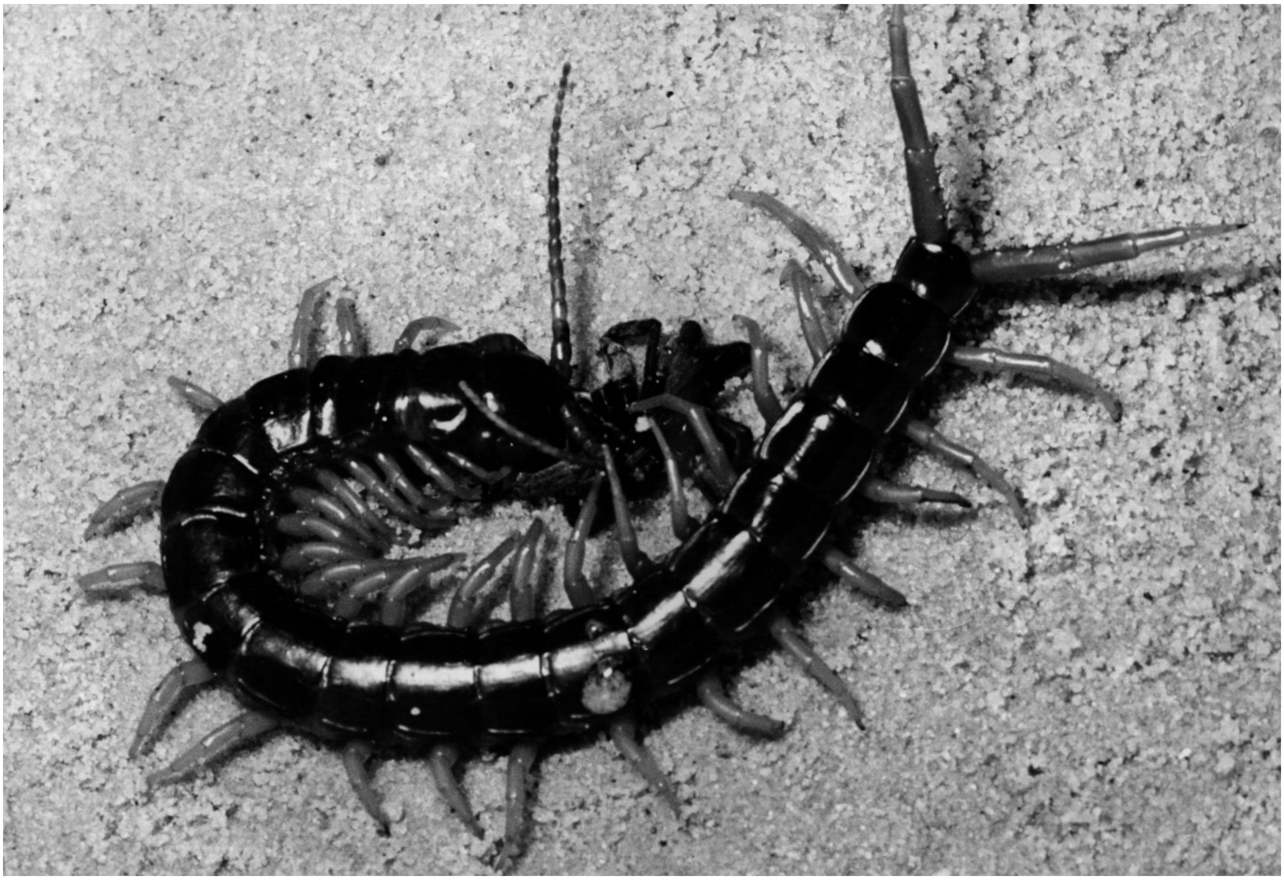


Figure 13.29 Giant centipede (*Ethmostigmus rubripes*)

house spider, control of other spiders must be weighed against their usefulness. There is a general fear of spiders, and this is often fed by sensational press statements that result in the death of useful non-toxic spiders. It is essential that the pest controller identifies the spider correctly and advises the client accordingly. Treatment of non-toxic ground-dwelling spiders often leaves a vacant niche that may be filled by toxic spiders, and such treatment has sometimes produced a very undesirable long-term effect.

Biological control

If the populations of the various spiders were not reduced by natural enemies and the adverse components of the environment (eg dryness and rainfall), the number of spiders would be immense. Among their predators are birds, insects and insectivorous mammals (eg the bandicoot).

Some wasps, particularly the mud daubers, seek out many arachnids and paralyse them. The victims are then taken away and placed in a mud nest to serve as food for the developing wasps. Other wasps are entirely parasitic on the eggs of spiders, choosing to lay their eggs in the egg sacs so that the young wasps develop by eating the spider's eggs. The cicada killer, a large wasp, is well known for carrying off quite

Figure 13.30 Jaws of the giant centipede, with which they bite

large spiders. Parasitic flies take their toll too. Often a large spider that has been kept for a day or so will die and several maggots will emerge from its body.

Spiders are also preyed upon by other spiders. Mites frequently attach themselves to the bodies of spiders; but unless they are present in large numbers, it is doubtful whether they exert any appreciable influence on the numbers of spiders.

Under many houses and buildings are geckos (lizards), and invariably, where these are found the spider population is small — in fact, seldom seen. These lizards are active at night when spiders also emerge to seek food.

Birds are able to kill and eat spiders; but since the periods of activity of birds and spiders often differ, birds are not a major controlling influence.

Control by hygiene

This is an often overlooked measure. Certain situations and environments are more favourable than others to particular species of spiders. For instance, funnelweb spiders are not found in the drier western districts of New South Wales. Situations such as rockeries, rubble in or on soil accompanied by dampness and vegetation are preferred by funnelweb spiders. To discourage these spiders, such conditions should be modified or eliminated. Redback spiders require shelter in piles of rubbish and protected sites in boxes and outside toilets to build their loose webs. These conditions can be eliminated and the spider population reduced. Much can be done without the use of chemicals. Toilet and garage spider problems can be reduced by using vacuum cleaners; the spiders are then destroyed by an aerosol insecticide in the bag.

Chemical control

Appendix VI outlines some of the pesticides that are used in the control of spiders at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

FURTHER READING

Brunet B. 1996 *Spiderwatch: A guide to Australian spiders* Reed Melbourne

Mascord R. 1977 *Australian Spiders in Colour* A.H. and A.W. Reed Sydney

Murray E. 1989 *Living with Wildlife* Reed Books Sydney

CHAPTER 14

RATS & MICE

Rats and mice are serious pests of humans and they can, in some cases, be difficult to control. This chapter looks at:

- their biology and habits;
- reasons for their pest status;
- some characteristics of the main pest species;
- the detection of their presence in and around buildings;
- non-chemical control procedures; and
- chemical control procedures.

While the vast majority of pests in urban environments are arthropods, certain mammals have established themselves, over many years, as extremely important pests of humans. Mammals are characterised by being warm blooded and covered with fur (or hair) and by their habit of suckling their young. Within the large mammal group, rats and mice belong to the group known as rodents (from the Latin *rodere* 'to gnaw'). This name refers to their gnawing habit, which is necessary to control the size of their characteristic, chisel-shaped, front incisor teeth.

The rodents that are of great concern in the urban pest control context, not just in Australia but in many countries, are:

- Norway rat *(Rattus norvegicus)*
- Roof rat *(Rattus rattus)*
- House mouse *(Mus musculus).*

These animals are well adapted to living in very close association with humans, sharing their food and shelter. Throughout history, rats and mice have been responsible for enormous losses of food and, owing to their ability to transmit diseases to humans by a variety of means, enormous losses of human life. Whether it be crops in the field or foods in store, rats still consume or contaminate vast amounts of food, and they can still pose a serious threat to health. Hence, it is not surprising that many countries have adopted legislation aimed at reducing levels of infestation. Urban pest control operators typically expend much energy in trying to control these very cunning and often cautious pests, which have so successfully exploited urban environments. Ironically, laboratory-bred rats and mice have, in more recent years, played a very important role in medical research, pesticide evaluation and other studies, where animals akin to humans are used as a guide for implications regarding human health.

BIOLOGY AND HABITS

Before examining each of the pest rodents in closer detail, some of their general characteristics can be considered.

The distribution and abundance of pest rodents are largely determined by the availability of food and shelter. Rats and mice may live and nest within buildings indefinitely, provided they have access to food (perhaps water) and shelter. Often, rodents will enter and nest in buildings only seasonally. In such cases, the rodents may begin to investigate buildings in autumn or winter, for if a suitable nesting site is established with a food source within reasonable range, the somewhat warmer nesting conditions may facilitate more productive breeding. Alternatively, rats may enter buildings owing to a change in the availability of food. Rats feeding in school premises, for example, may cause problems in adjacent buildings during school vacations.

Being basically social animals, rats and mice live in groups, in nests constructed of any soft materials available (eg paper, fabrics, insulation). Out of doors they may nest in burrows adjacent to waterways, under buildings and so on, in trees and vines, in garbage dumps, rubbish heaps and other places where food and shelter are within reasonable range. Indoors they may construct nests in wall voids, in roof voids, under floors and even within stored foods.

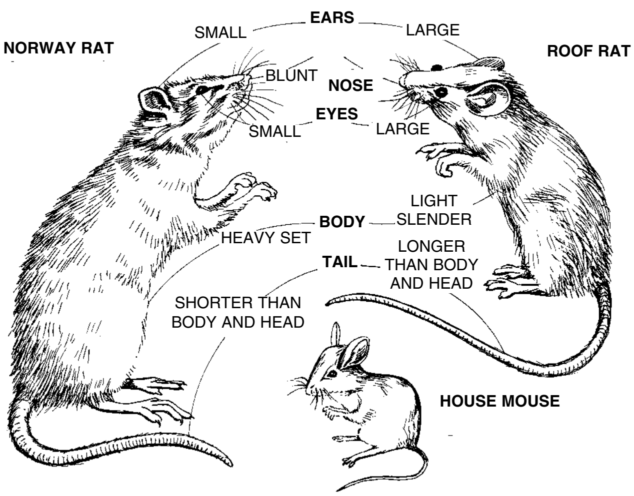


Figure 14.1 The common pest rodents

Rats and mice are generally regarded as very adaptable, omnivorous scavengers. They are very agile animals and mostly nocturnal, but they may range and feed during the day, particularly if the population is very large, food is short, or there is little disturbance or danger. In their movements to and from the nest site, they are very sensitive to, and wary of, their environment. In their travels, they tend to move and feed under or near cover, seldom running out in open spaces. This behaviour displays a marked reliance on the sense of touch and is much exploited in the placement of baits and traps.

Rats, in particular, are very much creatures of habit, tending to use the same routes of travel to and from food sources for as long as possible. They are sometimes referred to as being 'neophobic', suggesting that they have a fear of new objects (or other changes) in their otherwise well-known environment. This behaviour can be the cause of their apparent disinterest in a new bait station, at least during the first few days of its appearance. Mice, on the other hand, although seeming to maintain a high degree of caution in their movement, are very curious and adventurous animals. Mice often investigate new food sources within a very short time after their appearance, and they seem to prefer nibbling at small amounts of food at numerous different locations. This preference for feeding at several sites is often taken into account in mouse-baiting programs.

Rats and mice are competent climbers and can scale rough walls, pipework, trees and vines; in some cases 'tightrope-walking' across cables and the like is easily achieved. Rats (especially Norway rats), are very accomplished swimmers. They have fairly earned the reputation of being able to negotiate the S-bends in toilets, a feat that has no doubt caused alarm and personal discomfort over the years.

When at rest, rats and mice often groom themselves, licking their fur and feet. Clearly, this behaviour is exploited when toxic powders are put down on surfaces from which the rodents are likely to pick them up. As well, they constantly gnaw a variety of materials, but because their mouth and teeth are structured so that gnawings need not be ingested, this behaviour has little application in control procedures.

The senses of rats and mice are mostly very keen, with the exception of sight. In summary:

1. *Sight* — poorly developed. They cannot determine images sharply.
2. *Smell* — very keen. They use odour trails and can detect strange odours in foods.
3. *Taste* — very keen. They can detect strange tastes and may associate ill-feeling with certain tastes and/or smells in food. This may cause 'bait shyness'.
4. *Hearing* — very keen. Their hearing range extends into the ultrasonic range.
5. *Touch* — very keen. As they are mostly nocturnal, with poor eyesight, there is much reliance on the sense of touch. Touch sensors consist mostly of nerve endings at the base of the whiskers (vibrissae) and of long guard hairs on the body — hence their tendency to move along vertical surfaces, which afford some protection.

Some biological control of rats and mice is effected when they are preyed upon by cats, dogs, snakes and some bird species.

RATS AND MICE AS PESTS

The presence of rats and mice in buildings is usually regarded as undesirable from the viewpoint of food spoilage and contamination, physical damage, and the transmission of diseases to humans.

Eating and contamination of stored foods

Rats and mice are responsible for enormous losses of food in store, either by directly eating the foods or by rendering them inedible through contamination. As the rodents move in and around stored foods, they contaminate the food with droppings (of which often more than 50 per day are produced), urine (which tends to be sprinkled on surfaces over which they travel) and hairs. At times, poultry may be killed and eaten by rats.

Gnawing: physical damage

The constant gnawing of rodents can be the cause of serious damage to a range of materials. Typically, they may damage doors, skirtings and other parts of buildings, upholstery, books, food containers or packaging, and parts of equipment or machinery. The gnawing of wires and cables has caused the breakdown of telephone systems and short-circuiting, which may result in equipment breakdown or, at worst, very costly fires. Fire damage has also resulted from the gnawing of matches collected in the nest.

Disease transmission

Historically, the role that rats and mice have played in the transmission of diseases to humans has been of profound importance. The Black Death (bubonic plague), which claimed more than 25 million lives in fourteenth-century Europe, is perhaps the most documented case history of rats and disease. The plague bacterium (*Yersinia pestis*) was transmitted from rat to rat (ship rats) and from rat to human by the Oriental rat flea. The incidence of plague has not been entirely wiped out, but closer understanding of the mechanism involved has seen much reduction in the occurrence of this dreaded disease.

Among the many diseases transmitted to humans by rodents, some of which are outlined in Table 14.1, perhaps the most insidious and widespread problem involves the distribution of food-poisoning organisms (eg *Salmonella* bacteria). Unfortunately, the nature of disease organisms of this type is such that it will always be difficult to pinpoint, without any doubt, the cause of disease transmission. It is very likely that rats and mice play a significant role in the transmission of such diseases, particularly those which are gastro-intestinal and somewhat difficult to track back.

Rats and mice may transmit disease to humans by a variety of means:

1. Contamination of food or utensils with rodent urine or faeces. Examples: *Salmonella* food poisoning (bacteria carried by mice or rats), choriomeningitis, mild meningitis (virus carried by mice), Weil's disease, infectious jaundice (bacteria), tapeworm.
2. Contamination by direct contact with urine or faeces, where bacteria seem to enter the skin through small scratches; for example, Weil's disease.
3. Indirect contamination via blood-sucking insects (ie ectoparasites such as fleas); for example, bubonic plague (Black Death bacteria, via fleas), murine typhus fever (*Rickettsia*, via fleas).
4. Indirect contamination via pets to humans; for example, favus, skin disease (fungus from mice to pets to humans).
5. Contamination by directly biting humans; for example, rat-bite fever, relapsing fever (bacteria).
6. Indirect contamination by being eaten by an intermediate carrier; for example, trichinosis (worm-infested rodent eaten by pig, worm-infested pig eaten by human).

Rats and mice in buildings pose a serious threat to human health. The disease threat alone is justifiable cause for concern and for the implementation of sound control procedures.

THE IMPORTANT PEST RODENTS

The physical characteristics and habits of the Norway rat, roof rat and house mouse are summarised in Table 14.2.

Norway rat *Rattus norvegicus*

Also referred to as the common rat, sewer rat, brown rat and water rat.

The Norway rat is the larger of the pest rats and has a thickset body, blunt snout, small close-set ears and a tail shorter than its body length. It normally lives 9–12 months and may have 5–6 litters per year (each with 8–10 young). The young achieve sexual maturity at 3–4 months. Clearly, its reproductive potential is very high.

The Norway rat is very widespread and is possibly the most economically detrimental pest rodent in Australia. It infests warehouses, factories, flour mills, poultry farms, garbage dumps, shops, supermarkets, domestic premises, grain storage facilities, sewers, and many other locations that offer shelter and food. Outside buildings, these rats mostly live in burrows, which tunnel into stream banks, under buildings, under rubbish heaps and so on. Burrows commonly have 'bolt holes' hidden under debris or grass to facilitate fast emergency exits. They may enter buildings just for food, reside in buildings during the colder winter months, or live in buildings all year round. Nests in buildings are mostly located in wall voids, roof voids and other parts of the construction that offer a secretive, undisturbed area for shelter and access to food and water.

Norway rats are typically omnivorous in their feeding habits and will eat all human or animal foods and feedstocks. They do need regular access to liquid water; so in conditions where their food is low in moisture and available water is minimal, liquid bait preparations may be effective.

Norway rats are very much creatures of habit, and once they have explored a new environment, they establish quite rigid travelling routes. Being neophobic, they may take some days to adjust to new objects such as bait stations and traps.

In cases where the territory of Norway rats overlaps with that of other rodent species, it is entirely likely that the Norway rat will become the dominant species, often driving others out of the area.

TABLE 14.1
Diseases transmitted by rodents

Diseases	Cause or association	Effect on humans	Present or absent in Australia
Plague	Bacterium *Yersinia pestis* — carried by Oriental rat flea, *Xenopsylla cheopis,* on the 3 rodents, mainly roof rat.	Bubonic plague — bacteria arrested in glands. Septicaemic plague — bacteria enter blood, patient turns black.	Has occurred but not now present.
Sylvatic plague	*Yersinia pestis* — native animals of USA.	A reduced virulent form.	Absent
Pneumonic plague	Direct contact — coughing.	Bacteria affect lungs.	Absent
Murine typhus fever (endemic)	*Rickettsia typhi* — carried by Oriental rat flea. Also conveyed by dust and food etc. contaminated by rat faeces.	Rickettsial organism enters blood of man. Milder than epidemic typhus conveyed by the body louse.	Present (endemic)
Weil's disease (infectious jaundice or leptospirosis)	Spirochaete *Leptospira icterohaemorrhagiae* in blood and urine of rodents — to humans from food.	A debilitating illness, usually not fatal. Fever and increased pulse rate, then jaundice.	Present (endemic)
Rat-bite fever or relapsing fever	Bacteria *Spirillum minus* and *Streptobacillus moniliformis* — on teeth and gums of rodents from salivary glands.	Swelling of lymph glands and muscular pains. Relapses may occur after apparent recovery.	Present (endemic)
Trichinosis	Worm *Trichinella spiralis* — from pig to man via rodents. Pigs eat rats, and man eats pig meat.	Worms become encysted in muscles of humans. Mortality high in USA.	Not endemic. Brought in by migrants.
Lymphocytic choriomeningitis	Virus latent in mice — faeces to food or utensils to man.	Takes the form of a mild meningitis.	Present (endemic)
Rickettsial pox	Rickettsial organism — to man from mice by the mite. *Allodermanyssus sanguiensis*	A mild non-fatal disease resembling chicken pox.	Absent
Mouse typhoid or duck egg disease	Bacterium *Salmonella typhimurium* — from mice to man via faeces. Mice remain infective.	A severe food-poisoning, particularly in young children.	Probably present
Poliomyelitis.	Two different types of polio viruses — carried by mice via excreta. Also from sick to healthy person.	Various symtoms of poliomyelitis.	Present (endemic)
Favus	Fungus — from mice to man, or mice to cats to man.	Skin or ringworm.	Present

Roof rat
Rattus rattus

Also referred to as the black rat and ship rat.

The roof rat is the smaller of the pest rats and is of slighter build. It has a more pointed snout, large prominent ears and a tail longer than its body length. It normally lives 9–12 months and may have 4–5 litters per year (each with 6–8 young). The young achieve sexual maturity at 3–4 months.

The roof rat is often restricted to the indoors of premises and to areas around seaports. While Norway rats are very suited to rural life, where burrowing is advantageous, roof rats tend to be more restricted to city life, where their excellent climb-

TABLE 14.2
Characteristics of rat and mouse pests

Characteristic	Norway rat	Roof rat	House mouse
Weight	450 g	260 g	20 g
Body	Heavy-set	Slender	Slender
Nose	Blunt	Pointed	Pointed
Fur	Coarse, red-brown.	Fine, grey, black, brown, may be white beneath.	Fine, brown to grey.
Ears	Small, close-set, finely haired.	Large, prominent, almost hairless.	Fairly large, hairy.
Tail	Shorter than body and head. Pale underneath.	Longer than body and head. Uniform colour.	About as long as body and head. Partly naked.
Droppings	18 mm blunt	12 mm pointed	3–4 mm pointed
Sexual maturity	3–4 months	3–4 months	6 weeks
Gestation period	About 22 days	About 23 days	About 19 days
Number of litters	5–6 per year	4–5 per year	6–10 per year
Average per litter	8–10	6–8	5–6
Average length of life	About 1 year	About 1 year	About 1 year
Habits	Burrows, swims well,occurs in sewers, lives outside and inside, nesting in various places.	Does not burrow, climbs well, poor swimmer, rare in sewers, often in high places (roofs etc).	Burrows as well as nests in furniture, occurs outside and inside, not in sewers.
Range	40–50 m	40–50 m	3–10 m
Food	Omnivorous — garbage, meat, cereals, fish (food, 20–30 g/day; water, 20–30 ml/day).	Omnivorous — vegetables, fruits, cereal grains (food,15–22 g/day; water, 15–22 ml/day).	Omnivorous — cereal grains (food, 3 g/day; water, 1 ml/day).

ing abilities avail them of numerous nesting sites often in the upper parts of tall buildings. This ability also facilitates their crossing from one building to another via connecting cables. Within buildings, roof rats are likely to nest in wall and roof voids, but they may range and feed freely all over the building. Out of doors they may nest among vines and trees, but they seldom burrow. They commonly infest ships.

Although roof rats are usually described as being omnivorous, in practice they seem to consume a high proportion of vegetable and fruit material. Where they have ready access to foods with such a high moisture content, it is likely that they have a much reduced need for free water.

The roof rat can live in somewhat similar locations to those preferred by the Norway rat; but if territories overlap, it is likely that the roof rat will be driven out.

House mouse
Mus musculus

Also referred to, sometimes euphemistically, as the field mouse.

The house mouse is small and has rather large ears, a pointed snout and a tail at least as long as its body length. House mice living indoors are usually a darkish grey colour, with lighter grey on the belly, while those living mainly outdoors tend to a more sandy or yellow-brown colouring — hence the references to 'field mice'. They tend to live for about 1 year and may have 6–10 litters per year (each with 5–6 young). The young achieve sexual maturity at about 6 weeks.

The house mouse may live indoors or out of doors, sometimes entering buildings only when climatic conditions are adverse. Being such small animals, their access into buildings is probably easier than is the case for rats, and a greater range of nesting sites is available to them. Typically, within buildings they may nest in wall voids, cupboards, roof voids, stored foods, furniture and many other locations. Out of doors they live in burrows.

In their general behaviour, mice are much more curious and exploratory than rats, so trapping programs for mouse control can often be very effective. They are very good climbers, jumpers and swimmers, although they do not seem to swim very often.

In their feeding habits, mice are generally regarded as being quite omnivorous. A variety of foods (eg nuts, grains, fruits, meatmeals and animal feeds) may all be acceptable on baits or traps, depending on the main diet of the resident population. They are well adapted to low water intake and can live on just the moisture in grain without any supplementary intake of water. Preferably, though, they seem to enjoy dry cereals if free water is available. Mixing of certain baits with water can make them very attractive. Mice feed mostly around dusk and during the night, but if the area is relatively undisturbed, they may feed during the day as well. They seem to prefer to eat small amounts of food at various locations and at frequent intervals. Even though they do not directly consume large amounts of food, damage due to gnawing, nibbling and contamination with urine and faeces can be very widespread. In most cases, mice are not as suspicious of new food (baits) as rats.

In rural areas the occasional combination of mild weather, abundant food and shelter, and a reduction of natural enemies may cause mice to multiply to plague proportions, and then to migrate. Massive migrations can cause very significant damage and losses to farms and other buildings.

DETECTION OF RATS AND MICE

Any serious attempt to control rodents in buildings must, of necessity, begin with a thorough inspection of the premises. Operators seldom have the opportunity to inspect premises at night when the activity may be directly observed, so signs of activity observed during the day must be interpreted to yield as much information as possible about the type(s) of rodents present, the extent of their activity, their routes of travel and the approximate size of the population, and any other information that will aid in the determination of proper and effective control procedures. The following signs of rodent activity can be of great value in providing such clues:

Droppings Droppings may aid in identifying the rodent species present. When shiny, dark and pliable, they suggest very recent activity. Usually, within 2–3 days they become dull and hard as they dry out, and after some time they may be attacked by insects (eg spider beetles). Operators sometimes clean up droppings from particular areas, so that later inspections will more easily indicate the presence or absence of continued activity.

Runways Sometimes called rubmarks, runways are markings on surfaces deposited as greasy smears by continual contact with dirty, greasy rodent fur. Usually, they are most apparent on vertical surfaces, and they are very useful for the placement of traps (baited or unbaited) and bait stations and for rodent-proofing procedures. When covered with dust or cobwebs, they probably indicate no current rodent traffic.

Figure 14.2 Rodent faeces

Burrows Burrows are often present adjacent to waterways (streams, canals etc.) and buildings. Rat burrows generally have a 'bolt hole' hidden under grain or debris. If cobwebs or weeds cover the entrance, it is likely that activity has ceased.

Gnawings Rodents must gnaw to keep their incisors down. They tend to gnaw a wide variety of materials, including woodwork, soft metals, soap, food containers, conduiting and cables.

Nests Nests may be found in hidden parts of constructions. They are usually made of rags, paper, cardboard, straw and the like, and if fresh droppings are present, they are likely to be active. Collections of foods (eg snail shells) may indicate the proximity of rat-nesting areas.

Runs Outdoors, constant rodent traffic may pat down vegetation to form a rather obvious run. Indoors, dust-free runs in otherwise dusty areas may indicate constant traffic.

Tracks Footprints and tail marks sometimes confirm rodent activity.

Urine stains Rodent urine fluoresces when a black (ultraviolet) light is shone onto surfaces contaminated with it. Rat urine often appears like sprinkling over the areas travelled on. Care should be taken with the use of a black light, as some materials other than rodent urine also show fluorescence.

Urinating pillars Long-term activity of mice sometimes leads to a build-up of urine, grease, dirt and dust to form small mounds or 'urinating pillars'.

Disappearance of food Rats often carry food away to their nesting sites.

Sounds Occupants of buildings may draw attention to sounds heard during the evening and night. These are often described as bumping, squeaking, gnawing, clawing and sometimes fighting.

Odour The long-term presence of a rodent infestation usually creates a distinct odour not unlike that of acetamide.

Visual sightings Occupants of buildings sometimes report sightings of rodents during the day. This often suggests a large population or food shortage.

Excitement of pets Most pets are territorial and very sensitive to foreign odours, noises and so on. Pets such as dogs may become very excited about the intrusion of rodents, sometimes clawing and barking at the part of the building where rodents are active.

All of these clues, gathered during thorough inspection and perhaps during conversation with the building's occupants, will help to establish a sound approach to rodent control.

RODENT CONTROL METHODS

Pest control operators called on to control rodents infesting a building may choose to use one or, more usually, a combination of methods, depending on the circumstances. Procedures may include the following:

1 *Sanitation* — reducing the food and shelter available for rodent activity.
2 *Rodent-proofing* — altering the building structurally so that rodents cannot gain entry.
3 *Trapping* — using traps or glue boards physically to capture rodents.
4 *Chemical control* — which may involve a variety of chemicals and techniques:
   a) baiting:
   - with the traditional acute (single-dose) poisons (now uncommon practice that would require application to the relevant authorities for permit/permission);
   - with multiple-dose anticoagulant rodenticides; or
   - with single-dose anticoagulant rodenticides;

   b) use of tracking powders (poisonous dusts) or gels;
   c) use of fumigants (poisonous gases).

The control of some high-health risk, large-scale rodent infestations may require the implementation of several of the procedures outlined above. In dealing with all rodent problems, however, irrespective of the type of chemical control or trapping undertaken, the observant operator will always look for signs of poor sanitation and hygiene practices that, unless corrected, will continue to invite these unwelcome visitors.

Non-chemical control

Sanitation

It is quite reasonable to suppose that decreasing the food and shelter available to a given population of rodents is likely to lead to more competition between individuals and, eventually, to a decline in the number of rodents present. This aspect of rodent control often involves a largely educational component, whereby the pest control operator, following a thorough inspection of the premises, may advise the client about hygiene and sanitation in relation to rodent infestation. Reference to local government health regulations may be appropriate. The operator may advise the use of sound garbage containers with tight-fitting lids, a clean-up of rubbish heaps and overgrown weeds around the building, or cleaning of the building immediately after the day's work is completed, rather than on the following morning.

Each situation will be different, so each should be carefully inspected and assessed and then sound advice given. The operator, while inspecting and questioning, will be constantly looking for conditions of food and shelter that may help to sustain a rodent population. The importance of achieving and maintaining a high standard of hygiene and sanitation, in relation to the control or prevention of rodent infestation, cannot be overemphasised.

Rodent-proofing

Perhaps the most permanent method of rodent control is to make alterations to the building so as to prevent their entry. It is again necessary to carry out a thorough inspection of the premises, locating all cracks, crevices, holes and other potential access points that could allow the entry of rodents. All possible entry points should be blocked, using only sturdy, durable materials such as cast iron grills, heavy-gauge sheet metal, and rich cement mortar or concrete mixes. Materials such as plastics, wood and softer metals (eg lead) should be avoided, as rodents can gnaw through these.

In some buildings, because of the scale and type of structure, it is not economically feasible to consider proofing the entire building. In such cases the client may prefer to meet the costs of regular chemical control programs. In other buildings precisely the reverse may be the case, and proofing, in the longer term, may be the most economically feasible approach. Again, a thorough inspection and assessment of a given situation, taking into account sanitation, proofing and chemical control methods should determine the soundest approach.

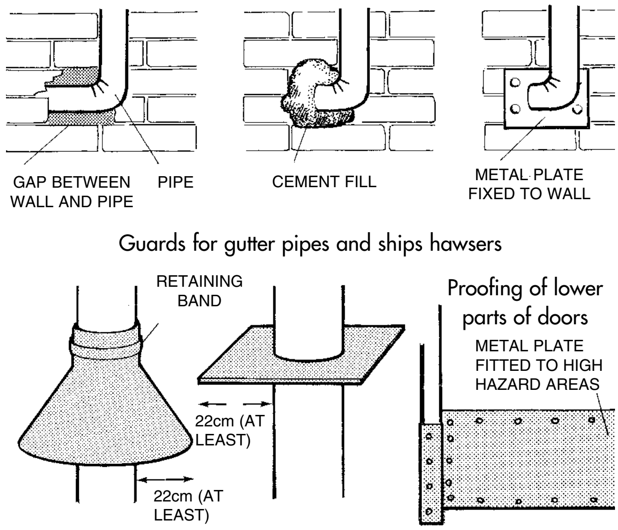


Figure 14.3 Some rodent-proofing techniques

Trapping

Trapping is a technique of rodent control that is not as popular in present-day pest control as it was in the past. This is probably because trapping can demand much time, skill and labour and the variety of chemical control methods now available are often seen as more cost-effective. There are still, however, situations where trapping is a more appropriate method. Trapping can be useful:

1 for rodent control in premises where inaccessible dead rats cannot be tolerated;

2 for rodent control in premises where chemical pesticides are not tolerated; or
3 for cleaning up remaining 'bait-shy' individuals after a baiting program.

Simple snap traps A variety of traps have been developed, but the simple snap-trap type is still preferred by many operators. They are available in the older wood and steel form, or in the more recently developed polystyrene and steel design (eg the Kness SNAP–E®) which have a somewhat larger trip paddle and a vertically set strike bar which travels a shorter distance and hence may do so more quickly.

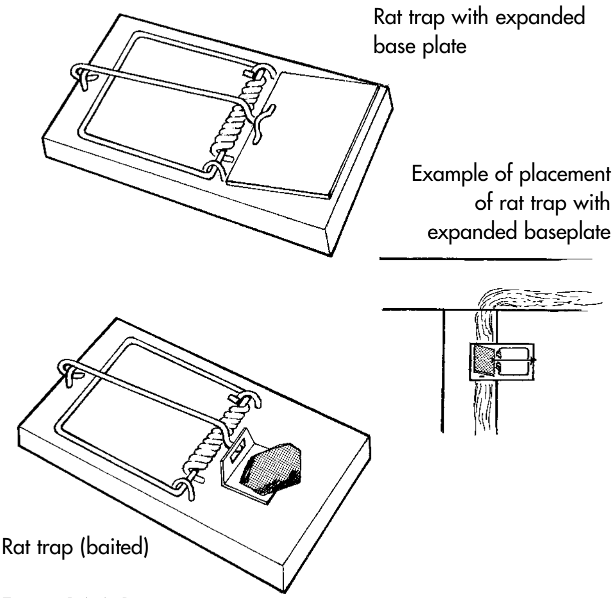


Figure 14.4 Rat traps

The type of bait used may be bacon, fish, nuts, prune, apple, peanut butter or some other food; the most attractive may depend on the particular eating habits of the rodents in each particular situation. The operator may experiment, using initially a variety of different baits and noting which are the most acceptable. At first it may be worthwhile, in the interests of avoiding early 'trap-shyness', to use only unset traps with their attractant bait. Baits should be securely attached to traps, as they may otherwise be pushed off without capture.

Thorough inspection of the infested premises should reveal clues as to where the rodents are active. Such clues (eg runways, droppings, gnawed surfaces) should influence the placement of traps, so that the rodents are likely to encounter them while going about their normal, usually fairly routine activities. The smell of humans or rats on traps does not seem to significantly affect rodents' behaviour towards them.

Traps may be used without baits, merely by covering the trigger with cardboard or sawdust and placing the trap strategically (eg at a right angle to a runway). In this way the unsuspecting rodent may be trapped during its normal activities. The setting of unbaited traps can be useful for cleaning up the last few individuals that are shy of baits or baited traps.

Traps should never be set in hazardous locations (eg above foods or food preparation surfaces), to avoid contamination by urine, droppings or blood. Traps should be checked at least daily, dead rodents placed in sealable bags, and the bags then disposed of appropriately. As ectoparasites (eg fleas) tend to leave their host when they detect that it is dying or dead, the operator should avoid the possibility of being 'tried out' as a new host. By collecting dead rodents swiftly in bags, wearing appropriate protective clothing, and perhaps judiciously using insecticides or repellents, the risk to health can be minimised.

Multiple-mouse-catching devices Particularly suited to larger scale commercial and industrial mouse control work, these 'metal box' type traps can capture several mice in each setting but they rely on careful placement and a thorough knowledge of building and activity patterns of the mice.

The Kness Ketch-All® is a spring loaded trap (a winding mechanism sets the trap) that can capture up to 20 mice per setting and available accessories include: clear view lid (for

Figure 14.5 The Kness SNAP–E® trap

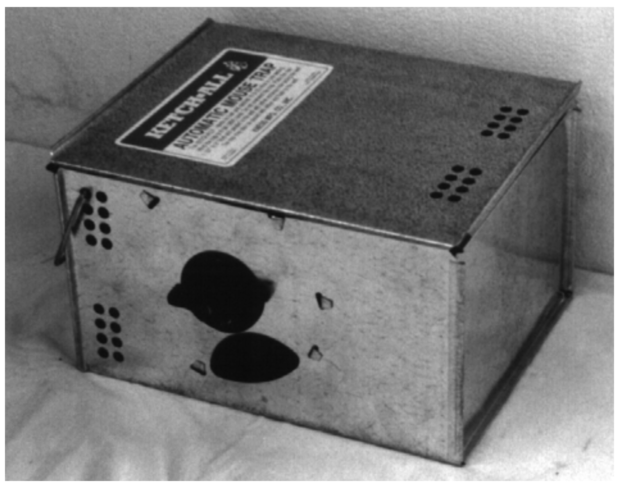


Figure 14.6 The Kness Ketch-All® automatic mouse trap

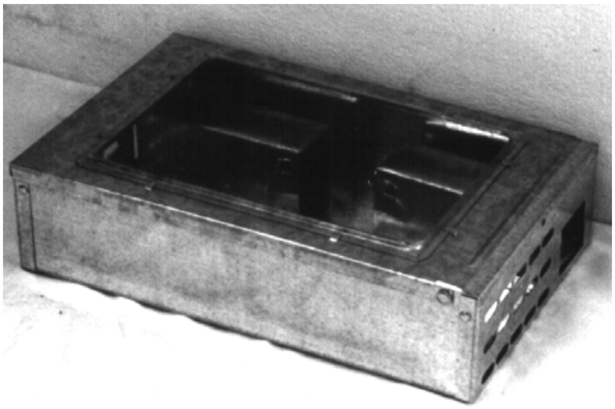


Figure 14.7 The Victor® Tin Cat® repeating mouse trap

easy examination of catch), a cleaning tray and a range of heavy steel wall guards and positioning brackets to protect the device in industrial situations.

The Victor® Tin Cat® repeating mouse trap has a window lid for easy examination of catch, a low profile shape to facilitate strategic placement, catches up to 30 mice and does not require resetting.

Glueboards This form of trap is particularly reliant on strategic placement so a thorough survey and inspection of the area is critical. Some types are bait-enhanced wherein the glue contains an attractive scent (eg peanut butter or banana). Some types are designed to be used flat, some fold into an L-shape to fit neatly into wall/floor junctions and others fold into a triangular tent shape so that the glue surface is protected from falling dust or other contaminants. As well, the Kness Stick-All™ Depot and Glueboard is a galvanised metal box that can house disposable glueboards hence protecting the glue from dust fallout and also hiding the trapped animals from the view of clients.

Figure 14.8 The Kness Stick-All™ Depot and Glueboard

Chemical control

Chemical baits

The early use of chemicals in rodent control employed largely traditional acute or 'single-dose' poisons (eg arsenic and thallium). Because these materials need to be ingested only once and have a very high level of toxicity to a broad range of non-target animals, it is not surprising that their use has declined significantly in more recent times and that they have been replaced by less hazardous alternatives.

It was not until the early 1950s that the much safer, 'multiple-dose' anticoagulant rodenticides (eg warfarin) were developed, and gradually these have come into very wide use. Because these materials require that the target animal feeds over a period of perhaps 4–8 days before the concentration of the anticoagulant is sufficiently high to cause death, these materials are far superior to traditional single-dose poisons, from the viewpoint of safety for non-target animals.

By research efforts to expand the range of anticoagulant rodenticides, and with the problem of warfarin-resistant rats developing in some locations, a new generation of acute 'single-dose' anticoagulant rodenticides has recently been developed.

Rodent control by chemical baiting is discussed in more detail below.

Tracking powders and gels

Some rodenticides (including some multiple-dose anticoagulant rodenticides) are available in a powder (dust) or gel formulation that is suitable for use as a tracking powder or gel. When these are placed where rodents are likely to contaminate their paws and fur (eg along runways, in burrows, on the floor of bait stations), the rodents will later, during grooming, ingest an amount of the poison. Tracking powders can be sprinkled in appropriate places, or a dust blower may be useful in less accessible situations. Care should be taken not to use tracking powders where the poison may be conveyed by the rodents onto food for human consumption.

Fumigants (poisonous gases)

Fumigation is useful for large-scale rodent infestations (eg on poultry farms) and for other circumstances where rapid elimination is required. Fumigants are very dangerous substances, so only specifically trained (and in some cases licensed) operators may carry out such work. The role of fumigation in rodent control involves largely outdoor applications treating burrows. The fumigant phosphine is sometimes used in such work.

Rodent control by chemical baiting

Using traditional acute (single-dose) poisons

Owing to the widespread use of the safer anticoagulant rodenticides, the traditional single-dose poisons have been experiencing a significant decline in use. This decline is largely attributable to their often highly toxic nature, whereby one accidental feeding by a non-target animal is very likely to cause death. There may, however, be circumstances in which these single-dose poisons are still useful, for example, where a quick knockdown of a rodent population is required owing to a significant disease risk, or in circumstances where anticoagulant baits are not sufficiently effective. When a rodent control program is to include the use of single-dose poisons, it is essential that the work be carried out by qualified operators with appropriate permits/permission.

Prebaiting Rats mostly use the same routes when travelling and tend to know well their immediate environment. Unlike mice, they suffer from 'neophobia'; that is, their behaviour shows an aversion to new objects in their environment. It may, for example, take a few days before the more suspicious rat will try a new food in a new container, while the more adventurous mouse may begin to investigate within minutes.

Before prepared baits are laid down, it is usually advisable to prebait. This involves laying down the attractant food with all other additives (eg mould inhibitors, dyes) in the bait, except for the poison. This may be carried out for a few successive sessions, or perhaps until the rodents appear to be feeding freely. Once their feeding habit has been established, the bait should be altered to contain the poison. This procedure lessens the likelihood of creating bait-shyness in rats.

Baiting A variety of foods are used in the preparation of poison baits, including bread, cereals, fish, meat, prawns, fruits, nuts or vegetables. The choice of food will take into account the feeding habits of the rodents to be controlled and, owing to the toxicity of the baits, they should be placed so that they are inaccessible to pets, children and other non-target animals, and this may require them to be enclosed in secure, clearly labelled bait stations. Baits should always be located in places with evidence of rodent activity, such as on runways or near burrows and harbourages. Where possible, the baits should be in an enclosed area to afford coverage and protection to the feeding rodent. Lockable and/or tamper-proof bait stations or boxes are usually preferred for reasons of efficacy and safety.

Acute (single-dose) rodenticides Owing largely to their high level of toxicity to mammals, the traditional acute rodenticides have been largely replaced by safer alternatives. Poisons that have been used as acute rodenticides include: sodium fluoroacetate (1080), thallium sulphate, zinc phoshide, arsenic trioxide, strychnine, red squill and antu.

Such materials are currently unlikely to be registered so any intended use would require special application for a permit to do so.

Using multiple-dose anticoagulant rodenticides

Much of the rodent control work in Australia probably involves the use of multiple-dose anticoagulant rodenticides. The effects of these materials are cumulative, requiring rodents to feed on the bait for several consecutive days until the concentration of anticoagulant in the blood is sufficient to cause death. As this may take 4–10 days, the safety implications are favourable.

Figure 14.9 Square bait dish for rat and mouse baits

Mode of action Anticoagulant rodenticides reduce the ability of the blood to clot, leading eventually to death, due mainly to internal haemorrhage. In order to understand their mode of action, the normal course of events leading to blood-clotting should be examined (see Figure 14.10). Injured tissue liberates an enzyme called thrombokinase, which facilitates the reaction changing prothrombin (a blood protein) into thrombin (an enzyme). The enzyme thrombin then allows fibrinogen (a normally soluble blood protein) to change into fibrin, which is an insoluble mass of thread-like structures that is clotted blood. This system, when untampered with, ensures that the animal's body is protected against excessive loss of blood.

Prothrombin, formed in the liver by the action of an enzyme containing vitamin K1 in its structure, is a critical requirement for the blood-clotting process. A shortage of vitamin K1 would cause a shortage of prothrombin, which in turn would reduce clotting. Anticoagulant rodenticides are chemically similar, in structure, to vitamin K1. If the prothrombin-forming enzyme contains the anticoagulant instead of vitamin K1, prothrombin cannot form, and this leads to a loss in the clotting ability of the blood. Internal bodily damage that occurs normally and that would normally be checked by clotting becomes lethal. Interestingly, the reaction is reversible, so the effective antidote for anticoagulant poisoning is vitamin K1, administered by qualified medical personnel.

Types of formulations Anticoagulant rodenticides may be obtained in various forms:

1. *concentrates* — used in the preparation of food or liquid baits, or perhaps as a tracking powder;
2. *ready-to-use baits* — mostly in the form of treated whole grain or pellets, available in bulk or 'throw-pack' form; and
3. *paraffin blocks* — usually treated grain in a matrix of paraffin wax, suitable for situations with excessive moisture.

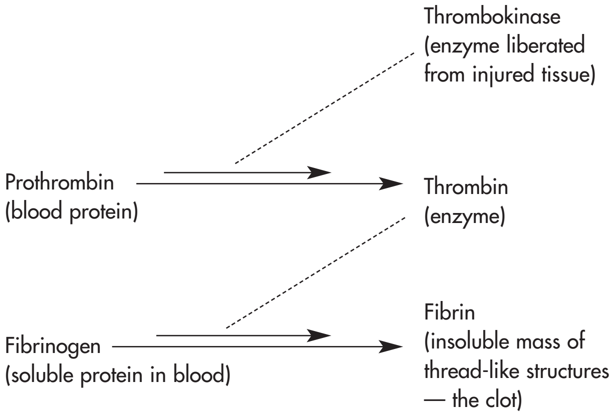


Figure 14.10 The process of blood clotting

Baiting Anticoagulant rodenticide baits, even though safer than single-dose poisons, should be placed so as to be inaccessible to pets, children and other non-target animals. Where 'throw-packs' (small amounts of treated grain prepackaged in plastic bags) are used, these should be placed unopened, allowing the rodents to penetrate them before feeding. Bait shyness does not usually develop, as the slowness of poisoning is not readily associated with bait intake. Daily inspections and topping up are advisable for the first 3 days, until feeding requirements are known. Where baits are in trays, smoothing the level of the bait will help to determine whether feeding is taking place. Baits should be removed when no longer required, as they may attract and facilitate the breeding of various beetles.

Some of the commercially available multiple-dose anticoagulant rodenticide products are outlined in Appendix VIII.

Using single-dose anticoagulant rodenticides

Research into anticoagulant rodenticides has led to the development of rodenticides that, while having the same mode of action as multiple-dose anticoagulants, give good control in small amounts and single feedings. A single lethal dose ingested by a rat will cause death in 3–7 days.

The toxicity hazard of these 'second generation' anticoagulants is more akin to that of traditional acute poisons; but because their mode of action is interference with prothrombin formation, they have an antidote — vitamin K1. Nevertheless, as these materials are toxic to warm-blooded animals other than rodents, great care must be exercised in bait preparation and setting. Provided that the safety record of these new anticoagulants stays as relatively clean as the record of multiple-dose anticoagulants has been to date, their future looks promising. Some of the commercially available single-dose anticoagulant rodenticide products are outlined in Appendix VIII.

Safety precautions in rodent control

- Always read rodenticide product labels prior to use and use in accordance with label information.
- When preparing or handling rodent baits, wear protective clothing and equipment (including respirator, to protect against inhalation of fine dusts or vapours, and gloves to protect against skin contact).
- Baits should be placed so as NOT to allow access to them by children, pets, wildlife, domestic animals and livestock. Specially designed bait containers may be required.
- All bait stations and containers should be clearly marked 'POISON'.
- All occupants of the building (eg employees, residents) should be notified about the placement of poisonous baits.
- Baits should be placed where they can always be retrieved.
- A record of bait placements should be kept to facilitate comprehensive checking and/or later removal.
- When handling dead (or near dead) rodents, wear gloves and consider using insect repellent to lessen risks of bites by ectoparasites (eg fleas).
- Do not place baits or tracking powders where their disturbance could cause contamination of food, or food preparation and handling surfaces.
- Always keep baits away from food.
- Inspect bait stations regularly and remove baits when rodent activity ceases.
- Destroy old rodenticide containers and untaken bait.
- Do not contaminate ponds, waterways or drains with rodenticides or their containers.
- If rodenticide contacts skin, or on completion of baiting, wash thoroughly with soap and water.
- Do not eat, drink or smoke while handling baits or tracking powders.
- Wash gloves and contaminated clothing before re-use.
- Do not give or sell rodenticides to clients.
- Store rodenticides in original containers, tightly closed and in a safe place.

FURTHER READING

Bennett G.W., Owens J.M. and Corrigan R.M. 1997 *Trumans Scientific Guide to Pest Control Operations* Purdue University/Advanstar Communications USA

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CHAPTER 15

BIRDS

Birds are useful animals, but sometimes, because of the activities of humans, they become pests in various situations. Seldom are the services of pest control companies drawn upon to control bird pests in orchards, cereal crops or, in fact, most agricultural situations. However, pest control companies are often required to carry out some form of prevention or control in domestic situations, manufacturing and food storage industries and town and city areas where the density of the human population is high.

BIRD PROBLEMS

This is an extremely sensitive area of pest control for seldom is there entire agreement, even where there is a small human population. Before any control measures are applied the possible human reaction should be determined.

Some of the more frequently encountered bird pest problems are listed below:

1. Birds may roost or nest in buildings, often gaining access through broken tiles and damaged ridge capping. This is usually a seasonal occurrence when birds are about to lay eggs. Pigeons, starlings and Indian myna birds are frequent offenders.
2. Bird droppings may deface buildings and footpaths and often modify food-handling procedures. Wheat and other grain storage facilities, particularly around harbour and railway terminals, frequently have a major bird and food contamination problem. Pigeons are the main offenders in these situations.
3. Some birds nest in situations such as guttering and downpiping which then causes water overflow and moisture problems in walls. Their faeces also reduces the normal flow of water in guttering, causing corrosion in some types of metal guttering. The main offenders here are starlings and pigeons.
4. Birds are hosts for bird lice and bird mites, and the latter become occasional pests of humans when birds nest in buildings. Sparrows, starlings, Indian mynas and pigeons are offenders in this area. The infestations inside houses and buildings such as hospitals and nursing homes can be very difficult to control. Mostly this type of infestation occurs after the young have left the nest and these external parasites also leave in search of food.
5. Birds become pests on aerodromes because of the large areas, sometimes partially grassed. They are a problem to propeller-driven aircraft, but a great hazard to jet aircraft, where they can be sucked into the jet engines on take-off and landing. The main offenders here are the silver gulls.
6. Histoplasmosis, cryptococcosis and aspergillosis are fungus diseases in bird droppings and the spores from these become airborne and inhaled by those nearby. These diseases produce symptoms in humans similar to influenza but can develop into more serious illnesses in susceptible people or those with reduced immunity. Pigeons, because of their roosting habits, are the main offenders.
7. A food-poisoning bacterium (*Salmonella*) can be contracted by humans from bird droppings. Several birds can be offenders in this regard.
8. One problem causing community concern is the displacement of native bird species by more aggressive species, either other natives, such as the Noisy miner or by introduced species, such as the Indian myna.

Common pest species

Table 15.1 lists some common bird pests, together with data on their characteristics and behaviour patterns.

Prevention and control

Birds frequently become pests, and control measures must be taken to relieve the many pest problems created by their presence. Preventive measures are preferred to killing, for it should be realised that in most instances where birds have become pests it is due to situations and environments created by human beings. Killing birds is not only an unpopular measure but often it is also unnecessary, as other measures sometimes exist. Pest control companies should handle bird control problems cautiously, for control techniques may be wrongly interpreted by sections of the population and lead to very adverse publicity for the company. Protected bird species occasionally become pests, but these problems may be resolved by seeking a licence under a state fauna-protection act to control the birds.

Methods of reducing bird problems are listed below, but each case must be considered on its merits.

Deterrent methods

1 If buildings were well designed, providing no suitable ledges for roosting, bird problems would be minimal in city areas. When old buildings have chronic bird problems, fine wire may be placed vertically over openings or monuments, thus causing birds to become frightened when they fly into it. Holes in roof areas, walls and other structures may be sealed using a fine wire mesh. Excluding birds is more satisfactory than killing or trapping thus causing them to seek other more acceptable environments.

There are nets which do not affect the natural lighting and are effective in preventing birds from alighting on window sills, and which have particular value in protecting factories, courtyards and fire escapes.

There are physical deterrents such as strips of perspex with sharp, pointed upright pieces along its length. The strips are glued to ledges, walls and window sills where pigeons land and roost. The strips are positioned so that pigeons are deterred from landing on their favoured spots. The structures are durable and will remain in place and effective for many years.

One product that has proved successful consists of fine stainless steel rods that can be applied to irregular surfaces. Stainless steel coils can also be attached to ledges to deter birds from landing.

2 The aircraft problem is reduced by draining aerodrome areas and adjacent land and also ensuring that food is not available. The location of airports is critical for they must

TABLE 15.1
Pest species of birds

Bird	Origin	Colour	Size	Nesting habits	No. of eggs	General comments
European starling *Sturnus vulgaris*	Introduced	Dark brown to black with a greenish sheen.	200 mm	Nests in roof cavities.	6 pale blue eggs, twice a year.	Suburban or town pests; sometimes flocks are large and feed on grains; insects are also eaten.
Indian myna *Acridotheres tristis*	Introduced	Brown and white; dark green neck area; yellow beak and legs.	250 mm	Nests in roof cavities, palm trees and sheltered areas.	4–5 glossy, pale blue eggs in spring and summer.	Numbers increasing in city areas; feed on insects but on food scraps also.
Pigeon *Columba livia*	Introduced	Various tones of grey with darker bars.	300–350 mm	Nests of twigs in warehouses, ceilings and on roofing girders etc.	1–2 eggs in each clutch several times a year.	Now domesticated; eats food scraps in cities and towns; occurs in grain terminals; defaces buildings etc.
English sparrow *Passer domesticus*	Introduced	Male — grey and brown; light bar on wings; dark throat. Female — darker underneath; no dark throat.	110–120 mm	Nests of grass and fibre; in ceilings under eaves; wherever there is shelter.	5–6 speckled eggs, three to four times a year.	Pests in orchards, gardens etc.; bird lice and mite problems; eats insects (useful in this regard).
Spotted turtle dove *Streptopelia chinensis*	Introduced	Grey head; black and grey-spotted neck; brownish back and wings.	300–320 mm	Frail structures built in small trees and shrubs.	2 white eggs, twice in each year in summer.	Not a serious pest but may destroy seeds and beds of plants.
Silver gull (seagull) *Larus novaehollandiae*	Native	White, with grey on the wings; red legs.	300–350 mm	Shallow holes in the ground lined with grass.	3–4 eggs with brown markings.	Generally a useful scavenger, but occurs on aerodromes when garbage disposal is nearby; often comes in from the sea in wet weather.

not be near major food-handling facilities and garbage disposal areas. Removal of seeding grasses and plants also assists in reducing the problem.

Pest species of birds have different food requirements and nesting habits, and these aspects must be taken into account when modifying the environment for control.

3 Repellent gels which are placed on favoured roosting sites such as window sills, ledges and internal structural beams have been used for many years. This method of control merely drives birds from one situation to another. The gel remains soft, causing the birds to have an insecure sensation underfoot, which eventually leads to their flight. These gels have the disadvantage of catching airborne dust and debris and finally must be removed. They are applied with a caulking gun, usually in 5 mm strips and 10 cm between strips.

4 When fruit trees and other food-bearing plants are infested, fine nylon threads placed over them cause birds to become entangled, giving warning distress calls to other birds which then avoid the area.

5 Sound used at roosting time may be used with success, but birds do become accustomed to explosions from guns and fireworks. Ultrasonic sound has been used with only limited success.

6 Fluttering and coloured plastic, flashing lights and mirrors have only limited value for a brief period.

The use of cardboard or plastic copies of large predatory birds have proved very useful, although they must not be left in one site for long periods, but only exposed for short and critical periods of the birds' roosting and feeding activities. Birds soon accept these if they are not regularly moved.

Trapping

Birds may be trapped in cages, but this is very time-consuming, for the traps must be attended daily to replace food. Traps have very limited value, for the birds must be destroyed when trapped. This is an unpleasant task, and it must be done discreetly to avoid public criticism. Trapping is most effective for controlling pigeons and sparrows and is usually done when there is a specific bird to catch and return to its home, such as a racing pigeon.

Poisoning

Before any poisoning is contemplated the relevant state authority must be contacted and the bird species and the proposed poison discussed, for the laws differ in the various states. Poisoning should be used only when other methods fail. Even though most pest birds are introduced, public feeling is aroused when birds are killed and found on streets and parks.

The food to receive the poison must be chosen carefully and must suit the species of bird. Pigeons like wheat and cracked corn; sparrows like small grains such as millets; starlings also like small grains, but bread, cake and similar foods are taken readily. Prebaiting for 3–4 days, using the same sort of food to be used for the bait, increases the chance of success. A break of a week or so between using poisons is desirable. Dead birds should be collected and disposed of soon after death. Secondary poisoning results from animals such as cats and dogs eating poisoned birds that are not dead, for animals like to kill their own birds.

Alpha chloralose is prepared in food appropriate for the bird species. Having eaten it, the birds go to sleep, and often fall. Unconscious birds should then be gassed with carbon dioxide. Treatment with alpha chloralose is recommended by the NSW National Parks and Wildlife Service; it should be used in preference to other chemicals such as 4-aminopyridine, which can cause birds to behave irrationally (eg fly en masse into traffic, buildings, water, etc) which in turn can provoke strong reactions from the public.

Distress poisons (eg 4-aminopyridine) prepared in grain baits (0.5% poison) have been used successfully in a variety of situations. The material 4-aminopyridine ('Skat-a-bird'), if taken well, is likely to kill a number of birds; but if the poisoned grain is diluted 20–30 times with more grain, mortality is reduced considerably. Affected birds set up distress cries and behave strangely, causing the remainder to avoid the area. Distress poisons are useful against sparrows and starlings (although starlings prefer bread to grain as a food medium). They must be taken by a large percentage of any pigeon population to be of any real value. Distress baits should be put where other animals have no access. Birds affected by distress poisons and eaten by animals such as cats do not cause secondary poisoning.

Aluminium sulphate, recommended only for golf greens, adheres to feathers. During grooming, it causes irritation and restlessness, so that the birds avoid the area. It also deters birds by giving their food a bad taste.

Shooting

This is sometimes of value to prevent birds from roosting in certain areas. It is seldom used by pest control operators because of the possible danger to property and person and legal restrictions pertaining to the use of firearms. Disapproval of this method is widespread and it is seldom an option for areas in towns and cities.

FURTHER READING

Bennett G.W., Owens J.M. and Corrigan R.M. 1997 *Trumans Scientific Guide to Pest Control Operations* Purdue University/Advanstar Communications USA

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MISCELLANEOUS PESTS

There are many pests which occur both inside and on the outside of buildings. The recognition of these and the damage which they cause is often part of pre-purchase and annual inspections. Many of these pest situations do not require treatment and an evaluation of the cause and its present position should be conveyed to the client. Some of the more frequently encountered problems are given below.

HONEY BEE

Apis mellifera, Family Apidae, Order Hymenoptera

Honey bees often leave commercial hives and settle in and around houses. When established between walls they present special problems. If the services of an apiarist are available, the unpleasant task of killing the hive can be avoided, but usually such a problem must be dealt with urgently.

A method sometimes adopted where insecticides are not acceptable involves fastening a cone of cardboard over the entrance into the wall, with the broad end against the wall over the problem area, and the small end (about 6–10 mm across) outwards. The bees can leave and resettle elsewhere, but they cannot re-enter the small aperture of the cone, so gradually the hive dies out. If the hive has not been established for any length of time, the entire hive may leave.

Where necessary, the hive must be killed, particularly when allergic people are likely to be stung. Some people may die from one bee sting, and if they know this they usually carry medication on them in case they are stung. Dichlorvos is an insecticide often used for the control of bees (pesticide regulatory authorities may require a permit if this use is not indicated on the product label). Holes may be drilled into the wall and the insecticide forced in using a cylinder of carbon dioxide and dichlorvos. This treatment is very effective, particularly if done at night, when most bees are in the hive. When control is necessary in the daytime, the pest controller must be experienced in handling bees and have all the protective clothing.

It is important that the bee is identified correctly, as the native honey bees (*Trigona* spp.) may be involved in a situation where killing of the hive is requested and is not necessary, for the native honey bee does not sting. The native bee also nests in trees and in hollow log sections of large stumps. It is a much smaller bee and of a different colour.

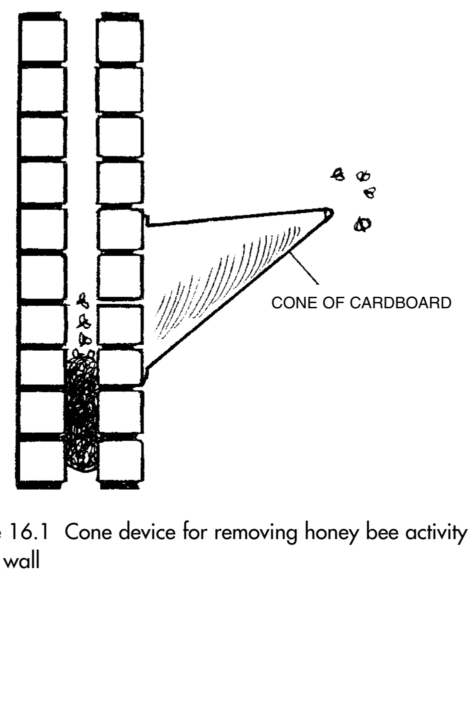

Figure 16.1 Cone device for removing honey bee activity from a cavity wall

WASPS

Order Hymenoptera

Papernest wasps

Family Vespidae

Wasps, particularly the papernest wasps (*Polistes* spp. and *Ropalidia* spp.) are day-flying insects. They can be caught and destroyed more easily and safely at night, when they have congregated on the paper or mud-nest. The paper-nest and wasps may be removed by enclosing the wasps and nest in sound plastic sheeting or a bag at night, severing the nest's contact with the surface, and sealing the bag for disposal or release elsewhere.

There are some people who are allergic to, and may die from, wasp stings.

European wasp

Vespula germanica, Family Vespidae

The European wasp is now established in New South Wales, Victoria and Tasmania and will in time occur throughout much of Australia. The English wasp (*Vespula vulgaris*) has been known in Victoria for some time and has similar habits to the European wasp. Separation of these two species is normally beyond the ability of pest controllers.

Appearance The workers of both species are sterile females about 12–15 mm long, with yellow bands on a black body. They are fast fliers, with clear wings that fold longitudinally over their bodies. Queens and males measure about 20 mm, the queen having a stout abdomen and the male a long thin abdomen. The nest varies in size from about 15 cm to about 5 m and may contain up to 4 million cells and over 100,000 workers. The wasps nest mostly in the ground, tree stumps, rockeries, wall cavities and roof voids.

Life cycle Each nest usually lasts 1 year, but in warmer climates the nest may survive and extend. In winter the males die off, and the newly fertilised queens hibernate to build other nests the following year. The new queen lays eggs in the cells of the nest, and after some weeks in the larval stage the wasps pupate and emerge as adults, which take over the work of the nest. After one summer the nest may have 10,000 individuals.

Pest status The European wasp may sting several times when disturbed or agitated, and the sting is very painful. In New Zealand, where the European wasp also occurs, it attacks weak hives of the honey bee, causing losses in honey production. However, to date there is no evidence of similar losses of honey in Australia. This wasp is predatory on other insects and their larvae and has some value in this regard.

Control Pest controllers who locate wasps and suspect that they are European wasps should have them identified, usually at the local department of agriculture, and seek the department's guidance on treatment. In New South Wales efforts were made to eliminate this wasp, but these were unsuccessful and the wasp now occurs widely throughout New South Wales and some other states.

Appendix VI outlines some of the pesticides that are used in the control of European wasps at the time of writing (note: always check current product labels to ensure appropriate registration status for the intended purpose).

MORTAR BEES

Amegilla spp., Family Anthophoridae, Order Hymenoptera

These bees are mostly large and have coloured bands across the abdomen. They normally make their nests in banks of hard soil or sand and, when near the coast, in rock fissures. Brick houses and those with brick foundation walls and poor quality mortar may be damaged by the female mortar bees who often make their burrows deep into the mortar. Each female makes its own burrow, but it may be part of a complex of separate burrows in the mortar. The female lines the burrow with a wax-like material and this gives some protection to the young which are reared in the burrow.

Insecticidal control is of little permanent value and must be repeated at least annually. The most satisfactory treatment is the replacement of the mortar with a high quality one which the bees cannot excavate.

THRIPS

Order Thysanoptera

Thrips are small soft-bodied insects that appear pointed at both ends. They are pests of plants, and during spring and summer they are attracted to damp washing on clothes lines, particularly babies' napkins. They cause irritation to babies when napkins containing the tiny thrips are used and a rash often results, probably because of their pointed abdomens.

Clothing with thrips embedded in it should be vacuumed or the insects cleaned from it before being worn. During periods of high hazard, clothes driers may be used to avoid this problem, but the insects must still be removed from the clothing.

CATERPILLARS WITH URITICATING HAIRS

Order Lepidoptera

Many hairy caterpillars (larvae of some moths) produce a rash on the softer-skinned areas of the body. These hairs enter the skin, causing irritation, which, if rubbed, becomes intense, often requiring medical treatment. The whitestemmed gum moth, white cedar moth, mistletoe browntail moth, gumleaf skeletoniser moth and cup moths all have larvae that can cause intense irritation.

The larvae (caterpillars) of the mistletoe browntail moth (*Euproctis edwardsii*) feed on mistletoe on trees and are very hairy. If they are handled, or when they pupate and thus shed many hairs into the atmosphere, intense irritation is caused, perhaps without the insect being visible. A school in New South Wales was closed for some days due to the hairs of the pupating caterpillars becoming airborne and affecting many pupils in the playground area.

Control is achieved by detecting the larvae early and then 'injecting' the tree with an appropriate insecticide or physically removing the mistletoe.

EARWIGS

Order Dermaptera

These insects are ground-dwelling, brown to dark brown, and have forceps-like structures on the end of their abdomen. The 'forceps' are merely organs for holding prey and would not normally penetrate human skin. They feed during the night on decaying vegetable matter, but some species feed on plants and cause economic losses.These insects may be encountered under timber stored in subfloor areas.

MOLE CRICKETS

Family Gryllotalpidae, Order Orthoptera

These are ground–dwelling insects having obvious wings and forelegs modified for digging (fossorial). They feed on grass roots and burrow in the ground. Occasionally they enter houses.

Control is seldom required in urban areas; but if it is necessary, an approved organophosphorus or carbamate insecticide should be effective. These insects are sometimes located in subfloor areas during inspections.

AFRICAN BLACK BEETLE

Heteronychus arator, Family Scarabaeidae, Order Coleoptera

The larvae of this beetle are known as curl grubs or, in other countries, cockchafers. They live in the soil, feeding on grass and other plant roots. The larvae are typical curl grubs, having a pale fore area and dark grey abdomen. They can cause great damage to lawns, grassed fairways and golf greens. Like other scarab beetles, they pupate in the soil and emerge as beetles, which are usually foliage feeders. The larvae resemble those of stag beetles, one of which attacks decaying timber, namely *Syndesus cornutus.*

Control by insecticides involves some of the organophosphorus and carbamate insecticides, but pest controllers are seldom required to treat these insects. Their identification is important and advice on control may then be given.

MOTH FLIES

Family Psychodidae, Order Diptera

These are small flies with hairy wings that are held roofwise. They are encountered in houses and buildings, mostly in moist areas such as bathrooms and laundries. The larvae feed in bacterial slime and organic matter on the inside of discharge pipes — on the 'freeboard' part — from kitchens and bathrooms where greases and waxes are discharged, some of which adhere to the inner surface of the pipes.

Moth flies are short-lived and easily controlled as adults by the use of space-sprays from aerosol cans, or from commercial carbon-dioxide-dispensing equipment. Cleaning out built-up organic material may assist in controlling breeding and aerosols (non-residual pyrethrins or dichlorvos) applied to the mouth of infested discharge pipes, particularly in the shower recess, may prevent the flies from appearing for some days at least.

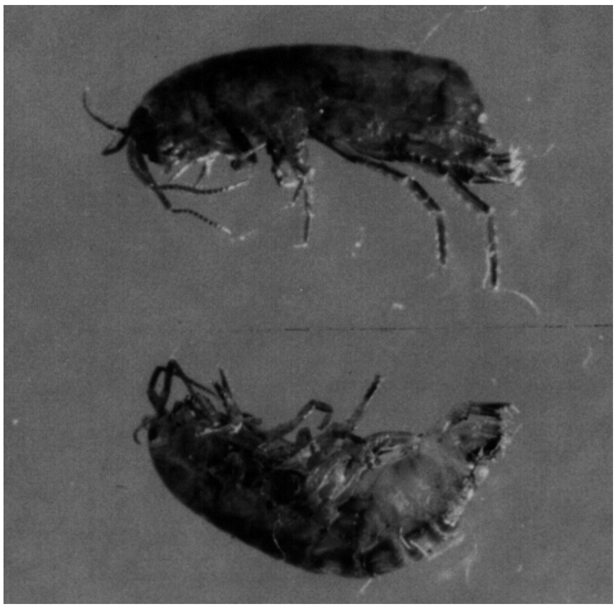

Figure 16.2 Amphipods (*Talitrus* sp.) — Order Amphipoda

AMPHIPODS (LAND HOPPERS)

Talitrus spp., Order Amphipoda

These amphipods are small prawn-like creatures about 5–10 mm long. They occur in moist areas of the garden, often among decaying vegetable matter. They are brought inside during wet weather on footwear and between the pads of dogs' and cats' feet. They are translucent when alive, but turn pink when dead, so that they look like miniature 'prawns'.

Control is seldom required, and indoors the use of the vacuum cleaner is usually sufficient. Control outside, if required, can be achieved by an appropriate organophosphorus, pyrethroid or carbamate insecticide. They are useful creatures.

LICHENS

Lichens are symbiotic associations of fungi and algae. They appear as flat green growths about 25–50 mm in diameter, often on the surface of tiles and tree bark. They mostly grow on the absorbent sections of roof tiles that have been imperfectly glazed. The fungus is dependent on the alga and vice versa. If either is killed, the other dies also.

There are several materials and combinations of materials suitable for killing lichens. Copper sulphate kills the alga, and many fungicides kill the fungus. The entire lichen growth flakes off some months later. There are commercial operators and techniques for removing lichens from roof tiles and certain types of walls.

POSSUMS

Possums are mostly rabbit-sized arboreal marsupials. Two species of possums are encountered by pest controllers as occasional intruders in buildings:

Common ringtail possum (*Pseudocheirus peregrinus*) This possum is mostly grey to black with red/brown tinges, white to red/brown below with pale patches below the eyes and ears and it has a long white-tipped prehensile tail. It is often observed in suburban gardens and occurs on mainland Australia (east coast from Northern Queensland, through NSW, Victoria and around to the south-east of South Australia and at the south-west of Western Australia) and Tasmania.

Common brushtail possum (*Trichosurus vulpecula*) This possum varies in colouring from silver-grey to black and off-white to red/brown below. The tail is bushy with a naked area below the tip. There are dark patches on the muzzle and white patches below the large pointed ears. It is very common in wooded areas and suburbs and occurs in much of Queensland, NSW, Victoria, the south-east of South Australia, the south-west of Western Australia and in parts of central Australia.

Possums naturally live in cavities of trees. They shelter there during the day and emerge to feed and explore at night. Possums enter roof voids when their natural nesting sites have been removed, mainly through broken tiles, damaged eaves and displaced ridge capping. When in the roof they make noises at night, urinate and defecate on ceiling plaster, causing stains and odours. Chimneys are also favoured sheltering places.

Possums are protected animals and must not be killed with intent. Trapping followed by release in bushland is acceptable. Cages are available for hire, but it is essential to empty these the next morning; if there is delay, the trapped possum must be provided with water and food. State laws differ in minor respects; and when pest controllers are trapping possums commercially, they should be licensed or have a permit for doing this type of pest control. The relevant state department should be consulted on its requirements. The favoured foods for trapping are fruit (apple, pear, banana), bread and honey, cake and honeycomb pieces, preferably with chocolate coating. If one food fails, another should be tried. All phases of possum-trapping, holding and release must be done humanely. Once it has been positively established that there are no longer possums in the roof, the entry points may be sealed, but not before.

All noises in roof voids should be investigated and not assumed to be possums, since roof rats also create noise. Faeces, footprints and odours are characteristic of these two animals, and are easily identified by an experienced operator. Also, the time of year can give a lead to the cause, for roof rats enter roof voids when the weather commences to cool in mid to late autumn.

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INTRODUCTION TO TIMBER & TIMBER PESTS

Unless pest controllers have a knowledge of the structure of trees and wood, their survey of buildings is made more difficult, as the various insects that destroy wood have distinct dietary requirements. By simply knowing that a wood is a pine or a hardwood the identification of damage is made easier. Pest controllers are expected to be able to identify the damage caused by most, if not all, timber insects. Incorrect identification may involve unnecessary treatment and this would expose a company to charges of misrepresentation. Instances of pinhole borer attack being identified as powderpost beetle or furniture beetle attack have often occurred, and treatments have been carried out.

CLASSIFICATION OF TREES

As Figure 17.3 shows, trees belong to both of the divisions of seed-bearing plants. The gymnosperms include the softwoods (conifers), and the angiosperms include the hardwoods.

Pest controllers are not expected to be able to identify the many different timber species in use today, but they should be able to separate pines from hardwoods and have a working knowledge of the characteristics of such timber species as white Cypress pine, Douglas fir, the various pacific maples as a group, and radiata pine. Table 17.1 lists some common timber species and their uses.

A superficial knowledge of the more frequently encountered timbers will supplement training in other areas of pest control. For instance, pest controllers should know that powderpost beetles do not attack pines and that furniture beetles do not often attack Australian hardwoods, preferring pines, except white Cypress pine.

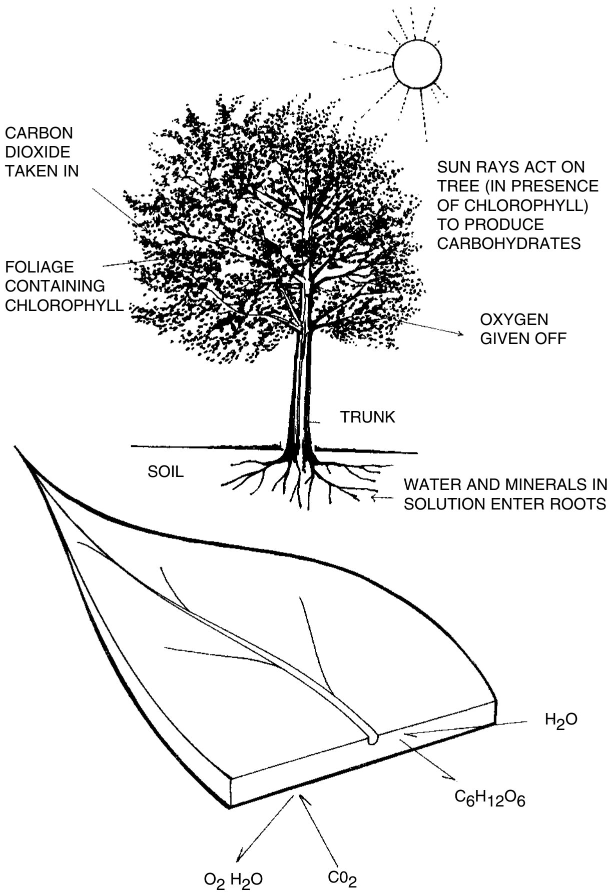
PARTS OF A TREE

A tree can be divided into three parts: the leaves, the trunk and branches, and the roots.

Leaves

The leaves of a tree are responsible for manufacturing food for the whole plant. The pigment in the leaves that gives them their green colour is called chlorophyll, and this is where photosynthesis takes place. Photosynthesis is the process whereby carbon dioxide (CO_2) from the atmosphere and water (H_2O) from the soil are transformed, using energy from the sunlight, into sucrose (a sugar, $C_6H_{12}O_6$) and oxygen (O_2). The sugar provides food for the tree, and oxygen is returned to the atmosphere. There are minute pores (stomates) on the underside of the leaf, through which most of the gases and water vapour pass in and out.

The leaves are capable of making more sugar than is needed for the immediate use of the tree, and this excess is turned into starch for storage. Starch is stored in various parts of the tree but can only be moved from one place to another as sugar. Thus, sugar may be made into starch in the leaf, then converted back to sugar and passed down to the roots, where it may again be converted to starch for storage until required. The sapwood is the area where most starch is stored in trees, for this is the living and conductive tissue.



PHOTOSYNTHESIS IN THE CHLOROPHYLL

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

CARBON DIOXIDE FROM ATMOSPHERE + WATER FROM SOIL VIA ROOTS → SUGAR FOOD FOR THE TREE + OXYGEN & WATER TO ATMOSPHERE

Figure 17.1 Photosynthesis in plants

The unique ability of green leaves to make food for the plant from raw materials using sunlight must be remembered when pruning is done. For instance, if a tree with very little stored starch has most of its leaves removed, it cannot survive long enough to grow new leaves, and the plant will die from 'starvation', although it may have an abundant supply of water and minerals in the soil.

Trunk and branches

Most of the trunk of a large tree is a core of dead, non-functioning wood. This central section is surrounded by a narrower band of live wood, which is in turn protected by the bark. It is this living area, in particular a narrow band of cells just beneath the bark, that is so important to the life and vigour of the tree.

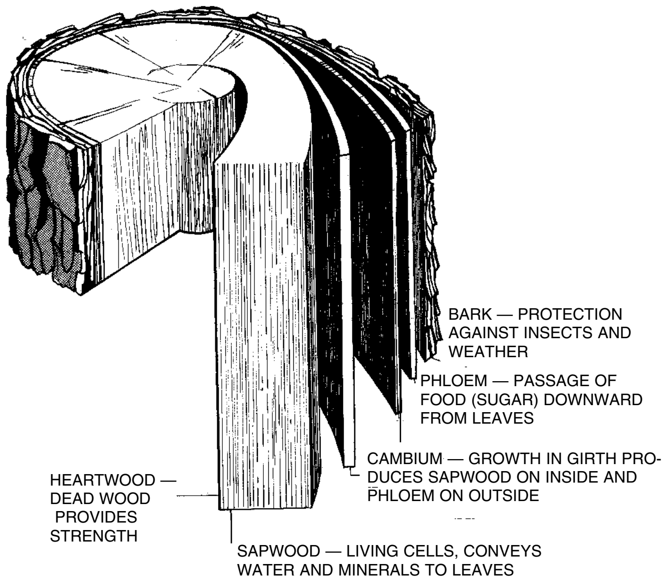


Figure 17.2 The regions of a tree

TABLE 17.1
Timber species and their uses

Timber species	F	S	J	W	P
Blackbutt	√	√		√	
Alpine ash	√	√	√		√
Mountain ash	√	√	√		√
Messmate stringybark	√	√			
Spotted gum	√	√		√	
Sydney blue gum	√	√		√	
Tallowwood	√		√	√	
River red gum	√	√		√	
Red mahogany	√			√	
Red ironbark		√			
Blackwood			√		√
Brush box	√	√		√	
Coachwood			√		√
Meranti			√		√
Queensland maple			√		√
Red cedar			√		√
White birch			√		√
Balsam fir		√			
Western hemlock		√			
Baltic pine	√	√	√	√	
White Cypress pine	√			√	
Western cedar				√	
Hoop pine			√		√
Kauri		√		√	
Oregon		√	√		
Radiata pine	√		√	√	
Redwood				√	

Key: F— Flooring; S — Scantlings; J — Joinery; W — Weatherboards; P — Plywood

The more obvious sections of a trunk or large branch can often be seen when looking at a cut stump or the end of a sawn log. The centre wood is usually darker than the rest. This is the heartwood — the dead wood that helps strengthen the trunk. Surrounding this is paler wood — the sapwood, consisting of living tissue that conducts water and minerals from the roots to the leaves. On the outer edge of the sapwood is a very narrow band of cells that cannot be seen with the naked eye; this is the all-important cambium, where growth in the girth of the trunk takes place. Beyond this is another narrow region — the phloem, where sugars from the leaves are passed downwards to the roots. Outside the phloem is the bark — the protective layers of the tree.

Pines and hardwood

The conductive cells in pines are elongate and needle-like, vary in length from 3 to 15 mm, and are known as tracheids. The walls of these cells may be modified by thickening of cellulose from within the cell. Certain areas of these cells, the pits, are not thickened, and conduction of water and minerals occurs through these from cell to cell.

When viewed with a xl0 hand lens, these tracheids appear close together, evenly distributed, and in zones of dark and light colour. The pale zone consists of thin-walled cells (early wood) and the darker zone of thick-walled cells (late wood). One dark zone and one light zone usually represent a growth ring.

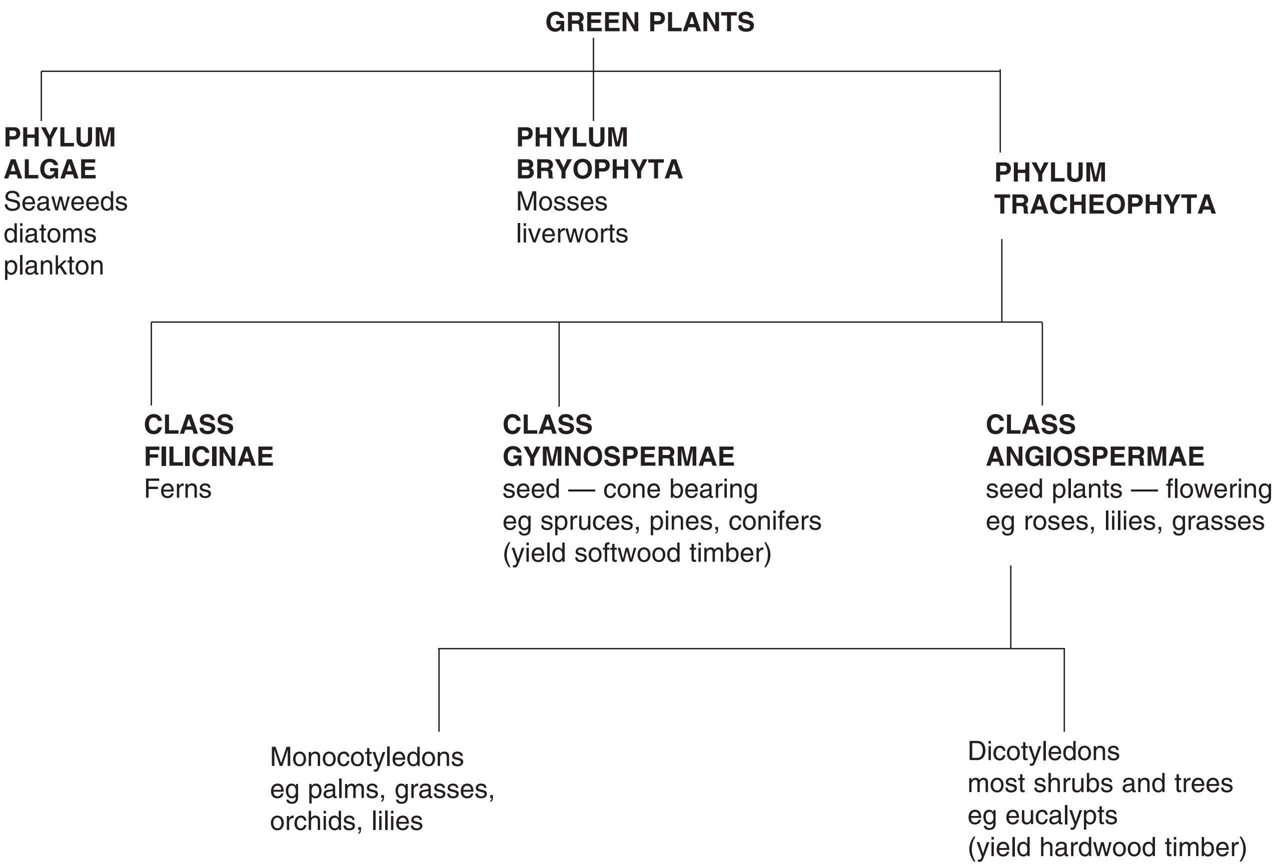
Wood parenchyma cells are split off from the cambium and are referred to as ray cells, which are associated with food storage. It is this stored food that often determines the susceptibility of a timber species to a particular insect pest. Resin, a gummy aromatic material associated with resistance to insect attack, is produced in the parenchymatous tissue.

Hardwoods have a small fibre length, and in the production of paper the pulp from hardwoods is inferior to that from softwoods. The strengthening tissue of hardwoods consists of fibres with pointed ends and few pits. The storage tissue is abundant, being mainly parenchyma cells and rays. The conducting region for water and mineral salts in hardwoods is the sapwood, which contains vessels or pores (open-ended pipes or tubes) arranged in a characteristic pattern. The many patterns of vessels, fibres, parenchyma and ray cells assist in the identification of the timber, even to the species.

To determine whether a wood is a pine or a hardwood, cut an end section with a sharp razor-blade or knife and examine the freshly cut surface for tracheids or vessels. It is best to learn on a known timber species and compare it with a pine and a hardwood (see figures on page 208).

The trunk increases in girth when new cells are produced

Figure 17.3 The classification of plants



by the cambium. These cells become sapwood, so that, as the tree grows, more and more sapwood is added to the outer edge of the sapwood zone. The sapwood of softwoods (conifers) and hardwoods differs in its structural components but carries out the same function: to pass water and minerals up the tree from the soil via the roots to the leaves. As new sapwood is formed on the outside, the sapwood towards the centre of the trunk ceases to function and becomes impregnated with oils, gums, resins and other complex organic compounds, which usually give it a darker colour. This wood then becomes heartwood. Although the heartwood is more durable than the sapwood, it can be attacked by insects and fungi, sometimes to the extent that the tree becomes a 'pipe' of living sapwood with a rotten hollowed-out centre. The tree remains alive because the sapwood is still intact and is continually being replaced by the cambium, and because the pipe-like structure of the trunk provides sufficient support for the tree.

The phloem forms the inner part of what is loosely called bark. In this region sugars are moved from the leaves downwards to the roots. The sugars may also move inwards to the sapwood in vessels called rays. In the sapwood they are then transformed into starch. In temperate climates during the winter, growth in the tree ceases or proceeds very slowly. In spring, the starch in the roots and sapwood is reconverted to sugar and moved outwards to the cambium, where new cells are formed as the tree starts to grow again.

Roots

Because the roots cannot be seen, their importance is often disregarded. They have two major functions: to obtain water and mineral salts from the soil; and to anchor the tree. The roots of trees are of little significance to pest controllers, who are concerned with the insects that attack timber in service.

Growth of a tree

At the tip of each branch is an area called a bud, where growth in length of the branch takes place. Other buds (axillary buds) occur at the base of each leaf, and from these areas flowers or branches may be produced. Increase in the height of a tree occurs at the extremity of its main trunk. The elongation of roots also occurs by the production of new cells at the tip of each root.

MOISTURE CONTENT OF TIMBER

The moisture content of timber is not only important in seasoning or drying, but is very significant in the later life of timber in respect of wood borers, termites and especially decay.

When a tree is felled and the log taken to the mill yard for conversion to sawn timber the moisture content of the freshly felled log varies between 50% for some dense hardwoods and 400% for a lightweight wood such as balsa. The water contained in wood is termed 'moisture content' and is the weight of the water in it compared to the weight of the wood. Wood is never devoid of moisture unless the wood has been kept at a temperature just above 100°C to remove all the moisture from it.

The sawn timber obtained from the green log gradually loses its moisture. Some dense hardwoods have a moisture content of about 50% while pines (softwoods) may contain about 200%.

The process of drying is known as seasoning and there are two main methods of obtaining seasoned wood. Firstly, the slower method is air drying. This involves the sawn timber being stacked in a special manner and allowed to lose most of its moisture over a period of 3–12 months depending on the timber species and weather conditions. The second method uses controlled heat and humidity in structures known as kilns. The latter method reduces the time taken to dry the wood to 10–20 days depending on timber species and sizes. The timber is then ready to be used in buildings and furniture soon after conversion from the green log form.

There are two main stages in seasoning, and these occur in both methods, whether the timber is air dried or kiln dried. The first stage involves the removal of the free water in the cells and the second is the loss of moisture from the cell walls or structural part of the timber. The stages are known as (1) fibre saturation point (FSP), and (2) equilibrium moisture content (EMC).

Fibre Saturation Point (FSP)

This is the stage in the drying of timber when the free moisture within the cells has been removed and the timber has reached a moisture content of about 30% (this figure varies from 22% to 32% depending on the timber species). The figure of 30% is merely an average figure for any individual piece of timber because the outer part has a lower moisture content than the inner core. There is a moisture gradient from the inner to outer areas of timber pieces so that moisture continues to pass from the wetter to drier areas.

Equilibrium Moisture Content (EMC)

When there is no further loss of moisture, in the case of air drying the core would have the same moisture content as that of the outer part of the piece of timber and the wood will have reached equilibrium moisture content; it is then regarded as seasoned timber. The moisture content of seasoned timber is approximately 12–15% in coastal areas, but will reduce to about 8% in inland areas. There are daily and seasonal variations in humidity and these are reflected in changes in the equilibrium moisture content — usually between 12% and 15% in coastal regions — but the actual moisture content also varies between different species of timber.

Shrinkage of timber occurs mainly between the fibre saturation point and the equilibrium moisture content, but once timber is at its equilibrium moisture content there is only small movement which is caused by changes in the humidity.

There are stresses which exist during seasoning when the inner layers of timber have a different moisture content to that of the outer case of a piece of timber.

Inspection of houses and buildings

The moisture of subfloor, roofing and internal timbers is normally within the range 8–15%, depending on locality. When the moisture content rises to 18%, and because metal corrosion can then occur, resulting in the corrosion of nails and fastening devices, such a moisture content should be further investigated to determine the cause.

When the moisture content rises beyond 20% and is continuing to increase there is concern that fungal decay may occur in the near future. If the moisture content reaches 28–30% fungal decay can be rapid once the air-borne spores have germinated on the timber.

The use of electronic moisture meters to detect the incipient stages of moisture increase is essential for annual and pre-purchase inspections, for much damage can be done within 12 months between annual inspections and after pre-purchase inspections.

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CHAPTER 18

BORERS

The wood of trees growing in the forest, although subject to attack by insects, is protected by bark and the tree's defensive systems.

These produce materials such as kino, resin, latex and other substances, which prevent insects from entering the wood and in many cases terminate the infestation. As soon as the tree is felled, the log is attractive to many insects of bark and wood and no longer can the tree produce its defensive materials, nor marshal them at the point of injury where they engulf young insects before they become established.

The only satisfactory and economic practice to reduce infestations in logs is to extract logs quickly after felling, transport them to the mill and saw them into the sizes required by the market. Rapid utilisation reduces the incidence of attack by moist-wood and bark-feeding insects such as greenwood longicorns, jewel beetles, ambrosia beetles, weevils and auger beetles (see Table 18.1). All these insects depend on a certain moisture content in the wood; and once this has been reduced by sawing to sizes, this particular hazard is eliminated.

Drying sawn timber in a kiln reduces the moisture content of timber quickly and also kills any insects present at the time of entry into the kiln. Once the timber emerges from the kiln, it is no longer susceptible to any of the pests of moist wood and bark.

Although pest controllers may regard the damage and sometimes the presence of the pests of moist timber as not in their field of activity, they should be aware of the appearance of the damage and its significance to householders. Sometimes damage made by insects such as ambrosia beetles may be confused with that made by pests of dry wood.

Table 18.1 lists the wood and tree borers that are relevant to pest controllers, according to the moistness or dryness of the wood they attack. These pests are considered individually in more detail below, and their characteristics and habits are summarised in Table 18.2.

Table 18.3 gives the susceptibility of common timbers to auger beetles, the powderpost beetle, the furniture beetle and the European house borer, and Figure 18.3 is a guide to identifying pests by the nature of their attack.

PESTS OF LIVING TREES AND FRESH LOGS

WOOD MOTHS

Economic significance

There are many species of wood moths that attack growing trees and are therefore forest pests. All these species are native to Australia. The larval stage is the destructive one, but their damage is seldom seen during inspections of buildings as the holes are usually large and detected during milling.

Biology and species

The native species of wood moth range in size in the larval stage up to 100 mm long. The giant wood moth is the species sometimes encountered at mills. These night-flying moths lay their eggs in damaged bark, and the larvae, which have 3 pairs of thoracic legs, mostly feed in the phloem–cambial region and enter the sapwood when fully grown to pupate. Some larger species live entirely in the sapwood and heartwood, leaving a covering of chewed wood and faeces bonded together with silk on the outside of the hole. The life cycle is variable in time, depending on the species, but is usually 1–2 years.

Treatment

Being a forest pest, the larvae do not continue to feed in sawn wood, and treatment is not required. However, pest controllers should be aware of the damage and correctly identity it. Tree surgery procedures are required where ornamental trees are affected.

WOODWASPS

Economic significance

Australia has no native species of woodwasp, and the species currently becoming established in the *Pinus* spp. plantations throughout the continent has been introduced from New Zealand. The sirex wasp (*Sirex noctilio*) is a forest pest and is of little relevance to pest controllers unless they are concerned with the fumigation of shipments of timber from other countries. Sirex damage may be encountered in pine timbers in buildings; but once the timber is dry, the insect dies or emerges.

Sirex noctilio was introduced into Tasmania some time before it was detected there during the 1950s. It was apparently introduced into Victoria in the late 1940s, but was not detected until 1960. It attacks *Pinus* spp. trees, often causing their death. Trees stressed by drought, poor site or other factors are more susceptible to attack than healthy vigorous trees. Hardwoods and native conifers are not attacked by the sirex wasp.

Biology and species

Many *Sirex* species have been intercepted in foreign timber at various shipping ports in Australia, but only *S. noctilio*, introduced in timber from New Zealand, is known to be established in Australia.

The adult female is a metallic blue, with a prominent ovipositor. The adult male also is metallic blue, with a deep orange abdomen. Adults vary greatly in size; but their length is about 25 mm. The larva may be identified by the sharp, hard, brown spine on the end of its abdomen.

The female wasp lays her eggs through the bark into the sapwood. Along with the eggs a fungus in a mucus is introduced, and this develops, blocking up the water-conducting tracheids and eventually killing the tree, for the foliage is no longer receiving water. The wood must be pre-conditioned by the fungus to support the sirex larvae, although larval damage on its own is not sufficient to kill the tree. When fully fed, the larvae pupate in the wood, and the wasps emerge through round holes measuring about 6 mm in diameter. The life cycle is mostly 1 year, although a 2-year life cycle occurs. Parthenogenesis may occur in this species.

Treatment

The sirex wasp is a forest pest, although its damage may be encountered by pest controllers when infested timber has been used in a house. In this situation no treatment is required as the wasps will have emerged and cannot infest sawn timber. When infested foreign timber enters a port, the Commonwealth Department of Health requires its fumigation or heat sterilisation in kilns.

TABLE 18.1
Wood and tree borers relevant to pest controllers

Pests of the living tree and freshly felled log (do not reinfest dry wood)	Pests of moist wood and partly dry wood	Pests of dry seasoned wood (reinfestation occurs)
Wood moths	Auger beetles	Powderpost beetles
Sirex wasp		Furniture beetle
Greenwood longicorns		Queensland pine beetle
Jewel beetles		European house borer
Weevils		Two-tooth longicorn
Ambrosia beetles		Dampwood borer
Bark beetles		

TABLE 18.2
Characteristics and habits of some wood borers

1. (Insect) 2. (Characteristics of larva) 3. (Host) 4. (Region of larval activity)

ORDER COLEOPTERA

Family Anobiidae

1. Furniture beetle *Anobium punctatum.*
2. 3 pairs of thoracic legs; no enlarged spiracle on 2nd last segment.
3. Conifers. Rarely hardwood.
4. Sapwood mainly.
1. Queensland pine beetle *Calymmaderus incisus.* Occurs in the warmer areas of eastern Australia taking the place of the furniture beetle.
1. Dampwood borer *Hadrobregmus australiensis.* Attacks many species of wood (hardwoods and pines) that are in a decayed condition and usually moist; pupal chambers usually stained black inside; beetles about 5–6 mm long.
1. Bark beetles eg *Ernobius mollis.*
2. 3 pairs of thoracic legs; somewhat curved body.
3. Conifers (*Pinus* spp. mainly).
4. Phloem/cambium. Sapwood.

Family Bostrichidae

1. Auger beetles.
2. 3 pairs of thoracic legs; curved body.
3. Hardwoods containing starch.
4. Sapwood only.
Example
1. *Mesoxylion collaris*:
Particoloured auger beetle; makes holes about 2.5–3 mm across.
1. *Xylion cylindricus*:
Cylindrical auger beetle; makes holes about 3–3.5 mm across.
1. *Bostrychopsis jesuita*:
Large auger beetle; makes holes about 5 mm across.
1. Powderpost beetles.
2. 3 pairs of thoracic legs; enlarged spiracle on abdomen.
3. Hardwoods only.
4. Sapwood only.
Example
1. *Lyctus brunneus* — powderpost beetle.
Lyctus discedens — small powderpost beetle.
Species probably native to Australia; can reinfest until sapwood is destroyed.

Family Buprestidae

1. Jewel beetles.
2. Legless; thorax flattened; cobra-headed.
3. Hardwoods mainly. Conifers.
4. Phloem/cambium. Sapwood.
Example
1. *Buprestis aurulenta* — oregon jewel beetle.
Introduced in douglas fir from the USA; does not reinfest; may emerge from timber up to 50 years after milling.
1. *Prospheres aurantiopictus* — hoop-pine jewel beetle. Native species that attacks *Araucaria* sp. (hoop pine) and may emerge many years later; does not reinfest.

Family Cerambycidae

1. European house borer.
2. Vestigial thoracic legs.
3. Conifers (*Pinus* spp. in Australia).
4. Sapwood mainly.

1. Two-tooth longicorn *Ambeodontus tristis.*
2. Legless.
3. New Zealand rimu.
4. Sapwood and heartwood.

1. Greenwood longicorn.
eg *Phoracantha recurva* yellow longicorn.
2. Legless; robust.
3. Hardwoods.
4. Phloem/cambium. Sapwood.

Family Curculionidae

1. Weevils.
2. Legless; head prominent.
3. Conifers. Hardwoods.
4. Sapwood mainly.
1. Ambrosia beetles or pinhole borers.
2. Legless; scroll on 1st thoracic segment.
3. Hardwoods. Conifers.
4. Sapwood and heartwood.
Example
1. *Platypus australis* — polyphagous pinhole borer.
Crossotarsus omnivorus — omnivorous pinhole borer.
Native species that cultivate a fungus on the inside of the holes and stain them.
1. Bark-beetles.
2. Legless; no scroll.
3. Hardwoods. Conifers.
4. Phloem/cambium. Sapwood only in some species.
Example
1. *Scolytus multistriatus* — elm bark beetle.
A true bark beetle; attacks living elms.
1. *Xyleborus perforans* — island pinhole borer.
Often encountered in island timbers from the Pacific; only in sapwood; does not usually stain holes.

ORDER HYMENOPTERA

Family Siricidae

1. Woodwasps.
Example
1. *Sirex noctilio.*
2. Almost legless; point on end of abdomen.
3. Conifers (*Pinus* spp. mainly).
4. Sapwood.

ORDER LEPIDOPTERA

Family Cossidae

1. Wood moths.
2. 3 pairs of thoracic legs.
3. Eucalypts, wattles.
4. Phloem/cambium. Sapwood and heartwood.

TABLE 18.3
Susceptibility of common timbers to insect attack[1]

Timber species		Powderpost beetle *Lyctus brunneus*	Auger beetles Family Bostrichidae	Furniture beetle *Anobium punctatum*	European house borer *Hylotrupes bajulus*
Common name	Scientific name				
Hardwoods					
Blackbutt	*Eucalyptus pilularis*	R	R	R	I
Alpine ash	*E. delegatensis*	R	R	R	I
Mountain ash	*E. regnans*	R	R	R	I
Messmate stringybark	*E. obliqua*	S	S	R	I
Spotted gum	*E. maculata*	S	S	R	I
Sydney blue gum	*E. saligna*	S	S	R	I
Tallowwood	*E. microcorys*	S	S	R	I
River red gum	*E. camaldulensis*	S	S	R	I
Red mahogany	*E. resinifera*	S	S	R	I
Red ironbark	*E. sideroxylon*	S	S	R	I
Blackwood	*Acacia melanoxylon*	S	S	R	I
Brush box	*Lophostemon confertus*	R	R	R	I
Coachwood	*Ceratopetalum apetalum*	R	R	R	I
Meranti	*Shorea* spp.	S	S	R	I
Queensland maple	*Flindersia brayleyana*	R	R	R	I
Red cedar	*Toona australis*	S	S	R	I
White birch	*Schizomeria ovata*	S	S	R	I
Softwoods					
Balsam fir	*Abies balsamea*	I	I	S	S
Western hemlock	*Tsuga heterophylla*	I	I	S	S
Baltic pine	*Picea abies*	I	I	S	S
White Cypress pine	*Callitris columellaris*	I	I	R	R
Western red cedar	*Thuja plicata*	I	I	R	R
Hoop pine	*Araucaria cunninghamii*	I	I	S	R
Kauri	*Agathis dammara*	I	I	S	S
Oregon	*Pseudo tsuga menziesii*	I	I	S	S
Radiata pine	*Pinus radiata*	I	I	S	S
Redwood	*Sequoia sempervirens*	I	I	R	R

[1] S = susceptible (often attacked).
R = resistant (rarely if ever attacked).
I = immune (never attacked).

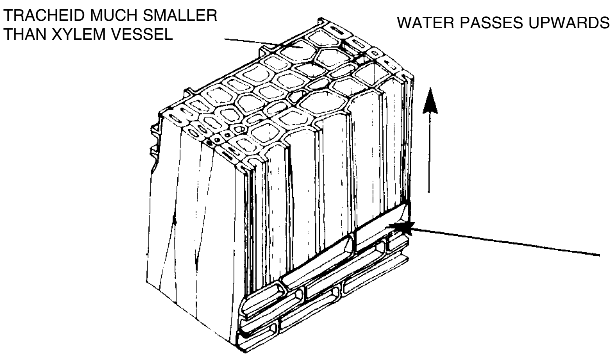


Figure 18.1 Section of sapwood of conifer — non–pored wood

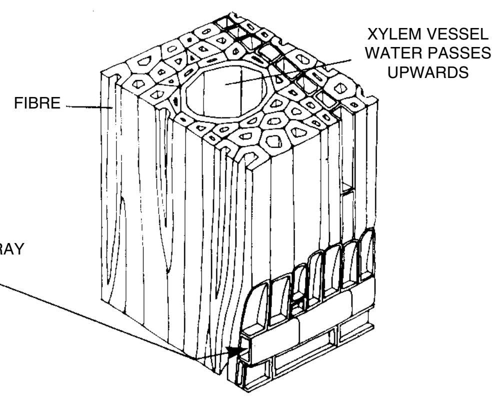


Figure 18.2 Section of sapwood of hardwood — pored wood

FIGURE 18.3
Nature of attack by pests of wood and bark

HARDWOODS

Round holes

Sound wood

1–5 mm. Wood species whose sapwood contains starch; moist wood; no reinfestation.
Particoloured auger beetle (2.5–3 mm)
Cylindrical auger beetle (3.5 mm)
Large auger beetle (5 mm)

1–1.5 mm. Wood species whose sapwood contains starch; dry wood; reinfestation occurs.
Powderpost beetles

1–2 mm. Any hardwood; no dust; holes usually stained.
Ambrosia or pinhole borers

Decayed wood

5–6 mm. Any wood species that is decayed.
Dampwood borer

4–5 mm. Any wood species that is decayed.
Stag beetle
(*Syndesus cornutus*)

Oval holes

Green wood

3–10 mm (long axis). Various hosts.
Greenwood jewel beetles

3–15 mm (long axis). Various hosts.
Greenwood longicorns

Irregular

Green wood

3–15 mm.
Wood moths

10–15 mm.
Giantwood moth

No holes

Borer holes revealed after removing surface.
Marine borers

Surface collapses on touch; earth present.
Termites

PINE WOODS

Round holes

Sound wood

1.5–2 mm. Pines, not white Cypress pine.
Furniture beetle
Queensland pine beetle

2–2.5 mm. *Pinus* spp. and Baltic pine.
Pine bark anoboiid

1–3 mm. Any pine; no dust stain may be present.
Ambrosia or pinhole borers

3–10 mm. Any pine; usually in tree or log.
Weevils

3–5 mm. Pines, not white Cypress pine; not active in dry wood.
Sirex wasp

Decayed wood

3 mm. Any wood species that is decayed.
Dampwood borer

4–5 mm. Any wood species that is decayed.
Stag beetle
(Syndesus cornutus)

Oval holes

Green wood

3–8 mm (long axis). Various hosts.
Greenwood jewel beetles

4–6 mm. White Cypress pine.
Small Cypress jewel beetle

4–6 mm. Douglas fir; emerges many years later.
Oregon jewel beetle

4–6 mm. Hoop and bunya pine.
Hoop-pine jewel beetle

3–10 mm. Various hosts.
Greenwood longicorns

Dry wood

4–6 mm. *Pinus* spp. and *Abies.*
European house borer

4–6 mm. NZ rimu.
Two-tooth Longicorn

No holes

Borer holes revealed after removing surface.
Marine borers

Surface collapses on touch; earth present.
Termites

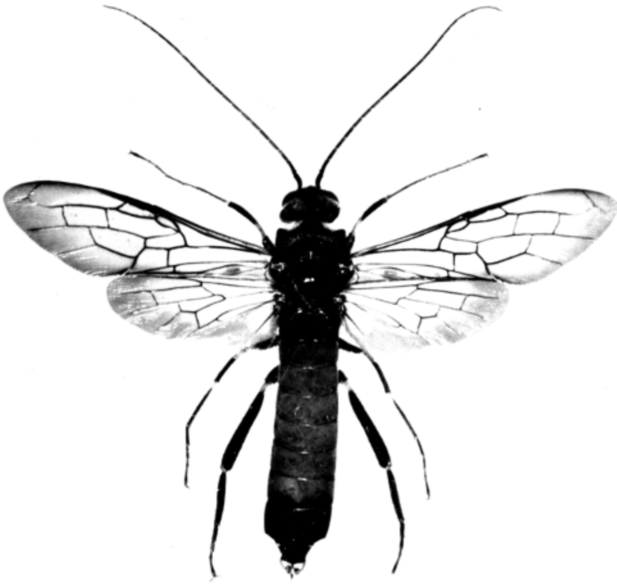


Figure 18.4 Male siricid woodwasp (*Sirex noctilio*)

Figure 18.5 Larva of *Sirex noctilio*

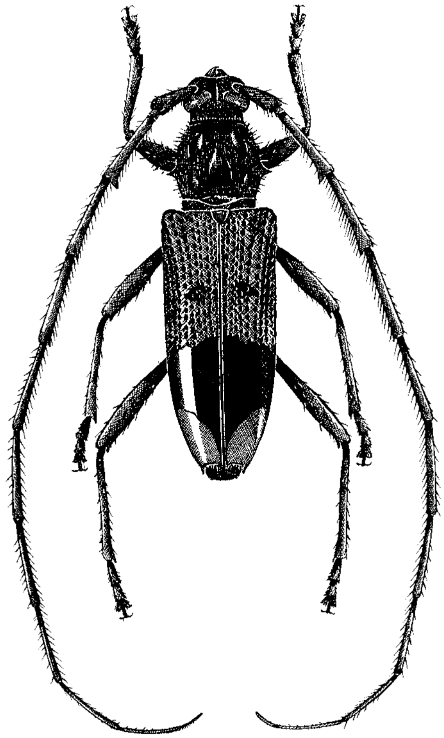


Figure 18.6 Adult yellow longicorn (*Phoracantha recurva*)

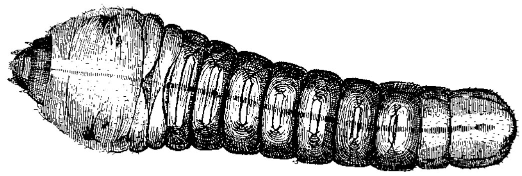


Figure 18.7 Longicorn larva

GREENWOOD LONGICORNS

Economic significance

Most species of greenwood-infesting longicorns are native and are forest pests or pests of ornamental trees. However, their damage when they enter the sapwood for pupation often carries over into buildings and is likely to be encountered by pest controllers. The beetles emerge from timber up to 6 months after milling; and when timber containing larvae or pupae is used in buildings and covered with gyprock or other internal lining, they emerge through large oval holes, sometimes causing great concern to householders because of the size of the holes. Most instances of this behaviour are from eucalypt timbers used in wall structures in timber and brick veneer houses and most emergences of these insects occur in the first six months of the life of the house. They do not infest dry, seasoned timber, but require moist bark in which to lay their eggs and sustain their larvae.

Biology and species

There are many species, ranging in size from 5 mm to over 70 mm. Australia is very rich in the number of species, most of which have particular food requirements, exhibited by their host specificity. Some species are found in only one or two of the many hundreds of eucalypts. In many parts of eastern Australia, particularly along the coast, the yellow longicorn, *Phoracantha recurva,* and the common eucalypt longicorn *Phoracantha semipunctata,* two very similar species, are encountered under the bark of logs and damaged trees. Attack in

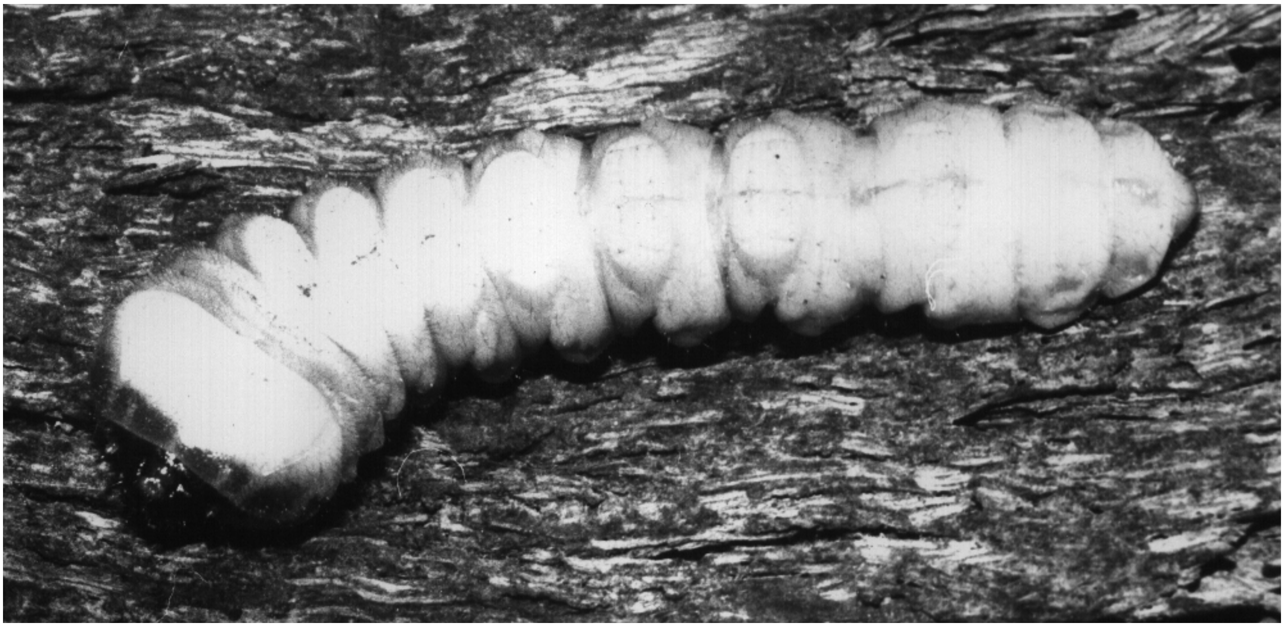


Figure 18.8 Longicorn larva

pines is less frequent, although some native species of longicorn attack ornamental Cypresses not native to Australia.

The female beetles are attracted to felled logs and fire-damaged and injured trees to lay their eggs. The eggs are mostly laid in the nutritious phloem–cambial area, where the longicorns spend much of their lives as larvae, only entering the security of the sapwood to pupate. In the sapwood they are protected from many predators (eg black cockatoos and certain predatory insects) and the entry of water. Most species complete their life cycle in 6–12 months, but some species take longer, even up to 3 years. The flight holes of emerging beetles are usually distinctly oval, although in some species the holes may approach roundness. Reinfestation does not occur, as moist phloem–cambium is essential for larval development.

The beetles can be identified as longicorns by their long flowing antennae, kidney-shaped eyes, which partly surround the bases of the antennae, and their rather elongate bodies. The larvae are legless and rather robust, gradually tapering towards the tip of the abdomen. Jewel beetle larvae occupy similar sites in the bark, but they have a flattened thoracic region and in some countries are called cobra-headed borer larvae. The longicorn larvae do not have the flattened thoracic region. Identification of the various longicorn larvae is a highly specialised task, and even then it is possible only for some of the more commonly occurring species.

Treatment

Some protection of logs in forest and mill yard storage may be achieved by the early application of aqueous sprays of an approved insecticide. Removal of the bark, either at the forest dump or at the mill yard prevents damage, since the larvae cannot then survive and penetrate the sapwood where they pupate. Early phloem-cambium feeding by larvae is of no significance, since the sapwood has not been penetrated. Larval damage degrades the wood in appearance; but as the larvae cannot continue their activity in dry wood and reinfestation does not occur, treatment by pest controllers is not required. The emergence of beetles through plaster/gyprock walls does not warrant stripping down the plaster, only sealing the holes and painting the restored areas. It is recommended that this restoration occurs about six months after the timber has been placed in service.

Logs for export must be clean and free of longicorn borers, and to meet this requirement fumigation with methyl bromide has been a normal procedure. This is a service area for pest controllers who possess the appropriate fumigator's licence.

JEWEL BEETLES

Economic significance

Jewel beetles are mainly forest pests, attacking damaged and weakened trees in forest and bushland areas. With the exception of the Oregon jewel beetle they are native insects and apart from the hoop-pine jewel beetle and the Oregon jewel beetle they are not pests of dry seasoned wood. The hoop-pine and Oregon jewel beetles may emerge from wood in service up to 50 years after milling. Other jewel beetles are of little relevance to pest controllers, but they should be able to recognise the damage made by jewel beetles and know that bark and moisture are necessary for attack, even in the case of the Oregon and hoop-pine jewel beetles.

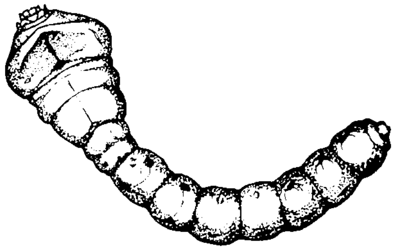


Figure 18.9 Jewel beetle larva

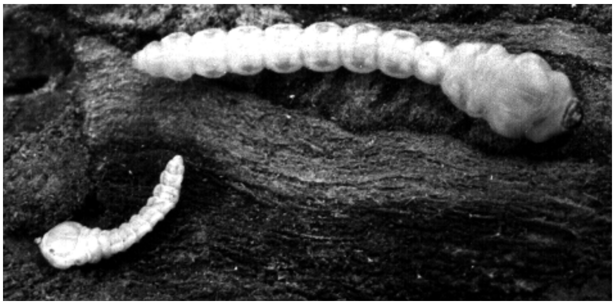


Figure 18.10 Jewel beetle larvae

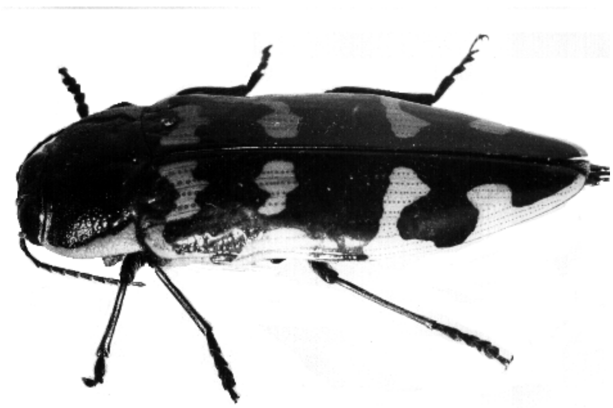


Figure 18.11 A jewel beetle adult

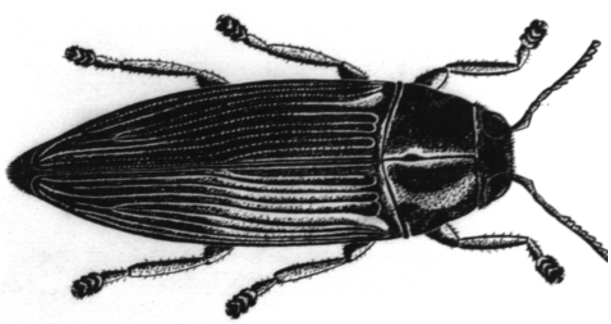


Figure 18.11 (a) Hoop-pine jewel beetle (*Prospheres aurantiopictus*)

Biology and species

Jewel beetles lay their eggs in the bark of stressed and damaged trees and their larvae feed in the phloem–cambial region, making crescent-like markings on the bark and wood — a feature that readily identifies their damage from that of longicorns. When the larvae are fully fed they enter the sapwood to pupate. The beetles emerge through distinctly oval holes. Life cycles are usually 6–24 months, except for the two dry-wood species, which have a much longer larval life due to the unfavourable conditions in the drying wood.

The beetles are oval-shaped and have short serrate antennae and usually brightly coloured wing covers. The first three segments (thoracic) of the larvae are characteristically flattened, resembling the front portion of a cobra snake (the larvae are often referred to overseas as cobra-headed larvae). The larvae are elongate and legless. The two most commonly encountered species in Australia are the Cypress jewel beetle, *Diadoxus scalaris,* and the small Cypress jewel beetle, *Diadoxus erythrurus.* These species attack fire-damaged and drought-affected Cypress pine trees, *Callitris* spp., emerging from flooring and weatherboards soon after milling and being placed in service.

There are two other species whose damage and appearance should be recognised by pest controllers: the hoop-pine and the oregon jewel beetles.

The hoop-pine jewel beetle, *Prospheres aurantiopictus,* attacks hoop pine logs and later enters the sapwood, where it also continues to feed. As the log or sawn timber containing larvae dries out, conditions in the wood become less favourable to larval development, and the larval period is extended, sometimes up to 20 years or more. The beetle is mostly encountered emerging from hoop pine framing of furniture covered by a face veneer. Reinfestation does not occur, as bark and moisture are essential prerequisites for attack.

The Oregon jewel beetle, *Buprestis aurulenta,* also has a protracted larval stage. It is imported in Douglas fir from North America and is similar to the hoop-pine jewel beetle in its habits, emerging from timber in service up to 50 years after milling. Occasionally the Douglas fir (Oregon) is severely damaged, but replacement is seldom warranted.

Treatment

No treatment is required for the damage of the true greenwood jewel beetles, apart from filling flight holes with a durable putty or silicone/acrylic compound to prevent the entry of water. Where timber has been covered by plaster and beetles have emerged, no treatment is required, and the holes in the plaster may be filled with a suitable filler after a period of six months from the installation of the timber has elapsed to ensure that all emergences have occurred.

While the Oregon jewel beetle may persist for many years in Douglas fir roofing and wall timbers, attack is usually restricted to one or two members and does not spread from these. Where attack is severe, the affected members should be supported or replaced rather than treated. Reinfestation requires bark, and therefore attack is confined to the members having the original infestation. Chemical treatment of roofing timbers for the prevention of further attack is not needed.

The hoop-pine jewel beetle in articles of furniture may be controlled by fumigation or carefully controlled heat treatment. Very small articles can be treated in a microwave oven, using carefully controlled exposure times.

WEEVILS

Economic significance

Weevils are forest pests, attacking damaged or stressed trees in the forest or freshly cut and extracted logs at the mill yard. There are many species of weevils, most of which attack dead wood. Most damage by weevils is caused by native species, although weevils in wood are frequently intercepted by quarantine authorities at various port facilities requiring shipments to be fumigated or heat sterilised. Apart from recognising damage by weevils, their control is not required by pest controllers. Any damage seen is the result of old infestations that occurred in the forest, and reinfestation does not happen in dry wood.

Biology and species

Weevils are really beetles, characterised by having their mandibulate mouthparts on the end of a rostrum or beak and by their very hard body shell. Weevils lay their eggs in bark or wood, and the larvae, which are legless, feed in either the wood or the bark, depending on the species. All pupate in sapwood. Weevil damage may be confused with sirex wasp damage when it occurs in *Pinus* spp. such as radiata pine. It may be distinguished often by the nature of the frass in the holes. The sirex wasp has compacted loose frass, while most weevils leave compacted frass that breaks off in pieces rather than loosely.

Treatment

No treatment is required when the damage is located in timber in service, as the insects will have left soon after milling. Fumigation of timber at shipping ports using methyl bromide is normal procedure for foreign insects in wood.

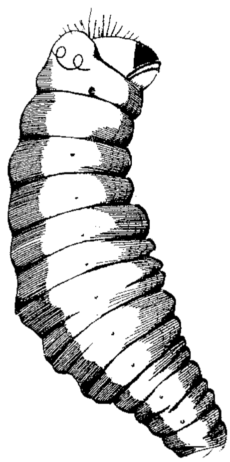
AMBROSIA BEETLES (Pinhole borers)

Economic significance

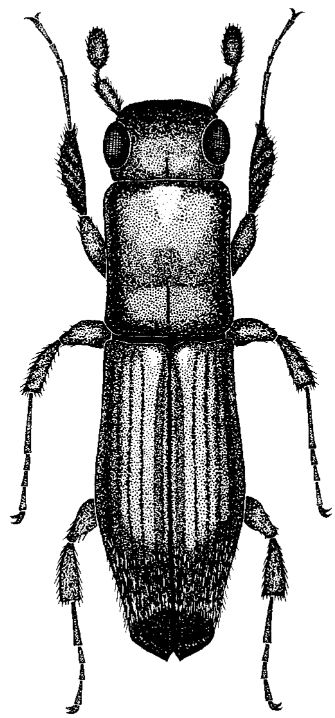
Ambrosia beetles are pests of green logs at the forest log dump and mill yard and of freshly sawn timber under very moist climatic conditions. The often stained holes persist through to the finished article, and this defect degrades the value of the timber for many uses. However, mostly it does not affect the strength of the wood. Damage by pinhole borers is often seen in certain timber species (eg tallowwood and blackbutt), but apart from detracting from the timber's appearance there is usually no reason for concern.

One species, the horizontal borer, *Austroplatypus incompertus*, attacks standing trees that have been injured by fire or stressed in some way and makes extensive gallery systems in one plane only. The fungus it carries breaks down the cellulose in a horizontal plane, causing even large-dimensional timber (100 x 100 mm) from the affected log to fracture at the plane of past activity.

Pest controllers are never required to treat pinhole borer attack in buildings, and doing so would expose the company and pest controller to charges of possible misrepresentation. Since the damage of some pinhole borers superficially resembles that of the powderpost beetle or furniture beetle, pest controllers must exercise care in identification.



Larva of pinhole borer (*Platypus* sp.)



Adult polyphagous pinhole borer (*Platypus australis*)

Figure 18.12

Biology and species

As soon as a tree is felled it becomes attractive to ambrosia beetles, which bore deep into the wood, lay their eggs and leave specific fungal spores on the walls of the moist tunnels. The spores germinate, producing fungal hyphae, which form the food of the larvae that hatch from the eggs laid deep in the parent galleries. The parent beetles often die at the entrance to the gallery system, thus protecting their larvae from predators and sealing the hole against moisture loss. Ambrosia beetle larvae are fungus eaters and do not eat wood. The holes usually penetrate deeply into wood and are free of frass; thus their damage may be readily distinguished from that of dry-wood borers. The holes are often darkly stained on the inner faces as a result of the fungal activity, another feature which separates their activity from that of dry-wood borers. Their life cycles are mostly about 6–12 months, but the horizontal borer has a more extended life cycle of up to some years.

Ambrosia beetles belong to the beetle family Curculionidae, which contains such species as the polyphagous pinhole borer, *Platypus australis,* the mountain pinhole borer, *Platypus subgranosus,* and the omnivorous pinhole borer, *Crossotarsus omnivorus.* These are all Australian species, although many other species are intercepted at ports by quarantine authorities.

Treatment

When infested logs are sawn, the timber dries out, leaving insufficient moisture to sustain the fungal growth inside the holes so the larvae die. Ambrosia beetle attack is therefore not a problem for pest controllers; but as it is frequently encountered in inspections, they should be aware of its significance and be able to allay the fears of clients.

Preventive sprays at the forest log dump or mill yard can be of some real value in reducing the incidence of infestation. Rapid extraction of logs from forest dumps and conversion into sawn timber are the most economic procedures of reducing damage by pinhole borers. Organophosphorus, carbamate compounds and pyrethroids have given some protection for short periods of storage in the forest and mill yards.

BARK BEETLES

Economic significance

Bark beetles are forest pests, but the larvae of some species encroach into the sapwood and damage it. Most species of bark beetles infest growing trees and are of little or no relevance to pest controllers, unless they are involved in the fumigation of imported timber, which should not contain bark to enter Australian ports. However, pest controllers must be able to identify bark beetle damage if it is located in buildings.

Biology and species

These small beetles lay their eggs in bark and the larvae feed mostly in the phloem–cambial area, some species entering the sapwood to pupate. The beetles emerge through round flight holes. Most true bark beetles belong to the beetle family Curculionidae.

The most frequently encountered damage in Australia is that due to the island pinhole borer, *Xyleborus perforans,* which attacks many of the 'pacific maples' entering the various ports. Its damage resembles that of pinhole borers, but the holes are not stained. This species attacks the sapwood only, and although it carries a fungus, it does not usually stain wood. For this reason its damage may also be confused superficially with that of the powderpost beetle.

The elm bark beetle, *Scolytus multistriatus* — the carrier of the fungus *Ceratocystus ulmi,* the cause of dutch elm disease in elms — is now present in Australia, but as yet it does not appear to be carrying the virulent fungus which has been so damaging to elm trees in Europe.

The pine bark anobiid, *Ernobius mollis,* an introduced species belonging to the beetle family Anobiidae, is a bark beetle attacking radiata pine at the forest log dump or mill yard. Once the bark is removed, this insect does not attack the log. However, when logs having bark adhering are cut into sawn timber and used for door frames and furniture frames and then covered by face veneers, emergence holes can seriously affect the appearance of these articles. The larvae enter the sapwood for a short distance, but when bark is removed, the problem is eliminated. Bark left on radiata pine roofing timber has the sapwood affected for a only very small depth when attack by this beetle occurs.

Treatment

No treatment is required for the island pinhole borer, as it does not survive in dry timber, being dependent on the fungus it cultivates on the walls of its tunnels. The elm bark beetle does not occur in building timbers and is therefore only a tree care problem. The pine bark anobiid in various articles of furniture or doors can be controlled by fumigation, using methyl bromide or careful heat sterilisation. Sometimes the round flight holes may be injected, using a special nozzle or hypodermic syringe and an oil containing an approved insecticide. When the insecticide is placed in one flight hole, it flows some 10–20 cm from the injection site. Always check to see what insecticide is approved under the state pesticide legislation for this purpose. When flooring or accessible timbers are affected, removal of the bark is all that is required.

PESTS OF MOIST & PARTLY DRY WOOD

AUGER BEETLES

Economic significance

Auger beetle larvae feed in moist sapwood containing starch, but they do not reinfest the dry wood when they emerge as beetles. Some moisture content is needed for egg-laying and for the larvae in their early development. The same timbers and region of the wood are susceptible to the powderpost beetle, which does reinfest until the sapwood is destroyed.

Auger beetle damage is often encountered in timber rounds (small–dimensional logs) used to support walls and

Figure 18.13 Large auger beetle (*Bostrychopsis jesuita*)

Figure 18.14 Giant wood moth (*Xyleutes sp.*)

ceilings in coal and other underground mines. When these natural rounds are used untreated for fence posts and transmission poles, these are also subject to auger beetle attack. Hardwoods (eucalypts) containing starch may be attacked, and when infested timber is used for flooring joists, emerging beetles may come through the floorboards, giving the impression that the flooring is infested. Wooden wine casks, because of their fermenting contents, attract auger beetles, particularly the cylindrical auger beetle, which bores through the wood, causing large quantities of wine to be lost.

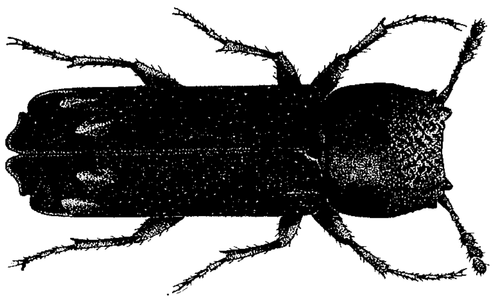


Figure 18.15 Adult cylindrical auger beetle (*Xylion cylindricus*)

Biology and species

The beetles lay their eggs in moist sapwood. Often the beetle bores a clean round hole where it lays its eggs. This activity of boring clean holes has given the beetles their name. The larvae feed on starch in the sapwood, pupate close to the surface and emerge through perfectly round holes. The life cycle varies between 4 and 12 months, depending on the species and time of year, but the beetles do not reinfest dry seasoned timber. They may, however, bore their characteristic auger holes into dry softwood.

There are several species, the most often encountered being the cylindrical auger beetle, *Xylion cylindricus*, the particoloured auger beetle, *Mesoxylion collaris,* and the large auger beetle, *Bostrychopsis jesuita.* The lesser auger beetle, *Heterobostrychus aequalis*, is frequently intercepted in foreign timbers entering the shipping ports of Australia, mainly from the Indo–Malaysian regions. If encountered, it should be reported to the appropriate quarantine authorities (see Chapter 23).

Treatment

In most instances treatment is not required, but it must always be realised that powderpost beetle attack usually follows, as both insects feed in the sapwood, which contains starch. Where falling dust (frass) causes inconvenience, flight holes can be injected with an approved insecticide in an oil solvent to reduce the problem. Spraying or painting with the same liquid is only partially effective. Pre-treating poles and fence posts with the inorganic salts of copper, chromium and arsenic prevents attack by both auger beetles and powderpost beetles. Wine casks may be protected from beetle damage, as distinct from larval damage, by enclosing the cask temporarily (January to April) with sheet plastic and locating and destroying the source of infestation. Chemicals could be hazardous and also would affect flavour if applied near wine casks.

PESTS OF DRY SEASONED WOOD

POWDERPOST BEETLES

Economic significance

These beetles attack only the sapwood of hardwoods containing starch, and their presence is usually detected during the first few years of the service life of the timber or article of furniture. The species mentioned below were probably in Australia before the first settlers and can be considered native species.

In the case of large-dimensional timber members (50 x 75 mm and 75 x 75 mm), the sapwood is seldom more than an edge, and its destruction does not significantly affect their strength. In small-dimensional members (20 x 50 mm), such as those found in tiling and ceiling battens and some framework in furniture, almost total destruction is possible. Attack in plywood that consists of centre veneers of untreated sapwood susceptible to powderpost (*Lyctus*) attack often results in complete separation of the plywood. For these and other reasons, two states of Australia have enacted legislation that makes it an offence to use such susceptible timbers for certain purposes. The *Timber Marketing Act* in New South Wales protects the purchasers of furniture and timber for houses against the use of *Lyctus*-susceptible sapwood.

In Queensland and New South Wales it is an offence to sell:

1. structural timbers having more than 25% of their perimeters of untreated susceptible sapwood (and provided that no more than 50% of any one face is susceptible sapwood); or
2. any manufactured article (eg furniture, flooring, architraves, window framing) having any untreated susceptible sapwood.

In the case of structural timbers, the strength of the member might be significantly affected if over 25% of the perimeter were destroyed. Attack of furniture timbers, architraves and flooring is detrimental to their appearance, and therefore no sapwood is tolerated in these by the two Acts. As most attack occurs in the first few years of the service life of the timber, a period of 24 months is given, during which time action may be taken against the timber supplier, builder and retailer.

Outside this time period the Acts do not apply. Subsequent replacement of infested timber or articles is usually assured, and seldom is it necessary for a person to pursue civil action in the courts to recover damages from the offending person.

These Acts are administered by the Department of Primary Industry in Queensland and State Forests of NSW in New South Wales. In case and crate timbers, and timbers expected to have only a short service life, the presence of *Lyctus*-susceptible sapwood does not constitute a breach of the Acts.

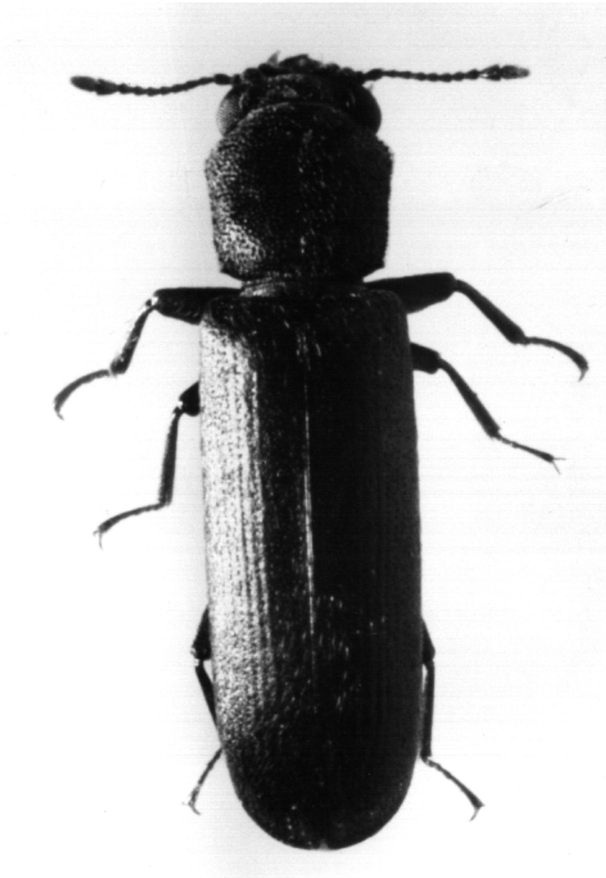


Figure 18.16 Powderpost beetle (*Lyctus brunneus*)

Biology and species

The female powderpost beetle lays her eggs singly to a depth of about 1–3 mm only in exposed end pores in the sapwood of susceptible timbers. These pores are really the water-conducting xylem vessels and occur only in hardwoods. Pines do not have pores; they have tracheids, which are much smaller than pores and too small for the female beetle to insert her ovipositor (egg-laying structure). They are therefore immune to attack. The end pores may be located at the cut end or exposed in the length of the wood by cuts or abrasions. About 50–100 eggs are laid by each female.

The eggs hatch after about 10–15 days into larvae having three pairs of thoracic legs. The larvae feed in the sapwood only on the small starch grains within it. They tunnel mainly with the grain of the wood. When fully fed they bore close to the surface of the wood, where they pupate and later emerge as beetles through round holes 1.5–2.0 mm in diameter. The dust (frass) from their workings is fine and flour-like and cannot be felt when rubbed between the fingers. The beetles can reinfest the wood as long as wood and starch are present. Usually the wood is reduced to dust, but this depends on the starch content. The larval period may occupy 2–12 months, the pupal stage about 2–4 weeks, and the beetles may live for 2–5 weeks. Generally the life cycle lasts 4–12 months, but this depends on many factors.

There are two main species in Australia: the powderpost beetle, *Lyctus brunneus,* and the small powderpost beetle, *Lyctus discedens,* but the identification of these is beyond the ability of pest controllers. The beetles vary in size from 3 to 6 mm, are dark brown and have short antennae with 2-segmented clubs — a useful diagnostic feature for lyctid beetles. Head, thorax and abdomen are all visible when viewed from above. The larvae are curled and have 3 pairs of well-defined thoracic legs and 2 enlarged spiracles on the second-last abdominal segment — a feature that enables powderpost beetle larvae to be distinguished from those of the furniture beetle.

Treatment

In New South Wales and Queensland the use of *Lyctus*-susceptible sapwood for many purposes is an offence under government legislation. Pre-treatment of *Lyctus*-susceptible sapwood has been commercially available since the 1940s. Surface treatments are not considered satisfactory and are not approved under either piece of legislation. Fumigation, although effective in killing insects that are present in the wood, allows reinfestation and also is not an approved treatment under either of the state Acts.

Pre-treatment involves the pressure treatment of timber in huge cylinders, using the water-soluble salts copper sulphate, chromium sulphate and arsenic pentoxide. These salts become 'fixed' in the sapwood mainly, thus resisting leaching even when the timber is used outside. There are two treatments involving the use of these salts: 'Tanalith C' and 'Celcure A'. 'Tanalith C' treatment is also known in landscaping where 'Kopper's logs' are used.

Another approved pre-treatment of timber involves the salts of borax and boric acid. These treatments have been available since the 1940s. There are several treatment modifications using these salts, such as heating by steam or hot solutions followed by cold soaking. Sodium fluoride also has been used, particularly as a dip for veneer prior to gluing to make plywood.

All the pre-treatment methods require a minimum concentration of chemical in the centre of the sapwood of the timber, so that, no matter how the timber is cut, the powderpost beetle has only a sapwood treated area or heartwood in which to lay its eggs.

An emulsifiable concentrate formulation of permethrin is available for surface treatments for borers such as the powderpost beetles. Replacement is recommended where collapse may occur, or the wood may be left untreated where the strength of the member is not significantly affected or likely to be affected by attack.

FURNITURE BEETLE (*Anobium punctatum*)

Economic significance

The furniture beetle was probably introduced into Australia during early settlements in New South Wales and has entered the various ports many times since then.

Attack is usually encountered in pine timbers, particularly those which have been in service for at least 20 years. Baltic pine, New Zealand white pine, hoop pine and some other exotic pine woods are attacked by the furniture beetle, but it will also attack hardwoods such as English oak, and infestations have also been recorded from spotted gum (*Eucalyptus maculata*), but these cases are very rare. Many species are resistant (eg white Cypress pine and many hardwoods). As a general rule, most hardwoods are regarded as a much better risk than softwoods where furniture beetle hazard is high.

Attack occurs mostly in flooring, panelling and furniture. It seldom occurs in roofing timbers, because of the higher temperatures in roof cavities, particularly those covered by corrugated iron. It occurs on the coastal areas of Australia, due mainly to the high humidities and more even temperatures. Sustained attack in the drier inland areas is virtually unknown. Most cases of attack in drier areas involve the transport of attacked furniture from coastal to inland regions, but attack soon terminates.

Radiata pine is susceptible, but at present there is not sufficient data to speculate on its future with regard to the furniture beetle, despite the extensive utilisation of Australian-grown radiata pine in the last 20 years. Imported timbers from North America, such as spruce, the various pines and fir to meet the softwood demand in Australia, will be attacked by the furniture beetle, particularly in the coastal areas of Australia.This will be an emerging problem beyond the year 2000.

Biology and species

The furniture beetle lays about 50–100 eggs, mainly in cracks and crevices and abraded areas in timber. These hatch in a few weeks to larvae which have 3 pairs of well-defined thoracic legs. They are distinguished from powderpost beetle larvae by the absence of the enlarged spiracles on the second-last abdominal segment of the furniture beetle. When pupating, the larvae come closer to the surface of the infested timber, and the beetles emerge through round flight holes about 2 mm in diameter. The egg-to-adult period may be as short as 12 months, but it is usually 2–3 years. The beetle is brown and about 3 mm long. Its head is concealed beneath the prothorax in the form of a cowl, and the antennae have a diffuse club of 3 segments.

Figure 18.17 Furniture beetle (*Anobium punctatum*)

Treatments

Attack by the furniture beetle is often noticed only when a heavy piece of furniture breaks through infested flooring, and by then treatment by chemicals is of no value. Attack may also be detected during a pest survey required by the prospective buyer of a house.

Replacement using a resistant timber, composition board or pre-treated wood (eg wood treated by copper, chrome and arsenic salts) is mostly the best approach to furniture beetle infestations, since, once this has been done, later sale of the house will not be affected by an unfavourable pest report. If there has been a previous surface treatment, a pest controller will always report on the presence of furniture beetle in the timbers of a house and will not usually accept a treatment by another company, particularly since surface treatments have only limited value.

When incipient (developing) attack is noticed, surface treatments have some value, but seldom do they eradicate the infestation. Oil formulations and emulsifiable concentrates of permethrin (a synthetic pyrethroid) are available for surface application for borers such as the furniture beetle. Surface treatments at best penetrate only 0.5–1.0 mm, but will kill beetles after they emerge and when they have constant contact with the treated surface. Fumigation using methyl bromide eliminates an infestation, but does not ensure against reinfestation. Injecting chemicals is more effective than surface treatments, but often stains any surface lacquer or paint.

QUEENSLAND PINE BEETLE (*Calymmaderus incisus*)

Economic significance

The role of the furniture beetle is taken by the native Queensland pine beetle along the northern coast of New South Wales and in Queensland. In New South Wales, attack is seen mostly in hoop pine and to a lesser degree in bunya pine. Hoop pine was once used extensively for flooring and panelling, but now, due to its exploitation in past years, it is rarely used in these parts of the house.

Biology and species

The damage is similar to that of the furniture beetle. The Queensland pine beetle is different in shape and colour from the furniture beetle, being darker and more shiny and having a wider body. It is about 3 mm long, with the characteristic 3-segmented antennal club. The larva is similar to that of the furniture beetle, and identification from larvae is usually beyond the ability of pest controllers and requires specialist assistance.

Treatment

Treatment is similar to that required for the furniture beetle. Replacement of the wood is often advised.

EUROPEAN HOUSE BORER (*Hylotrupes bajulus*)

Economic significance

The European house borer has been introduced regularly into Australia during the last 50 years, in softwood timbers and prefabricated houses of softwood, mainly from Europe. To date it does not appear to be established, due mainly to the several occurrences of this borer having been fumigated with methyl bromide as a quarantine measure.

In other countries where this borer has been introduced the damage to existing buildings is considerable, and in South Africa it is compulsory to use pre-treated pine timbers or non-susceptible hardwoods for structural purposes. The introduction of this insect into Australia is viewed with great concern, since most state forest services have extensive planting programs of radiata pine — one of the more susceptible timber species. If this borer became established in Australia, the future utilisation of this softwood would be threatened, and the mandatory pre-treatment of building timbers of radiata pine would be a likely result.

H. bajulus was found in many prefabricated houses of foreign origin in Queensland during the 1950s, and as a result almost 3000 houses were fumigated with methyl bromide, using plastic sheets to cover the houses and contain the gas. It was the largest job of this type in the world, and to date it appears to have been successful. This borer has also been located in buildings in Sydney, Melbourne and Cooma, which also were fumigated with methyl bromide.

Biology and species

The beetle is dark brown, about 20 mm long, and has white patches on its wing covers (elytra). Antennae are somewhat shorter than those of the typical longicorn. Eggs are laid in cracks and abraded areas of pine woods (*Abies, Picea* and *Pinus* spp.). The larvae, which have tiny vestigial legs, feed mainly in the sapwood. The life cycle is about 1–3 years in Australia and South Africa, but in Europe, its country of origin, the period is usually about 5–7 years. Beetle emergence holes are oval and about 5–7 mm across the long axis.

Treatment

At present this insect is not considered to be established in Australia. Therefore, its suspected presence in timber should be notified to a State or Commonwealth scientific authority to confirm or otherwise the identification and, if necessary, arrange a fumigation of the building or destruction of the timber, whichever is appropriate (see Chapter 23). Like all other destructive pests of timber, European house borer larvae are not eradicated by surface treatments of insecticide, and until the insect is known to be established, control by surface treatments is not relevant. Timber pre-treated with copper, chrome and arsenic is not attacked by the European house borer.

TWO–TOOTH LONGICORN (*Ambeodontus tristis*)

Economic significance

This longicorn beetle, introduced from New Zealand, is found only in New Zealand rimu on coastal New South Wales, and even then it is encountered only rarely. It is mostly located in flooring where ventilation is poor. When this insect is located, a few emergence holes often indicate extensive damage, necessitating replacement rather than treatment. Most houses where this insect is found were built during the 1920s and 1930s, when substantial imports of New Zealand rimu occurred. Although this longicorn is seldom encountered by pest controllers, they must be aware of its damaging potential and of the conditions that favour its development.

Biology and species

The two-tooth longicorn is uniformly brown and about 12–20 mm long. It has the characteristic long antennae. Eggs are laid into cracks and crevices in timber. The legless larvae feed extensively in the sapwood, often leading to flooring collapse. The life cycle varies between 2 and 5 years, and emergence holes are oval and about 4–6 mm across the long axis.

Treatment

Replacement of the affected boards with a hardwood, treated pine or white cypress pine is the most satisfactory procedure. Treatment of infested boards can be only partially successful, and there is always the possibility of flooring collapse. Treatment of the remaining unaffected boards with the same

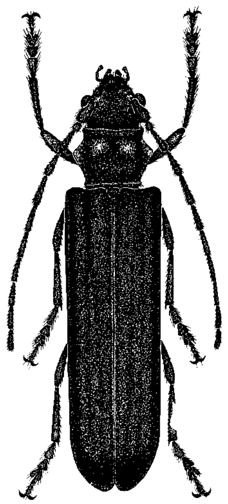


Figure 18.18 Two-tooth longicorn (*Ambeodontus tristis*)

insecticide used for the furniture beetle may have some value, but pest controllers should be aware that leaving a board with one or two emergence holes can lead to collapse.

CONTROL OF BARK AND WOOD INSECT PESTS

Biological control

Bark and wood insects have several naturally occurring enemies which assist in their control.

Yellowhorned clerid (*Trogodendron fasciculatum*) The larvae of these beetles are pink, about 20–25 mm long when fully grown, and have paired processes on the end of their abdomens. The adults are about 20 mm long and have yellow antennae. Both the larvae and beetles are found under bark, feeding on longicorn and jewel beetle larvae and adults.

Whitebanded clerid (*Paratillus carus*) This beetle and its larvae are predatory on the larvae and beetles of most wood-infesting insects, particularly auger beetles and powderpost beetles. When wood infested with powderpost beetles is treated with, say, boric acid, it no longer contains active insects, but the whitebanded clerid and its larvae search the workings, throwing out dust in the vain hope of finding a larva. The beetle is about 5–7 mm long and has a white band across its dark brown wing covers. The larva is about 13 mm long, cream to brown in colour, with paired processes on the end of the abdomen.

Parasitic wasps Small parasitic wasps are often found near infestations of wood-boring insects (eg powderpost beetles and furniture beetles). Several species found in these situations belong to the wasp families Braconidae and Ichneumonidae. Their eggs are laid in or on the borer larvae.

Straw itch mite (*Pyemotes herfsi*) These minute, pale creatures are often found in association with wood-boring beetles and their larvae. At most, this mite reduces the life of the borer and thus affects its reproductive ability. The mites are located on the body of the larvae and under the wing covers of the beetles.

Sapstain Wood affected by sapstain fungi does not appear to be attacked by powderpost beetles, probably because the starch has been utilised by the fungus.

Black cockatoos Black cockatoos are effective predators of bark-infesting insects (eg greenwood longicorns and wood moth larvae), although they cause serious damage to trees by tearing at bark and wood to obtain a larva.

Non-chemical methods of control

There are several methods of eradicating a borer infestation without the use of insecticides. Most are within the scope of the average householder, but they are seldom advised by pest controllers or used by them. Reinfestation is possible.

Heat Articles of furniture may be wrapped in black plastic and placed in the sun for periods of up to six hours, depending on the thickness of the timber components. Microwave ovens are very good for sterilising small wooden articles, such as small carvings, bamboo products and timber ornaments, but great care must be exercised to avoid distortion of the article.

Freezing Large wooden articles may be placed in refrigerated rooms even for extended periods, with complete elimination of attack, but this depends on the insect involved for some are more susceptible to chill than others. This treatment does not prevent reinfestation.

Submergence in water Certain articles may be submerged in water. Timbers for marine purposes can be submerged in either fresh or salt water with success. Again, reinfestation can occur.

Radiation Infested timber exposed to gamma radiation eliminates all activity in wooden articles, even some of considerable size. This type of treatment is not available to pest controllers, but in the future they may have access to such procedures. There is also great apprehension concerning the use of any radiation procedure, particularly in or near houses or buildings.

FURTHER READING

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CHAPTER 19

TERMITES

A survey of many hundreds of houses carried out in New South Wales in 1982–83 showed that one house in every five had active termites or had a termite history. It is therefore essential that pest controllers engaged in the control of structural pests have a good working knowledge of termites: the pest species and non-pest or casual species, their habits and, of course, their control and prevention.

Identification of the species is important, as many species require no action, and expensive control measures against these destroy client confidence in the pest control industry generally. The dry-wood termites present special problems, particularly since soil-barrier treatments are of no value in the control of these species. Once a pest controller has given a client all the facts concerning the infestation including identification of the termite species involved, it is the decision of the client whether the treatment is carried out. It is normal practice to obtain more than one quotation.

The organochlorines (cyclodienes) are no longer used in Australia as their use was banned in 1995 except in the northern areas of Australia; they are now banned over all Australia. The use of organochlorines as soil barriers has been replaced by the organ-ophosphorus insecticide chlorpyrifos, the pyrethroid bifenthrin and the chloronicotinyl, imidacloprid. Chemical barriers may also be applied using a reticulation system of PVC pipes that facilitate the application and renewal of the chemical barrier.

Bait monitors using termite-attractive timbers or matrices assist detection, species identification and eradication procedures and are now used extensively. The use of moisture meters, sound detection apparatus, fibre optic equipment and other devices also assist in termite detection.

Insect growth regulators (IGRs) used in conjunction with bait monitoring systems are achieving colony eradication, often where the colony cannot be located. These materials are hexaflumuron and triflumuron and in some areas they are replacing the arsenic dust eradication procedures. Physical barriers of finely divided granite particles and stainless steel mesh are also used in preventing termite access.

Technical skills involving colony location and eradication treatments will now be an important facet of termite control as they were 50 years ago before the organochlorines were used in termite control and prevention.

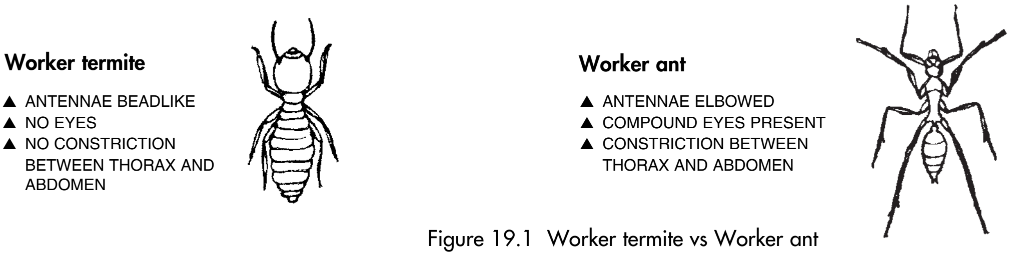

Figure 19.1 Worker termite vs Worker ant

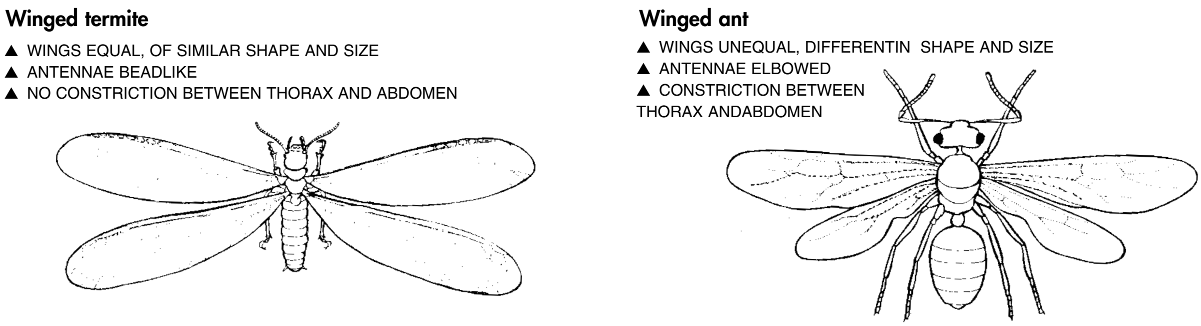

Figure 19.2 Winged termite vs Winged ant

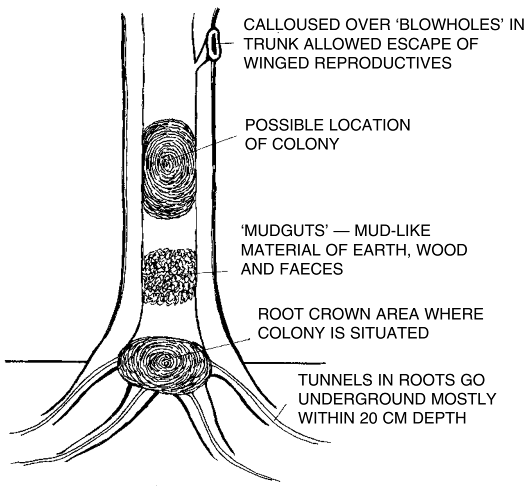

Figure 19.3a Tree nest of *Coptotermes acinaciformis*

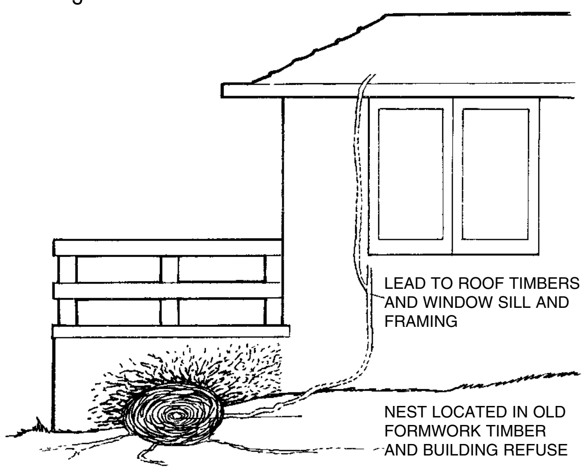

Figure 19.3b Nest of *Schedorhinotermes intermedius* under a balcony

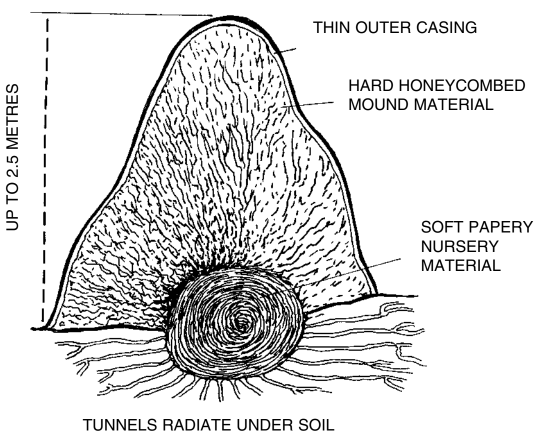

Figure 19.4a Ground mound of *Coptotermes lacteus*

Figure 19.4 b Mound of *Coptotermes lacteus*

CLASSIFICATION

Termites, insects belonging to Order Isoptera, are usually called 'white ants'. However, apart from their social habit of living in colonies as several forms or castes, they do not resemble true ants.

Termites are mostly pale brown to white, have no constriction between thorax and abdomen, and have beaded antennae. Reproductive forms have two pairs of equal wings and one pair of compound eyes. Workers and soldiers are blind, sexless and wingless and have thin cuticles that are susceptible to desiccation in dry or exposed environments.

Ants, on the other hand, vary from brown to black, depending on the species, and have an obvious constriction between thorax and abdomen. Antennae are variable, but often characteristically elbowed. They have two pairs of wings, unequal fore- and hindwings and one pair of compound eyes. Workers, soldiers and sexual forms of ants have cuticles that are not sensitive to desiccation so they can exist outside the more humid environment of their colony.

Carpenter ants are true ants, some of which belong to genus *Camponotus*, and often occupy similar environments in trees to termites; but unlike termites they do not destroy sound timber, living in decayed wood that they excavate for themselves. Their workings are clean and free from the faecal marks that are often characteristic of termite workings.

Figure 19.5 Aboreal nests of *Nasutitermes walkeri*

BEHAVIOUR AND CASTES

Colonies

Termites live in colonies, which are assemblages of different individuals with definite functions or tasks. The size of the colony varies from a few hundred, as in *Neotermes insularis*, to hundreds of thousands or even millions, as in the mound-building species, *Nasutitermes* and *Coptotermes*, and also the destructive *Mastotermes darwiniensis.*

The colony takes various forms, for some species build mounds, some nest underground and some live in small colonies in the wood of trees. There are five main forms:

Ground mound Species such as *Coptotermes lacteus*, *Nasutitermes exitiosus, Microcerotermes turneri* and *Amitermes* spp. in the Northern Territory build substantial mounds on the ground. Most of these have a hardened outer casing, an extensive layer with tunnels and an inner central area of softer, often papery material, forming the nursery where the queen is located along with her eggs and young. The temperature within the colony, particularly in the nursery area, is usually maintained by the termites at 30–36°C. A humidity of about 100% is most important to prevent desiccation of the termites, as they have thin and soft cuticles. High humidity is also required to support the fungi on which termites feed.

Arboreal mound or tree nest The best-known builder of arboreal nests is *Nasutitermes walkeri*. This species constructs arboreal nests, some of which are quite large and contain many thousands of individuals. These nests have internal contact with a cavity inside the tree and often act as a nesting place for birds, such as the small and attractive kingfisher. Food is plentiful, and the kingfisher is provided with an 'air-conditioned' home for its young.

Pole nest *Microcerotermes turneri,* which occurs north of Taree on the central coast of New South Wales, makes its small round nest on top of fence posts and even transmission poles, as well as on the ground and on trees.

Subterranean nest The pest species (eg *Coptotermes acinaciformis*, *C. frenchi* and *Schedorhinotermes intermedius*) mostly nest underground, but some can nest above ground provided there is a constant water source. *C. acinaciformis* has been found nesting between floors in large city buildings and inside trees, even well above ground level. Trees and stumps are favoured nesting places for subterranean termites. When live trees are selected, the colony is often found in the root crown area. *C. acinaciformis* builds mounds in northern Australia, but it does not do so in southern areas. The subterranean nest lacks the outer hard casing of the ground mound and the arboreal nests, but its structure is much the same, with softer nursery material at the centre. These termites do not kill trees, but they often weaken them in an area near or at the colony level, sometimes causing the tree to collapse. They also excavate the roots on which trees depend for their stability. Those species which attack wood either in buildings or in the ground can range up to 50 m from the colony, usually in underground tunnels up to 20 cm below ground level.

Tree wood Species such as *Neotermes insularis*, *Porotermes adamsoni* and the many species of the genus *Cryptotermes* live in small colonies throughout the branches and trunks of trees, often preferring the softer growth rings. *N. insularis*, which feeds in the softer growth rings, is known as the 'ring-ant' for this characteristic. *P. adamsoni* is a dampwood termite, which attacks dead stumps and occasionally timber in service, mostly in houses where the timber is in contact with the ground. *N. insularis* makes rambling galleries in a tree, and the number of individuals in the colony is quite numerous for a species that does not produce workers: the role of the worker is performed by nymphs.

Biology

Termites have a gradual metamorphosis. The developmental stages are egg, nymph and adult. The eggs are laid singly except in *Mastotermes darwiniensis*, which lays its eggs in long rows.

The eggs hatch into first instar nymphs, which are fed by the workers or, in the case of *M. darwiniensis* and species of the family Kalotermitidae, which have no true worker caste, by the older nymphs. By moulting several times the young nymphs differentiate into the various castes: workers, soldiers and alates. The developmental period may take 2–4 months to several months, depending on such factors as food availability, temperature and the vigour of the colony. The fully winged forms (alates) leave the colony during the colonising flight to set up new colonies.

When a pair of de-alates (alates which have dropped their wings) set up in a suitable environment (eg in decayed wood in soil), they hollow out a small chamber in which they mate, and then the female lays a small number of eggs. At this stage this future king and queen must feed and care for the young, but later the task becomes the responsibility of the workers or, in the case of the primitive species, the nymphs. A colony of the pest species *Coptotermes acinaciformis* requires some 2–5 years before it has sufficient strength in numbers to seriously damage timber of a building. When extensive damage is caused to a building that is only some months old, it is due not to a founding pair of termites, but to an established colony in a tree, tree stump or similar site, mostly within 50 m of the infestation. *M. darwiniensis*, whose immature forms can split off from the main colony, can reach a damaging potential sooner than other pest species.

At first, egg production of the founding pair is small, perhaps initially a batch of 10–20, but after some years the original queen may lay over 1000 eggs per day. Some tropical species with a large central colony have a much greater egg potential than this.

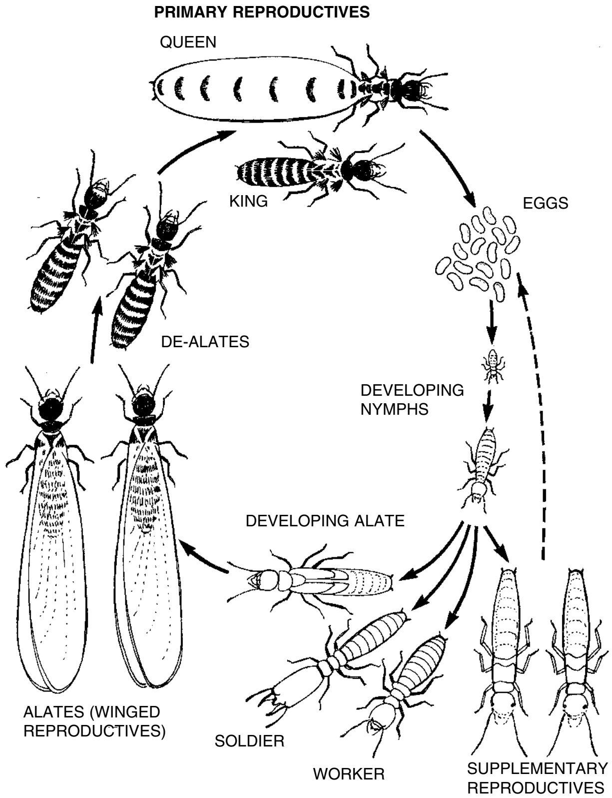

Figure 19.6 Termite life cycle

Castes

Termites exist in a colony in several 'forms' or castes, each of which has particular structures and functions related to the survival and maintenance of the colony.

The queen

The original (first-form) queen left the parent colony as an alate or fully winged reproductive at the time of the colonising flight and set up a new colony with the king. The main function of the queen is reproduction, but during the early developmental period of the colony she, together with the king, tends her young until the workers are numerous enough to take over these nursery duties. The first-form queen is usually long-lived, in some species over 20 years, and is fertilised by the king at intervals during this time.

Some queens become enlarged and distended with eggs. This condition is known as physogastry. Species such as *Mastotermes darwiniensis* do not have physogastric queens; others such as *Nasutitermes exitiosus* do.

Queens are of two main forms:

Macropterous queen These are primary or first-form queens, which were once fully winged (alates) and left the parent colony on the colonising flight. They have dropped their wings and become de-alated, and can be identified by the retained bases of the wings.

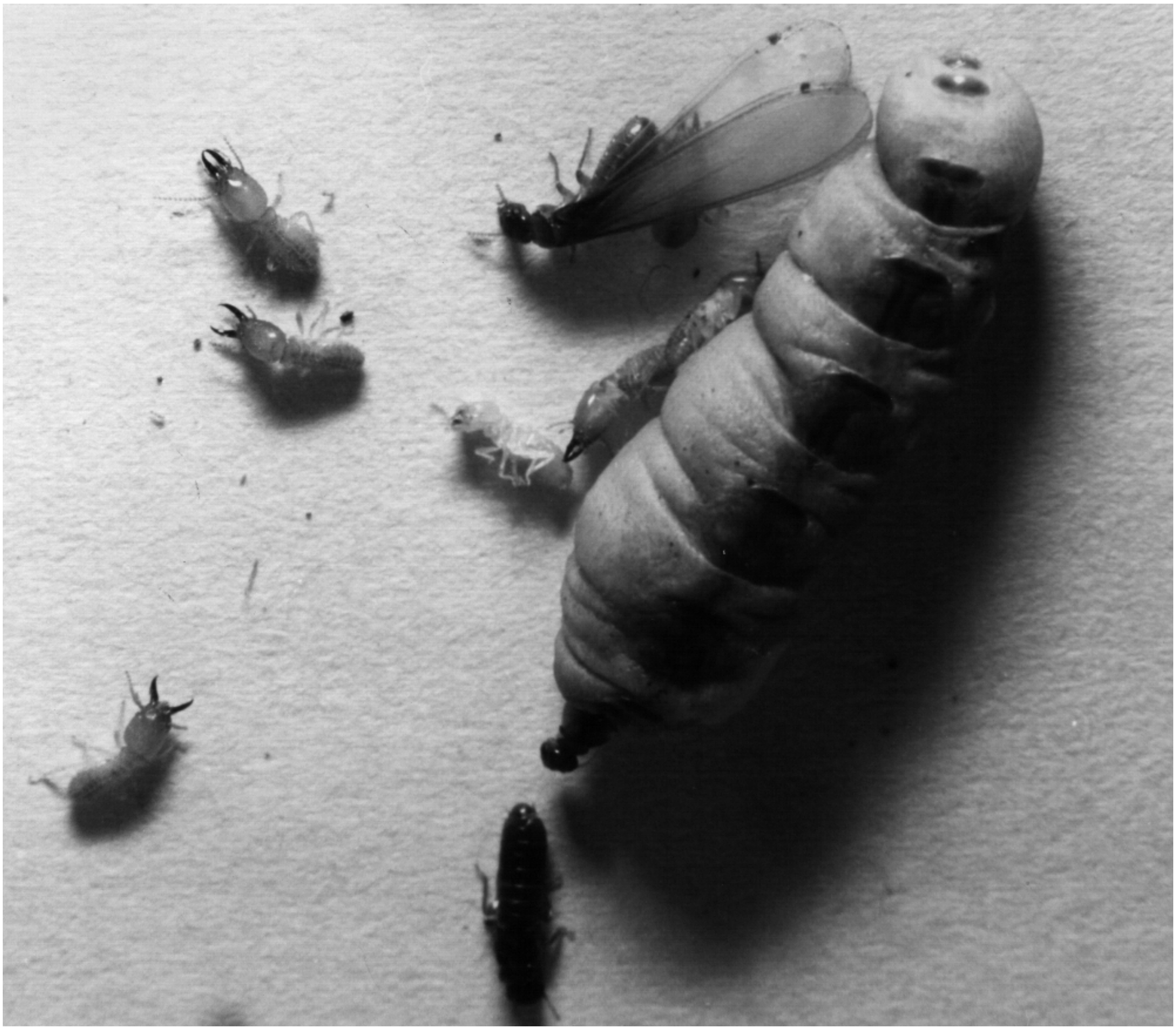

Figure 19.7 Queen, soldiers, worker, alate and de-alate of *Coptotermes acinaciformis*

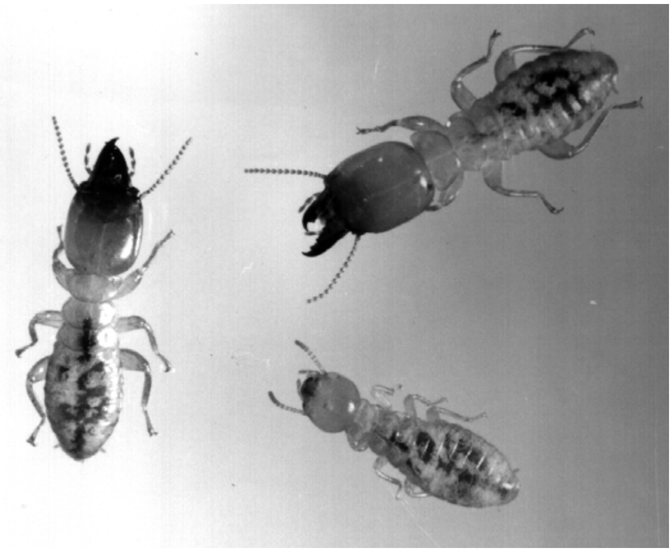

Figure 19.8 Soldiers and nymph of *Neotermes insularis*

Supplementary queens or neotenics These have been referred to as brachypterous queens, since they were not on the colonising flight and have either no wings or rounded wing buds, as they have been selected from the reproductives developing in the colony. The presence of supplementary queens is mostly due to the death or degeneration of the primary queen. The stage at which the reproductives are selected is reflected in the size of the wing buds. Such queens do not lay as many eggs as a primary queen, so several usually take over from one original queen.

The king

The original king, along with the queen, tends the young during the early life of the colony. He fertilizes the queen from time to time and, like the queen, is long-lived. It is likely that supplementary kings can be formed from the developing reproductives for similar reasons to those for the selection of supplementary queens.

Workers

These usually constitute the greatest number of individuals in a colony. They do the work of the colony: gathering food, feeding the young, repairing damage, and tending and feeding the queen. They are not involved in reproduction and have no compound eyes. They are males and females whose reproductive organs and secondary sexual characteristics have not developed.

Workers' bodies are mostly white and often coloured by the food they are eating, for this can be seen in the gut tissue through their thin cuticles. They are confined to the enclosed workings and also the nursery area of the colony, where humidity is high and the temperature is even. When they leave the colony, it is usually when the outside humidity and temperature are high, similar to the conditions inside the colony and workings, and there is very little chance of desiccation.

Soldiers

Soldiers are usually darker in colour and have larger and darker heads than the workers. Although the soldiers are basically males and females, their reproductive organs have not developed, nor are their sexual characteristics apparent.

Soldiers' main function is to defend the colony against invaders, mainly other insects such as ants. There are two main types of soldiers: (a) mandibulate, where the jaws are very well developed, and (b) nasute, where the head has been drawn out into a snout with tiny mouthparts beneath. Soldiers of *Coptotermes* spp. are mandibulate, while *Nasutitermes* spp. soldiers are all nasute.

Some species have two size classes of soldiers. This is particularly apparent in *Schedorhinotermes* spp. where minor soldiers (smaller ones) are in the incipient (developing) colonies and major or larger soldiers appear, with the minor soldiers, in the strong and developed colonies. At least one *Nasutitermes* species also has two size classes of soldiers.

Figure 19.9 Soldier and nymphs of *Neotermes insularis*

Reproductives

These are the sexual forms of a colony — the future kings and queens of colonies yet to be established. They develop in the colony by shedding their cuticles at the end of each growth stage until they reach the adult, when they are fully winged. They are darker than workers and soldiers, have compound eyes and are able to resist the outside environment more effectively than the other castes by having a more sclerotised cuticle (the cuticle has more chitin and therefore resists water loss).

Reproductives may be present in various stages of development, depending on the time of year when collected. Some have no wings, while others have rounded wing buds, depending on their stage of growth (instar). At each moult the nymph (larva) increases the size of its wing buds until it is fully winged (alate) and ready to leave the nest and go on the colonising flight.

If the queen dies or degenerates, in many species some of their reproductives are selected to carry on the colony as neotenics.

Nymphs — 'Workers' of the primitive species

In the primitive termites of the families Mastotermitidae, Kalotermitidae and Termopsidae there is no true worker caste. The developing nymph moults until it reaches an advanced stage of growth and then does the work of the colony. This stage can:

1 continue to feed and moult without differentiation into any particular caste;
2 moult to a presoldier and then a soldier;
3 moult to a reproductive nymph with wing buds and finally to the alate; or
4 form reproductives in the same colony.

Termites in the other and less primitive species do not have this versatile nymphal stage, but have distinct workers, soldiers and reproductives determined very early in their nymphal development.

Caste determination

Shortages of any caste in a colony appear to be reflected through a hormonal imbalance, and this is then compensated for by the production of more of the particular caste that is deficient in numbers. There are other possible explanations for caste determination, but at present there is not sufficient evidence to support these.

Parthenogenesis is not considered to occur extensively in termites, if in fact it occurs at all. In such social insects, parthenogenesis is difficult to detect.

Colonising flight

When the reproductives are fully winged they are ready to leave the colony and set up new colonies. The colonising flight occurs during periods of moderate temperatures and high humidity, approximating to those conditions inside the nest, often before or after a storm. After rain, humidity is often assured, and the winged termites are less likely to desiccate under these conditions.

The colonising flight usually originates very close to the main nest, and in those species with populous colonies a breach is made in timber, tree or post to allow the many thousands of winged forms (alates) to be discharged. When a nest of *Coptotermes acinaciformis* occurs in a tree, the alates emerge from slits made through the wood and bark. These slits are known as 'blow holes' or 'flight cuts'; after the flight has finished, the tree calluses over these slits, producing raised tissue. Several of these areas indicate colonising flights made over several years.

The colonising flight in many species occurs mainly during the November–December and March–April periods, thus avoiding the very hot period of January–February.

Food

Most termite species are grass and debris feeders, and are not usually pests of buildings. Termites of economic importance to wooden buildings eat cellulose, starches and sugars (carbohydrates) that they obtain from wood. Sapwood is preferred by termites to heartwood, because it has a better food value and is less durable. Heartwood of some species also has toxic inclusions, which make these species resistant to termites.

Termites obtain their protein from fungi that grow in and on the surface of wood, usually in moist soil situations or in the confines of the colony, which also are moist. When a termite colony is controlled, termites cease to graze on the fungi; and when the workings are examined some days afterwards, fungal growth is found in the nursery and inner mound material.

Many termites (eg *Coptotermes* spp. and *Schedorhinotermes* spp.) have tiny single-celled organisms known as protozoa in their intestinal tract. These flagellated protozoa are essential in the conversion of cellulose to soluble sugars that can be used by the termites; they produce an enzyme that digests the cellulose. Termites, belonging to the family Termitidae (eg *Nasutitermes* spp. and *Microcerotermes* spp.), do not have these single-celled protozoa in their intestinal tract. Instead, they have intestinal bacteria that convert cellulose to sugars by enzymatic action.

The bacteria or protozoa are transferred from termite to termite, particularly to the very young, by contact during the grooming process, when secretions from both the anal and oral areas are exchanged. This characteristic is made use of in the control of some termite species by introducing finely divided arsenious trioxide into their workings. The dust is passed on from one termite to another with the secretions.

Moisture and temperature

Termites have thin cuticles and are therefore susceptible to desiccation. They spend most of their lives in the high humidity and temperature conditions within their workings and colony. The relative humidity in a colony of subterranean termites is about 100%. When the outside humidity is close to 100%, termite workers and soldiers may leave the security of their workings, probably in search of food. In buildings with air-conditioning ducts, termites may be found walking on floors, having been blown out of the system when the air-conditioning was turned on.

Subterranean termites obtain their moisture mostly from the soil, and in this way they maintain the colony's humidity and also use moisture evaporation for lowering the temperature in the colony. Subterranean termite colonies can survive without soil contact, but they must have an assured and constant supply of moisture. When termites occur on the top floors of buildings with no ground contact, the source of water is usually a plumbing leak or faulty roofing.

Drywood termites do not require external water sources and obtain their water from the timber in which they feed, attacking timbers in buildings that are at equilibrium moisture content. Ventilation of the subfloor areas of buildings reduces moisture and stops the growth of wood decay fungi, discouraging, but not preventing, termites. Termites favour decaying wood in moist situations to set up their colonies as it provides them with protein and often moisture.

The temperature within a termite colony usually varies between 25 and 36°C, but this depends on the species of

Figure 19.10 Packing and access galleries of *C. acinaciformis*

termite and the weather conditions prevailing. When the temperature conditions outside the colony are either very cold or very hot and the colony temperature remains at 25–36°C, the colony is considered to be healthy and vigorous.

COMMON TERMITE SPECIES

There are over 300 species of termites in Australia, but only those which damage wood are of concern to pest controllers. However, pest controllers should be able to recognise the main pest species with the aid of a hand lens. The accurate identification of termites is best done by an entomologist specialising in termites. For the identification of termite species, the soldier caste is favoured by entomologists, as this is the most characteristic caste. These may be placed in 70% ethyl alcohol or methylated spirits in a glass specimen tube and submitted for identification. If the specimens are to be sent by mail, fluids are not permitted and it is recommended that the specimens be placed in a plastic tube or container with a piece of paper or material moistened with methylated spirits and then placed in a postal pack or similar. Along with the specimens, a card indicating collector, date, place, nesting habits and abundance will assist the entomologist in identification.

Several families in the order Isoptera (termites) are represented in Australia. The most primitive (oldest in geological terms) is the giant northern termite, *Mastotermes darwiniensis*. The families and species most often encountered by pest controllers are listed below.

Mastotermitidae	*Mastotermes darwiniensis*
Kalotermitidae	*Cryptotermes* spp. (native)
	Cryptotermes brevis (introduced)
	Neotermes insularis
Termopsidae	*Porotermes adamsoni*
Rhinotermitidae	*Coptotermes acinaciformis*
	Coptotermes frenchi
	Coptotermes lacteus
	Coptotermes michaelseni
	Coptotermes raffrayi
	Heterotermes ferox
	Schedorhinotermes intermedius
Termitidae	*Microcerotermes turneri*
	Microcerotermes serratus
	Nasutitermes exitiosus
	Nasutitermes fumigatus
	Nasutitermes walkeri

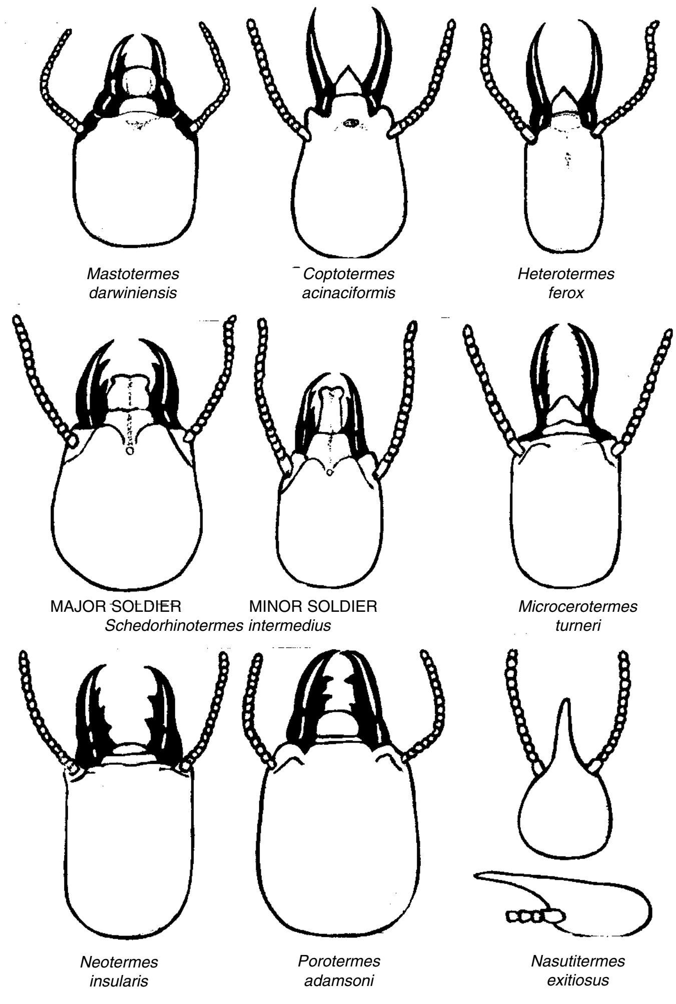

Figure 19.11 Important termite species showing the structure of the heads of the soldier caste

Family Mastotermitidae

Giant termite *Mastotermes darwiniensis*

This species occurs north of the Tropic of Capricorn, but avoids areas of high rainfall such as in rainforests.

It is the most destructive termite in Australia but, because it is limited in distribution to northern Australia, its reputation is virtually unknown by residents of southern towns and cities. It attacks any wood in contact with the ground or accessible from the ground, including shrubs and trees. It can also eat leather, certain clothing, paper and many other articles.

M. darwiniensis is a primitive species that has changed little for millions of years. The colonies are usually small, consisting of a few thousand individuals, but large colonies of some hundreds of thousands also occur. It makes subterranean nests in many places, including tree stumps and the root crowns of trees. The queens are not physogastric and there is no true worker caste; worker functions in the colony are performed by nymphs. Some of these, by a series of moults, develop into alates and leave the parent colony to establish new colonies. When a colony is opened few, if any, developing reproductives are found. Breaking-off ('budding-off') occurs when numbers of the main colony break away and establish separate colonies using developing reproductives as neotenic queens.

Control of this species usually involves arsenic dust treatments followed by a soil-barrier treatment. Eradication by arsenic dust without a chemical soil-barrier treatment does not ensure against attack from the colonies that have broken off and can exist without the parent colony. Protection of buildings may be achieved by a chemical soil-barrier treatment, but physical barriers are being tested against this species. The use of preservative-treated timber (eg wood subjected to pressure treatments using water-soluble salts of copper, chromium and arsenic) is an added protection in high hazard areas where a barrier may be breached.

Family Kalotermitidae

Most of the native species of the so-called 'dry-wood termites' live in decayed or dead wood in trees and also in tree stumps and logs. *Neotermes insularis* is typical of this group.

However, the true dry-wood termites belong to the genus *Cryptotermes* since they can live in dry wood in buildings and never require contact with the ground. They obtain their moisture from the timber in which they feed and therefore are more often encountered in tropical areas, where atmospheric conditions are more humid and wood is at or near 20% moisture content for most of the time. Even small articles of furniture and structural timber in houses can be attacked.

Cryptotermes spp. may be distinguished by their location and dark and rather compressed heads, which slope severely in front. They have short mandibles that are sharply angled inwards. They generally live in small colonies, and the reproductives may establish new colonies or groups from the parent colony even within the same host area.

West Indian dry-wood termite *Cryptotermes brevis*

This species has been introduced into Australia on several occasions and has been detected in Brisbane, Maryborough (Qld), Sydney and other areas. These infestations have been treated by fumigation using methyl bromide, as the techniques for the control of other termites are not effective against this species.

Because of its ability to attack even very small articles of wood, this species is considered the world's most serious termite pest. It has been introduced into several countries, where it has soon overshadowed existing native species. There are several reasons for its pest reputation:

1. It is easily transported from one place to another.
2. It can exist, feed and breed in very small pieces of timber and articles of furniture, as it makes small colonies.
3. It does not have contact with the ground and moisture is not a limiting factor as with subterranean species.
4. Its moisture requirement is small and it is able to exist on the timber's moisture content.
5. Reproductives leave the colony and set up new ones in dry wood often near the parent colony.
6. Damage is very difficult to detect, as no outward signs are present, particularly during the early stages. Often, first signs are the collapse of the article and the appearance of 'poppy seed' faecal pellets.
7. The winged reproductives are attracted to light and can spread in this way.

Recognition of the species is important, and it should be reported to a government authority if suspected. The soldiers are about 5.0 mm long with the typical *Cryptotermes* head, but are more rugged than most species. The mature nymphs are much the same in size, but paler in colour.

Ring-ant termite *Neotermes insularis*

This species occurs over eastern Australia from Victoria to Torres Strait Island. The name 'ring-ant' has been acquired from its habit of working in the softer growth rings of living trees. It is a tree and forest pest, living mainly in upper branches, but it can also be found in the trunk and tree stumps. Eucalypts are its main hosts, where it degrades logs that appear to be sound. Being tree-infesting termites and having their moisture requirement met by the tree's moisture, contact with the ground is not required.

Pest controllers are seldom called upon to control this termite, as it rarely attacks timber in houses and, when it is found, its site of attack is in timber which is decaying and which has a high and assured moisture content. It has been found in fascia boards below a leaking guttering. Identification of the species is important to allay the fears of householders who do not appreciate the differences in termite habits related to the species. When the termite is encountered in trees in parks and gardens, the gallery system may be quite extensive and there may be several different colonies. These are generally revealed during tree surgery, pruning or wind storms.

Determining the extent of the damage would involve considerable damage to the tree, and it is more effective to introduce a liquid insecticide into the exposed gallery system and then seal the exposed cut. Arsenic dust treatments are not recommended for there are usually many small colonies in one infestation site.

Neotermes spp., like *Kalotermes* and *Cryptotermes* spp., have no worker caste. Nymphs perform the duties of workers, but can develop into reproductives and soldiers.

N. insularis may be confused in size and appearance with *Porotermes adamsoni* which occurs in similar sites, but it may be distinguished by the following characteristics of the soldier castes:

1. The pronotum (first dorsal plate of thorax) is as wide as the head in *N. insularis*, but narrower in *P. adamsoni.*
2. The head is not obviously flattened in *N. insularis*, but in *P. adamsoni* it is.
3. The mandibles are long and curve upwards in *N. insularis*, but not in *P. adamsoni*.

Bifiditermes improbus is a species often encountered in trees and stumps in a similar host range to *N. insularis*, but it is significantly smaller than *N. insularis.*

Kalotermes atratus is a species often located in trees. It has a phragmotic head (head sloping steeply to the mandibles) similar to *Cryptotermes* spp., but can be identified on other head characteristics.

Family Termopsidae

Dampwood termite *Porotermes adamsoni*

This termite is a pest of forest trees, forming pipes and thus degrading logs for various timber uses. The pipes it forms are filled with a mud-like material often called 'mud-guts'. This species will attack timber in contact with the ground, such as poles, fencing and weatherboards, but it does not attack buildings unless there is timber-soil contact allowing access to other timbers. While *Porotermes* can tunnel below ground from dead roots of trees to wood in soil, it does not produce the external plastering and runways so characteristic of the pest species of subterranean termites. *Porotermes* requires damp and decaying wood to initiate its attack, and infestations are mostly encountered in older houses where wood is in contact with the ground and there is poor ventilation or leaks from plumbing.

This species can spread to sound timber but poses little hazard once the wood is isolated from the ground and conditions become dry. The use of arsenic dust treatments is not indicated, nor are soil treatments required unless other termite species are present. The elimination of damp conditions and the removal of decayed wood in contact with the soil significantly reduces the chances of infestation from this species.

Family Rhinotermitidae

Heterotermes ferox

This species is often encountered attacking posts, poles, paling fences and even flooring of houses. Weathered flooring, such as in timber decking and fences, is a favoured feeding site for *Heterotermes* spp. *Heterotermes ferox* has a wide distribution throughout Australia, but fortunately is not a major pest species, causing mainly superficial damage and not ranging far from its small and not populous colonies.

There are several species of *Heterotermes* but, as most are very similar, identification of the particular species is a matter for the specialist. However, *H. ferox* is the species most frequently encountered. The soldiers measure 4.75 $\pm$ 0.2 mm and have parallel-sided heads and prominent dark mandibles. Both workers and soldiers have long slender bodies when compared to the pest species of the genus *Coptotermes.* Workers and soldiers move slowly, and the soldiers are not courageous as in some other species of termites. *H. ferox* does not build mounds, nor does it have extensive gallery systems, preferring to nest near mounds or nests of other species of termites. *H. ferox* liberally plasters over its workings, and the surface of affected timber has a mottled appearance.

The location and subsequent control of this species are comparatively easy. Soil-barrier treatments are not usually required and the colony, once located, may be sprayed using one of the termite soil-poison insecticides or dug out and destroyed physically.

Coptotermes spp.

There are several species of *Coptotermes* and in most cases their identification is usually referred to a specialist in termite taxonomy. However, pest controllers familiar with the species in their area can, after observing their nesting and feeding habits, often identify the species, or at least narrow it to a choice of two. Six species of the genus are mentioned here, but there are also other species less relevant to pest controllers.

All species of the genus *Coptotermes* may be separated from species of other genera by the following characteristics:

1. The soldiers have pear-shaped heads.
2. The size of the soldiers is between 3.5 and 6.5 mm
3. A white material is exuded from a pore in the head of soldiers when they are disturbed.

Coptotermes acinaciformis This species occurs all over Australia, except for a few isolated areas. Soldiers measure 5.8 $\pm$ 0.8 mm.

This species is the most destructive of wooden buildings and other wooden structures in Australia. It is exceeded in its destructive potential by *Mastotermes darwiniensis* but as *C. acinaciformis* occurs over most of Australia, it is the more destructive species.

C. acinaciformis does not build mounds, except in its more northern occurrences. It nests in a variety of places, including tree stumps, living trees, under filled-in patios and even in walls of houses. The pepper tree (*Schinus areira*) and the English oak (*Quercus robur*) have been considered favoured nesting sites for this species, but practically any large tree, particularly eucalypts, may be chosen. A tree containing a nest of some age may house half a million to one million termites in the single colony. The nest may be located in the root crown of the tree or in the main trunk, mostly up to a height of 3 m. When nesting in a tree, this species hollows out the centre and fills much of it with the earth-like material known as 'mud-guts'. This material is usually packed above the actual nest area and is used as a guide to locating the nursery area when the colony is to be treated.

From these nests, buildings within a radius of 50 m may be attacked. The termites use their underground tunnels to achieve this range. Where a house is built near a tree containing a nest, it is often found that thousands of dollars worth of damage is done before the damage is detected and the source determined. It is therefore essential when building that trees be investigated to ensure that they do not conceal a nest. During annual inspections trees often provide clues to termite activity which is still in its early stages and not obvious.

It has been considered by many that this species needs contact with the ground; but provided there is a constant water supply and food is available, soil contact is not essential. Isolated colonies of *C. acinaciformis* have been found several levels above the ground in city buildings where there was no contact with other floors. Wooden barges on Sydney Harbour have often contained a colony, and these termites could not have had any soil contact.

The treatment of this species varies, depending on the situation of occurrence and the hazard to buildings nearby. The following broad control procedures are listed, but each infestation must be considered individually:

1. Locate and destroy the colony where possible, using chemicals approved for this type of treatment or whatever appropriate control measures are indicated.
2. Use arsenic dusts treatments where eradication is feasible.
3. Chemical soil-barrier treatments are usually necessary, as there may be another colony or dust treatment may have been only partially successful or not possible in the particular sites.
4. Where timber replacement is necessary, the use of preservative-treated timber often saves the embarrassment of replacing the replaced timbers eaten out after the initial attack and treatment.
5. Inspect the building annually or more frequently, depending on the degree of hazard.

Coptotermes dreghorni This species occurs mostly in the rainforests of northern Queensland. The soldiers measure 5.2 ± 0.4 mm. It is not a pest species, since it feeds on wood in the forest debris.

Coptotermes frenchi This species occurs from northern Queensland to South Australia. It is a forest pest, nesting in trees. The soldiers measure 4.6 ± 0.6 mm. Although it attacks houses and buildings in Victoria, it does not have the same destructive potential as *C. acinaciformis.* It does not pack pipes in trees as does *C. acinaciformis*, a useful diagnostic feature, and the control measures are the same as for the pest species.

Coptotermes lacteus This species occurs in Victoria, New South Wales, the Australian Capital Territory and southern Queensland. The soldiers measure 4.4 ± 0.4 mm. It builds large mounds and attacks any timber in the ground, such as posts, poles, and timber and forest debris on the ground. Control is seldom required, as the species does not attack buildings, but when necessary the colony may be broken up or destroyed using short-term residual insecticides.

Coptotermes michaelseni This species occurs in south-western Australia, South Australia and the Murray Valley region of New South Wales. The soldiers measure 4.0 ± 0.2 mm. It makes low dome-shaped mounds and may at first be confused with *Nasutitermes exitiosus*. Its feeding habits are similar to *C. lacteus.* As it does not attack buildings, control, when required, merely involves destruction of the colony.

Coptotermes raffrayi The occurrence of this species is restricted to south-western Australia, where it is regarded as a pest species attacking buildings. The soldiers measure 5.5 ± 0.5 mm. It makes small mounds near trees or stumps. Control measures involve the destruction of the small colony, when it has been located, or the treatments outlined for *C. acinaciformis.*

Schedorhinotermes spp.

There are several species of *Schedorhinotermes* which occur throughout Australia. While there are species which overlap in their distribution the approximate ranges are given for each species. However, the identification of the species is a very specialised task.

Schedorhinotermes intermedius This species occurs over most of Australia in its various forms. It is characterized by having two sizes of soldiers, which also differ in appearance. They are both mandibulate and are generally known as either major soldiers, which measure 5.6 ± 0.6 mm, or minor soldiers of 3.6 ± 0.6 mm. The head shapes are characteristically different in the soldier castes, and they do not produce a white latex as do *Coptotermes* spp.

S. intermedius is a subterranean termite, nesting in trees, under patios and in tree stumps; it is often located in the ground immediately under fireplace foundations. The nest may be very populous, consisting of many thousands of individuals. When only minor soldiers are found, the colony is either weak or young. The appearance and abundance of major soldiers indicate a well-developed and strong colony.

The species is second in pest status to *Coptotermes* spp. in most parts of Australia where it occurs, except in the northern part of Australia, where *Mastotermes darwiniensis* is the major pest species. Although *S. intermedius* is a destructive species, there may be extensive surface tunnels and plastering but insignificant damage, although the converse also holds. It is very difficult to evaluate its damage to buildings without a very thorough survey of its activity.

Various species of *Schedorhinotermes* occur throughout Australia. Identification of these species is well beyond most pest control operators and 'general practitioner entomologists' and must be referred to termite specialists with all collection details. However, the following distribution details of the various species may serve as a rough guide:

Schedorhinotermes intermedius occurs from southern Queensland to Nowra on the south coast of New South Wales and is mainly coastal.

Schedorhinotermes actuosus occurs in northern Australia, from Geraldton in Western Australia, through Alice Springs to Cairns in Queensland.

Schedorhinotermes breinli occurs in the Northern Territory southwards to Newcastle Waters and in coastal Queensland north of Gladstone.

Schedorhinotermes derosus occurs in northern Western Australia

Schedorhinotermes reticulatus This species occurs in Western Australia, New South Wales and northern Victoria, but there is very little difference in size of the soldiers compared with *S. intermedius.*

Schedorhinotermes seclusus occurs in coastal eastern Australia, from Cairns in Queensland, to Taree on the central coast of New South Wales.

Control of *Schedorhinotermes* spp. involves locating the nest where possible, arsenic dust treatment of the workings where appropriate, and treatment of the soil around foundations to prevent further access to buildings. The use of arsenic dust eradication treatment is seldom successful as the termites disappear rapidly from the treatment sites and insufficient dust is distributed amongst the workers and soldiers to be returned to the nest area to eradicate it.

Family Termitidae

There are several genera belonging to this family, most of which differ markedly in appearance.

Microcerotermes turneri

This is a frequently encountered species occurring north of Port Macquarie on the central coast of New South Wales and well into coastal Queensland. The soldiers measure 5.20 ± 0.4 mm.

It builds arboreal nests, nests on posts and poles, mounds on the ground and also nests underground. The workings of *M. turneri* may be distinguished from those of *Nasutitermes walkeri* by their paler colour.

There are several species of *Microcerotermes,* but these have their particular areas of distribution. *M. serratus* has similar habits to *M. turneri,* and occurs in the Northern Territory, Queensland Western Australia and some parts of New South Wales. The size of the soldiers is 4.40 ± 1.0 mm. The soldiers of all species have long mandibles which, when viewed from the side, do not curve, and their heads have rather straight sides. Identification of the separate species in this genus is well beyond most pest controllers and, if a species name is required, the assistance of a specialist should be sought. However, identification of a termite to the genus *Microcerotermes* should be within the ability of pest controllers.

There are other termites belonging to several genera, but the identification of these requires specialist knowledge and microscope facilities. In some cases the nest is characteristic and an identification is possible without seeing the soldiers. This is the case when a colony of the compass termite is seen near Darwin.

Compass termite *Amitermes meridionalis*

This is the best-known species to those visiting the Darwin area. Its nests reach a height of 3–4 m and are about 3 m thick on the east–west face, but only about 1 m thick on the north–south face. In this way it reduces the extremes of summer and also stores warmth in winter.

Nasutitermes spp.

Identification of the many species in this genus is for the termite specialist, who needs information on the area of occurrence and nesting habits as well as specimens. Species of this genus have soldiers with nasute heads (head tapering to a long snout or nasus) and very much reduced mandibles, which are not obvious from above. The soldiers are smaller than the workers, and their legs appear longer and more fragile. The workers are somewhat arched and more heavily built in the front section than the workers of mandibulate genera. They also have two small dark areas on the top of the head.

Some species damage timber in service, while others feed only on decaying wood. Most species, however, are grass and debris feeders and are of no concern to pest controllers. The mound-building habit is very pronounced in some species, but others build arboreal nests, and some are entirely subterranean.

Some of the more frequently encountered species of *Nasutitermes* are listed below. Although their identification is for the termite specialist, their distribution and nesting habits may allow pest controllers to identify the more obvious species.

N. apiocephalus (3.60 ± 0.20 mm) — Southern region of Western Australia.

N. dixoni (3.75 ± 0.25 mm) — A coastal species occurring from the Victorian/South Australian border to the central coast of New South Wales.

N. exitiosus (4.20 ± 0.60 mm) — Most areas of southern Australia, generally south of the New South Wales/ Queensland border.

N. fumigatus (3.5 ± 0.20 mm) — Coastal South Australia to central Queensland.

N. graveolus (4.30 ± 0.30 mm) — Coastal northern Australia from Townsville to Darwin.

N. longipennis (4.00 ± 0.50 mm) — Coastal Queensland to the Northern Territory.
N. magnus (5.50 ± 0.50 mm) — Coastal eastern Australia from Grafton, New South Wales to Cairns, Queensland.
N. occasus (3.9 ± 0.20 mm) — Southern region of Western Australia
N. triodiae (4.5 ± 0.25 mm) — Northern Australia
N. walkeri (6.0 ± 1.0 mm) — Coastal eastern Australia from Sydney to Cairns.
N. westraliensis (4.8 ± 0.5 mm) — Southern region of Western Australia.

Nasutitermes apiocephalus This is a debris-feeding species which occurs in Western Australia.

Nasutitermes exitiosus This is a mound-building species, except in drier areas, where it nests in tree stumps or below ground, often leaving bare earth above it. Because of its obvious nesting habits it is not regarded as a serious pest species, but it is capable of extensively damaging timber structures where the nest goes unnoticed. This species often builds its nests under houses and unless the subfloor area is inspected the colony can go unnoticed. The mounds are usually 30 to 70 cm high and 1 m in diameter. When the nest is prised up at ground level, there is always a good chance of collecting the physogastric queen, which may measure 25–30 mm. Control is simply achieved by destroying the colony, as the species does not form supplementary queens. As in most species of *Nasutitermes* the soldiers are courageous and rush to any breach in the colony system.

Nasutitermes fumigatus* and *Nasutitermes dixoni These are subterranean species doing very similar damage. They attack decaying wood that is mostly in contact with the ground. Where decay has occurred to flooring timbers in a house, due usually to bad ventilation, these termites will further damage the wood, often making replacements necessary. They do not attack sound structural timbers in well-ventilated situations. These species must always be considered as the possible pest species in badly ventilated subfloor areas. Where a nest of *N. exitiosus* cannot be found, these species must be considered as a possible cause of damage where nasute soldiers are involved.

Nasutitermes graveolus This species is similar in habits to *N. walkeri*, but it occurs further north and its soldiers are smaller.

Nasutitermes longipennis The soldiers of this species have distinctly red heads. They may build mounds, which may resemble those of *N. exitiosus*, or they may be entirely subterranean. This species also attacks wood that is contact with the ground, but it is not a pest of sound dry wood.

Nasutitermes magnus This is a mound-building species and a grass eater. Apart from its detection and separation from pest species it is of no concern to pest controllers as it does not attack timber in service.

Nasutitermes occasus This species has much the same role in south-western Australia as *N. fumigatus* and *N. dixoni* have in eastern Australia.

Nasutitermes triodiae This species builds large mounds, often up to 6 m high, is a grass eater and its presence is not a hazard to buildings, even if the mound is nearby.

Nasutitermes walkeri This species has the largest soldiers and is often encountered in the coastal bushland of Sydney and further north, where it constructs its characteristic arboreal nests. It mainly nests in stressed trees, and some years after a bushfire its nests may be abundant in a comparatively small area. Colonies appear to be initiated in the root crowns of trees where there is some decay or basal fire damage. When the colonies are well established and numbers are large, it constructs arboreal nests higher up the trees. Although damage may be done to fences, poles and wood in the ground, attack of buildings is rare and is usually associated with unusual circumstances such as decaying wood and high moisture.

Nasutitermes westraliensis This species is mainly a grass and debris feeder. The soldiers have a characteristic downward turn in their rostrum (extension of their nasute head).

CONTROL OF TERMITES

The survey

When inspecting or surveying a building suspected to be infested by termites, it is important to consider the following aspects:

1 Prepare a diagram of the building and the grounds around it, including the trees and landscape modifications. This will assist in the final recommendations on control. Such a diagram could reveal the nest area and even the point or points of entry.
2 Collect soldier caste termites from areas of infestation both outside and inside the building without disturbing the areas excessively. The possibility of the existence of more than one colony, of the same species or of a different species, must always be considered. Identify or have identified the species. This information is placed on the diagram. The destructive species should be known by the average pest controller.
3 Make an effort to locate the colony or nest. There may be more than one, perhaps of different species.
4 Inspect fences, trees, tree stumps and areas where timber may have been buried during building or other soil changes.
5 Inspect the house, including the roof and subfloor areas, paying particular attention to the soil/building contact, whether of slab construction or on foundations.
6 While confirming the termites' presence, take great care not to disturb the workings excessively. This is best achieved by making a very tiny opening in a shelter tube or infested timber. Sometimes a splinter of the timber can be partly levered off and then replaced in position. In this way soldiers can be collected for identification.

7 Also indicate old damage as distinct from active workings on the survey sheet.

The survey sheet not only provides an accurate record of an inspection, but also allows the person doing the treatment to concentrate chemicals in areas of greatest hazard.

Eradication by use of dusts

The introduction of finely divided arsenious trioxide dust into active termite workings exploits the termites' habit of grooming each other. The fine dust is taken in by the termite doing the grooming, along with the exudate from the other's body. Arsenic is a metal poison that damages the cells lining the intestinal tract, so that the termite dies. Cannibalism of sick termites and eating of the dead are considered by many to occur, but grooming is the main cause of the colony's destruction, as many thousands of termites are found in the nest and surrounding area after a successful dust treatment.

Arsenious trioxide (white arsenic) is the most frequently used chemical for eradicating termites, but it is essential that it is very finely divided and does not clump. Ferric oxide is often added to keep the arsenic powder dry when it is in the workings, which may at times be moist. Paris green (copper acetoarsenite) has also been used successfully as a dust for termite eradication, but most pest control operators in Australia use arsenious trioxide, either straight or diluted with up to 50% of ferric oxide.

When using any arsenical dust it is essential that as many termites as possible be dusted, preferably workers, which are directly associated with the activities of the colony. This must, however, be done with minimum disturbance of the colony. The following points will assist in using arsenical dusts, but it is essential for the operator to be patient and thorough; experience in termite dust treatments is essential.

It is important that arsenious trioxide dust be used and not arsenious pentoxide which absorbs atmospheric moisture and becomes partly soluble in the sapwood of trees when the nest is treated. Trees have been killed by the use of arsenic pentoxide and it is not an approved chemical.

1 Use a blower suitable for the task. This is a personal choice, but a de Vilbiss powder blower, a dental chip blower or a specially made blower fabricated for this work is suitable and these are available.

2 Only quarter- to half-fill the blower, as the air must contain a very small amount of dust. If there is too much dust, the workings will be blocked, and the termites will seal off the treated area.

3 The dust may travel about a metre from the treatment point as it is blown into the opening. In this way the walls as well as the termites will be very lightly dusted.

4 Treat the damaged timber, starting mostly at the less remote sections. Leave the main earthen access shelter tubes to the building untreated where possible. Treat as many separate sites as possible, so that many of the dusted termites will return to the nest.

5 Prise open the area in which the dust is to be applied, carefully insert the tip of the blower and gently introduce the dust, and then allow the small piece of timber to fall back into place, so that no hole is left. If a hole does remain, it will be mostly sealed off by the termites or a piece of adhesive paper may be applied over it.

6 Dust treatments are more effective when the termites are active. This is usually in the warmer months, particularly just before a swarming flight. In the case of *Schedorhinotermes intermedius*, where dust treatments often fail, a successful result is more likely immediately before a colonising flight.

7 To clear the treatment sites of the toxic dust, a battery-operated vacuum cleaner is very effective and should be standard equipment for arsenic dust treatments.

8 Remember: the dust is poisonous and will remain toxic for long periods in the treated sites, so it is often safer to use an approved liquid insecticide, flooded into the colony where the nest is located. The use of permethrin dust is considered under the heading of 'location and treatment of termite colonies' and is an approved treatment where the nest or colony has been located. Metal probes may be used to facilitate the entry of liquids or dusts into a located colony. However, each situation must be considered independently and the choice of treatment method determined.

9 Note all treatment sites on the previously prepared survey sheet.

10 Inspect the workings after 10–20 days to determine whether the treatment has been successful. The possibility of a second or even a third colony must always be considered and other inspections may be necessary.

11 Arsenious trioxide dust has been used successfully for many years for the eradication of colonies of *Coptotermes* spp. There is always a slight danger of some of the dust lodging in the sapwood area of the drilled hole. The sap may change some of the water-insoluble dust to a soluble form of arsenic and this could have a damaging effect on the tree. When using arsenic dusts in living trees a thin sleeve of plastic tube in the sapwood area would protect the tree from any toxicity. Liquid insecticides such as chlorpyrifos are used or permethrin dust where this hazard is to be avoided.

Triflumuron, an insect growth regulator — IGR (chitin synthesis inhibitor) — is undergoing commercial trials for the eradication of termites when used as a dust. The application is similar to that for arsenious trioxide, but it has a low toxicity to warm-blooded creatures. The termites, mostly the immature stages, have their cuticle formation blocked by triflumuron and death occurs when replacement of the cuticle fails. However, the time period for eradication is much longer than that for arsenious trioxide, and usually occurs within 2–6 months after application.

Location and treatment of termite colonies

When termite activity is located, it is imperative that the species of termite is known so that a search for the colony can then follow. The identification of the species is important because the nesting habits vary significantly.

The basic procedures in termite control are:

1. Locate the colony and eradicate it. This requires some skill and experience and there is always the possibility of a second or third colony in the immediate vicinity. When the offending colony is located the cost involved is usually small in comparison to chemical barriers. Nest location is one of the very few options remaining to those who do not wish chemical barriers to be placed around their houses.
2. When termite damage and activity are present and the colony cannot be found, the arsenious trioxide dust treatment of the workings with the aim of eradicating the colony is usually carried out. Often, when the amount of activity is small, the chances of success in such cases are slight. When a dust treatment has been carried out, regular inspections must be made for some time afterward as this type of eradication procedure is not considered reliable.
3. The establishment of chemical soil barriers to isolate a building from a termite colony has proved successful for many years. These treatments also may involve drilling through concrete slabs for the injection of the chemical in order to form a barrier beneath that will prevent access through the concrete.

'Termatrac' is a recently developed device in Australia for locating termite activity behind timber, masonry or brick. The unit emits signals that penetrate the material without disturbing the termite activity within or affecting the surface in or behind which this activity occurs.

The location and treatment of a colony is important whether arsenic dust is used before or after, or whether a chemical barrier has been installed around a building. When inspecting the area surrounding an infested property, trees, stumps, wood piles and in fact any food source for termites should be investigated as a possible location of the colony. *Schedorhinotermes* spp. nests are also found in and under compost heaps and piles of woodchip that have been in place for some months. These species are often encountered in woodchips over the soil and this can assist in the location of the nest.

Trees and tree stumps are favoured nesting sites for *Coptotermes acinaciformis* and some other termite species. There may be no obvious outward signs, but the trained and perceptive eye can often detect the presence of termites within. Earthen material at the base of a tree often betrays the existence of an internal colony. Callused areas of bark produced to seal flight cuts from which the winged sexual castes had previously left the colony may assist in establishing the presence of a colony.

To confirm the existence of the colony within and to locate the actual nursery area of the nest, the tree or stump is usually drilled. Large holes damage live trees and unless carefully treated and filled, rainwater will enter the holes and cause basal decay and later instability of the tree. Too many holes and failure to seal them reflects unfavourably on the pest control company. The following is a procedure for locating and treating a nest in a tree, but practical application is essential for successful results.

1. The first hole is usually drilled towards the centre of the trunk and the root crown area using a 10–12 mm auger bit. The length of the bit is usually 15–20 cm. To confirm the location of the nest area it is often necessary to drill 3–4 holes.
2. When the drill bit is removed examine it for active or dead termites. Insert a long blade of grass or similar into the hole, leave for a few minutes and when it is withdrawn termite soldiers should be hanging onto the grass with their jaws.
3. As each hole is drilled insert a long temperature probe which records the temperature within the tree/nest area on an external digital display.
4. The temperature of a healthy colony of *C. acinaciformis* is usually about 36°C. Temperatures of 26–34°C often indicate the central nursery area is close and a further hole must be drilled to locate it.
5. Once the centre of the colony is confirmed its eradication is usually achieved by treatment with liquids of chlorpyrifos or bifenthrin. Permethrin dust can also be used and arsenious trioxide dust can be used in some states. Triflumuron is also a successful dust treatment, but is usually slower in achieving eradication.
6. To prevent decay in the holes they are usually lined carefully with copper naphthenate and then filled with a durable caulking compound which will ensure against water entry.
7. The tree should be reinspected and the temperature taken about 2–4 weeks after the treatment to confirm the result.

If the temperature is taken a few days after the treatment, readings up to 45°C may be obtained due to the decomposing bodies of the dead termites. After two weeks the temperature inside will be approximately the same as that outside if the treatment has been successful.

However, if part of the termite population has been isolated at higher levels in the tree and in buildings, it does not always return to the contaminated nest area and will slowly degenerate over the next few months. They may live longer, particularly if there is an assured moisture source.

Permethrin dust

Permethrin is a pyrethroid insecticide of relatively low toxicity to mammals. It kills on contact within a few hours those termites occupying a nest area. The treatment usually requires about 200–250 gm of permethrin dust and is applied from a small container connected to a cylinder of compressed air or carbon dioxide to ensure its distribution within the colony. Those termites in remote locations are not killed, and they usually do not return to the contaminated nest. Depending on the conditions, these isolated termites can live for several months.

PREVENTION OF ATTACK

Prior to 1993 there were three Australian Standards that dealt directly with termite prevention and control. These were:

1 **AS1694–1974** — Code of Practice for Physical Barriers Used in the Protection of buildings against Subterranean Termites.
2 **AS2057–1986** — Protection of Buildings from Subterranean Termites — Chemical Treatment of Soil for Buildings under Construction.
3 **AS2178–1986** — Protection of Buildings from Subterranean Termites — Detection and Treatment of Infestation in Existing Buildings.

As from 1993 these three Australian Standards were incorporated into one Australian Standard, namely AS3660 — Termite Management. This standard has since been revised and is now available in three parts:

1 **AS3660.1–2000** — Part 1: New Building Work.
2 **AS3660.2–2000** — Part 2: In and Around Existing Buildings and Structures — Guidelines.
3 **AS3660.3–2000** — Part 3: Assessment Criteria for Termite Management Systems.

Australian Standards in the AS 3660 series cover most aspects of termite prevention and control. Therefore the specifications and application techniques covered in the Standard are not repeated here. Those performing this work must possess a copy of the Standard, skills in the work and the necessary equipment for the establishment of chemical and/or physical barriers.

Chemical soil treatments (Soil-barrier treatments)

The chlorinated hydrocarbon insecticides of the cyclodiene group that includes chlordane, heptachlor, aldrin and dieldrin were used in Australia from the early 1950s to establish protective chemical barriers preventing the entry of termites into buildings. The use of these chemicals was banned in most parts of Australia in 1995 and throughout Australia soon after. Many other countries have also banned their use for environmental and toxicity reasons.

The organochlorines have been replaced with the organophosphorus insecticide chlorpyrifos, the pyrethroid bifenthrin and more recently the chloronicotinyl im idacloprid. Imidacloprid does not repel termites but kills them slowly. When they enter treated soil areas; it spreads through the soil so that even on the edge of a treated zone termites are affected by certain pathogenic soil fungi and slowly die. These pathogens can also affect those termites in the nest, leading to its possible eradication.

Existing buildings

Where termite attack has occurred to existing buildings and the colony cannot be located, pest controllers usually use an arsenical dust to attempt to eradicate the colony. This type of treatment cannot always be relied on and to protect the building against further attack and ensure against recall treatments and costly repairs, a soil-barrier treatment is often carried out. Chemical soil treatment, using a residual insecticide such as chlorpyrifos enables the pest control company to give some warranty against further termite attack within a certain time period. Where a client does not wish to have such a soil-barrier treatment done, the pest control company is usually not prepared to give any warranty on arsenic dust treatments alone. Many companies do not use the dust treatment, preferring to apply a soil-barrier treatment only, and on this they may be prepared to give a warranty. Soil-barrier treatments do not usually kill the colony, as their function is purely to exclude termites from the building, and therefore the colony must find other sources of food — sometimes the building next door.

The barrier is established by trenching around foundations, scarifying the soil where necessary or injecting the insecticide into the soil with special equipment. Concrete paths which adjoin buildings are usually drilled and the soil beneath injected with an approved chemical. This is all detailed in the current Australian Standard.

Where a treated barrier is required around a concrete slab, creating this external barrier involves digging a trench and treating the soil with an aqueous emulsion of chlorpyrifos or an approved insecticide for this purpose.

Where slab treatment is required, the slab may be drilled and an aqueous emulsion insecticide injected into the soil beneath. Drilling the slab usually involves lifting carpets or other covers and re-laying them after the chemical treatment and sealing the holes. Special types of flooring present rather special problems, and the cost of such a prerequisite to treatment may be considerable.

Buildings under construction (pre-treatment)

The cost of termite treatment and the renewal of damaged timbers have been major factors in the general acceptance of soil pre-treatment during the erection of a building. It is now a normal provision in many building specifications for a soil-barrier treatment to be carried out. One of the most costly termite treatments is required when attack occurs in a building on a concrete slab-on-ground or slab-on-fill. It is therefore sound judgement and good procedure to have a soil treatment carried out before the concrete slab is poured.

For normal pier and foundation wall construction, the treated soil must be continuous around all foundation piers, walls and footings of cavity walls. There must be no untreated soil through which termites can gain access to any part of the building foundations or footings. External barriers are of special value in preventing access from garden areas where vegetation may hide earthen termite access tubes. Any disturbance of the chemical barrier during subsequent building operations will allow termite entry and require the soil to be retreated.

A reticulation system whereby PVC plastic piping is placed under a building, including slab-on-ground, thus providing access to the soil for the distribution of an approved chemical, is an alternative method of installing chemical soil barriers. The chemical is usually administered via the pipes from a position external to the building and is then distributed through the soil by perforations in the PVC pipes which ramify beneath a slab or subfloor area. The retreatment is done approximately every 3–5 years depending on the site and the result of annual inspections. Reticulation systems may also be used for perimeter treatments of slabs.

Chemical moisture barriers

Plastic moisture barriers are under concrete slabs, but 'Kordon TMB' is a product which serves two purposes, namely it provides both a chemical and physical barrier by incorporating a termiticide (deltamethrin) within the plastic moisture barrier. The deltamethrin, a pyrethroid, is bonded into the fibrous webbing between the upper and lower and lower sheets of plastic. Special provision is made for sealing areas

TABLE 19.1
Termite control: summary of methods and species

Termite species	Arsenic dust treatment	Surface spraying	Soil barrier treatment	Other methods
Mastotermes darwiniensis	Yes	No value	Yes	Take care that subsidiary nests do not exist.
Neotermes insularis	No value	No value	No	Tree-infesting; control not often required. Liquid insecticide into exposed colonies.
Porotermes adamsoni	No	Yes	No	Isolate timber from soil to remove risk. Locate the source.
Heterotermes ferox	No	Yes	No	Small colonies; spray treatments adequate.
Coptotermes acinaciformis and other pest species	Yes	No value	Yes	Flood nest if located with aqueous insecticide or permethrin dust.
Coptotermes frenchi	Yes	No value	Yes	Often nest in trees, flood nest if located with aqueous pesticide or permethrin dust.
Coptotermes lacteus	No	No value	No	Not a pest species; flood mound nest with insecticide.
Schedorhinotermes intermedius	Yes. Seldom successful	No value	Yes	Flood nest if located with aqueous insecticide.
Microcerotermes turneri	No	No value	No	Colony obvious; flood nest if located.
Nasutitermes exitiosus	Optional	No value	Optional	Nest or colony usually obvious; flood or remove.
Nasutitermes fumigatus	No	Yes	No	Attacks timber in ground; spray the source or nest.
Nasutitermes walkeri	No	Of some value	No	Remove nest from tree; flood into area of attachment and the root crown.
Cryptotermes sp.	No	No value	No	Flood into area that reveals activity in tree.
Cryptotermes brevis	No	No value	No	Report activity to a scientific organisation with specimens.

where plumbing and other service facilities pass through the plastic sheet. A warranty period of 10 years is given once the barrier is installed correctly. Disturbance or fracture of the plastic during any repairs to a building can allow termite entry and would negate any warranty.

Deltamethrin kills those termites which gain entry into the plastic and there is also a degree of repellency.

Use of chemically treated timbers

Surface treatments of timber using insecticides are of little practical value and may serve only to create an impression of false security. Preservative-treated timber, which has been available on the Australian market for many years, is of great value where termite attack has occurred or there is a long termite history. Preservative-treated timber has usually been treated with copper, chromium and arsenic salts by a pressure process or a dip diffusion method. The sapwood is completely impregnated with a minimum lethal concentration of salts that remain 'fixed' in the timber and are not leached under normal service conditions. The complex of salts is toxic to termites, borers and most decay fungi. The heartwood is not penetrated by these preservatives because of its cellular composition.

When a building's structural timbers are of preservative-treated wood, termite attack is restricted to untreated interior-joinery timbers, and even these can be purchased treated by one of the currently approved processes. Replacement of termite-damaged timbers with treated wood ensures against the embarrassment of again replacing timbers if the termites have not been eradicated or their entry has not been prevented.

Use of naturally resistant timbers

Timber species resistant to termites have been known for many years and exploited for building by settlers in areas of high termite hazard. However, not all these resistant timbers show resistance to all species of termites. For instance, douglas fir (oregon) is resistant to *Nasutitermes exitiosus* but very susceptible to *Coptotermes acinaciformis* and *Schedorhinotermes intermedius*. The following timber species show varying degrees of resistance to most termite species:

American redwood (*Sequoia sempervirens*)
Black bean (heartwood) (*Castanospermum australe*)
Bloodwood (*Eucalyptus corymbosa*)
Jam acacia (*Acacia acuminata*)
River red gum (*Eucalyptus camaldulensus*)
Southern Cypress (USA) (*Taxodium distichum*)
White Cypress pine (*Callitris columellaris*)
Jarrah (*Eucalyptus marginata*) is susceptible to *N. exitiosus*, but resistant to *C. acinaciformis*, and hoop pine is resistant to *N. exitiosus* but susceptible to *C. acinaciformis*.

Naturally resistant timbers are of little practical significance in the building industry at present and there is no evidence that this will change for the average person in the future.

The physical barriers

Physical barriers have been designed to isolate a building from termite colonies located outside. The colonies are usually in trees, tree stumps or a food source on the ground.

Prior to the mid 1950s before slab-on-ground type construction, most houses were build on piers and dwarf walls and had raised flooring. Ant caps, usually of galvanised iron, were placed on piers and as continuous runs of metal on walls to prevent termite access to the subfloor bearers and joists and thence to the structural timber in the walls and roofs. While pier construction is still available, most houses are now constructed on concrete slabs or partly so.

The main pest species of termites are able to cross metal caps by building earthen leads and packing over the edges of caps, even when these have been correctly applied. However, caps are often not applied correctly or have been damaged during building and therefore do not have the specified turndown angle of 45°, thus making the termites' crossing easier. Once crossed, the earthen leads betray the presence of the termites and are then detected during annual and pre-purchase inspections or even by vigilant homeowners; this is the main value of ant caps.

In recent years finely divided granite has been used as a physical barrier under concrete slabs to prevent termite access to the timber component of the building. Stainless steel mesh has also been tested for protection against termite entry into buildings and it is now available to those building new houses.

It will require many years of service life of these two products to evaluate their effectiveness. The principle of exclusion of termites has been tested by various scientific organisations with good results, but these products face such factors as home sale without records, failure to continue annual inspections, landscaping and gardening procedures near a protected house, tree roots and rodent activity, particularly in respect of granite barriers, service plumbing and electrical changes and various home additions. Communication between vendors and purchasers of houses would help to preserve these barriers and ensure inspections are made on a regular basis. The relevance of termite activity and the importance of established barriers should be conveyed to new owners at time of sale, possibly with the deeds of the property. This will assist the new owners to respect and preserve the physical barriers.

Granite barriers

The use of finely divided basalt was first tested in Hawaii for the protection of buildings from attack by *Coptotermes formosanus*, the local pest species in that state. The particle size tested and later approved was 1.7–2.4 mm. *C. formosanus* could not pass through the basalt barrier because the particles were larger and heavier than the termites could move. As with most inert barriers, termites can go around them and therefore exterior vigilance is necessary.

Granite was tested in Australia against native *Coptotermes* spp. which are comparable in size to *C. formosanus.* The size of the particles is similar to that of the basalt tested in Hawaii and the specifications and other relevant application details appear in the Australian Standards AS 3660 series. A larger termite species such as *Mastotermes darwiniensis* would probably require a different particle size from *C. acinaciformis*.

Details of these barriers for new homes and existing buildings where slab-on-ground construction is used are featured in the Standard series AS 3660. It is claimed that such a barrier under a slab will adjust to any movement which may occur and thus remain impenetrable. The granite barrier appears to have particular application where the waffle-pod slabs are used. This is also covered in AS 3660. Further details appear in the Standard and are also available from the companies that market this product.

Stainless steel mesh barriers

The Australian Standards in the AS 3660 series describe in detail and with illustrations the application of stainless steel mesh barriers to buildings under construction. The product also has relevance to certain sites where cracking occurs in existing buildings.

The material depends on the mesh size and its durability for its efficacy in protecting buildings. The mesh, when applied in accordance with the illustrations and descriptions in the Australian Standard, is claimed to prevent termites penetrating it and gaining access to a building. The heads of termites are too large to pass through the maximum aperture size of 0.66 x 0.45 mm.

The companies that market the stainless steel mesh advise on the installation and can provide information on the testing of the product against pest termite species. A special size of mesh, 0.40 x 0.40 mm, is used for northern Australia, where *Heterotermes vagus* occurs, because termites of this species have small heads. Special items for placement around service pipes are also part of the installation and this aspect is also covered in the Standard.

Annual or more frequent inspections depending on the termite hazard are essential for granite barriers and stainless steel mesh when these have been installed.

Steel-framed houses

The use of steel frames in houses reduces the incidence of termite infestation in two ways. First the presence of steel piers, bearers and joists in the subfloor area deters termites from entering a building. Secondly when termite leads are present they are more easily detected during inspections.

Steel wall framing and steel roof trusses will significantly reduce major termite damage in buildings. While timber is used for joinery within buildings, the presence of termites is easy to detect both in the subfloor areas and roof voids when steel members are present. Steel frames in walls ensure termites have further to go when searching for susceptible timbers.

Use of timber bait monitors

Timber bait monitors serve several purposes. They provide evidence of termite presence, enable identification of the termite species and a site where an eradication treatment using arsenious trioxide or an insect growth regulator (IGR) can be applied.

The bait monitors are made from susceptible species of timber such are douglas fir, radiata pine or mountain ash. The most simple monitors are pieces of timber approximately 100 x 100 x 400 mm partly buried in the ground. A frequently used bait monitor originally developed by the CSIRO consists of a foam plastic box with access holes for termite entry that is placed in the ground. The box is usually filled with timber, cardboard or paper or a mixture of these and the top sealed and then covered. When the materials inside the box are attacked and the termite species identified, the interior is dusted with arsenious trioxide or an IGR or other approved treatment.

The selection of the timber species is important. One pest species, *Nasutitermes exitiosus*, is not attracted to pine timbers. Mountain ash, *Eucalyptus regnans*, a timber species often used for bait monitors, is susceptible to most pest species of termites, particularly *Coptotermes* spp. and *Schedorhinotermes* spp. These termites attack many species of pine with the exception of our native cypress pines which have some resistance, particularly in the heartwood. The location of bait monitors is critical for both efficacy and safety when treatment is carried out.

Permethrin dust is not suitable for treatment of bait monitors as it kills quickly and the dust is not passed on to the colony and other areas of activity.

The 'Sentricon Termite Colony Elimination System' is a sophisticated method for the eradication of termite colonies and embraces three phases in its activity, namely:

1. Initial monitoring of termite activity with specially designed bait stations containing susceptible timber.
2. Replacement of the susceptible timber in the bait station with a bait containing the IGR hexaflumuron. The hexaflumuron, a chitin synthesis inhibitor, is spread throughout the colony until eradication is achieved.
3. Once eradication has been achieved, monitoring is resumed to detect any new activity.

Plastic monitoring stations are placed in the ground around the periphery of a building. When the timber within the station is replaced with the hexaflumuron, some time may elapse before eradication is achieved. Even when the bait monitoring stations are in place, termites can still have access to a building and only when the bait monitors are attacked is the hexaflumuron passed on to those termites in the nest.

Other commercially available bait monitoring systems are currently being evaluated. Many pest control technicians prepare and install their own types of bait stations and in most cases arsenic trioxide is used to eradicate the colony.

FURTHER READING

Australian Standard AS 3660–2000 *Termites Management* Standards Australia Sydney

Australian Standard AS 3660.1–1995 *Protection of Buildings from Subterranean Termites — New Buildings* Standards Australia Sydney

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CHAPTER 20

FUNGAL DECAY

During pre-purchase and annual inspections of houses and buildings the detection of high levels of moisture is an important part of the report. Many problems in the area of pest control are moisture-related or even dependent on higher than normal moisture levels. Wood decay, termites and even certain cockroach species are favoured by abnormal moisture levels.

When dampness is detected, the location of its source is important in a report and also when advice is given to a client. Rising damp, a source of moisture, is sometimes encountered and is an area of pest control which requires staff skilled in its treatment. There are many other causes of dampness, such as plumbing leaks, bad ventilation and roof damage and all of these can be precursors of wood decay which can then occur between annual inspections Mould fungi which are only superficial in their activity should alert the pest controller to possible high moisture levels which may be present in other areas of the building.

A moisture meter is an essential piece of equipment in the inspection of houses for it can detect incipient and increasing moisture levels in wood. These can be due to water leaks, termites and other causes. A knife is an important tool for detecting and evaluating decay in timber during these inspections.

THE FUNGI

Fungi differ from plants in that they do not contain chlorophyll and therefore do not manufacture their food by photosynthesis. Most fungi derive their food from the breakdown of other organic material. When this organic material is living, the fungus is parasitic and when it is dead the fungus is saprophytic. When saprophytic the fungi return to the soil and the atmosphere those elements which formed part of the plant or plant products. Wood is one of the more durable products produced by plants and is attacked by certain fungi under particular environmental conditions.

The life cycle of fungal decay

Most fungi that affect wood produce spores. These serve the same purpose as seeds of plants, but are microscopic in size, 0.01–1.0 mm, and they are very light in weight so that they are carried long distances by wind, air currents and also dispersed in water and on animals. Spores are produced in large numbers, millions in some species, from the fungal fruit bodies, but most of these spores fall on surfaces unsuitable for their germination and development.

Those spores that fall on wood surfaces with a moisture content of 28–30% will germinate and produce fine thread-like structures known as hyphae (sing. hypha). These hyphae then branch, forming a mass of threads which finally form a mycelium. When conditions of food and moisture are favourable the hyphae enter the cells where, by enzymatic action, the cellulose is converted to more soluble compounds which are used by the fungus to extend its activity within the wood. Finally, the fungus reaches a stage of development where it produces a fruit body or sporophore from which spores are released and dispersed into the environment. Unlike many plants which die after flowering, the fungus continues its activity, often deep in the wood, provided the moisture levels are suitable for its continued development. Fungal activity (growth and decay) will continue within already decaying timber, even if the moisture content of that timber happens to be reduced to as low as 18 to 20%.

The decay fungi

The species of fungi that decay wood have different food requirements to those fungi that cause surface moulds and sapstain in wood. For ease of identification in the field, the decay fungi described below have been divided according to the characteristics they produce in the wood they attack.

Brown rot fungi

The brown rot fungi, also known as brown cubical rot, attack only the cellulose, leaving the lignin (a phenolic substance), which turns brown when exposed often giving the wood a darker colour than it was before the attack. Wood that is attacked by brown rot fungi cracks across the grain often producing large cubes of wood.

White rot fungi

White rot fungi attack both the cellulose and the lignin, and most commonly result in white stringy rot (while less frequently resulting in white pocket rots, where numerous small spots of white rot are separated by thin bands of non-discoloured timber). The exposed surface becomes white and fibrous, a characteristic which enables these fungi to be distinguished from the brown rots. After attack the colour of the wood is usually whiter than it was before the attack. Hardwoods (pored woods) are generally considered to be more susceptible to white rot than are softwoods (non-pored woods).

Soft rot fungi

These organisms are a mixture of fungi and bacteria that are mainly soil inhabiting. They thoroughly attack restricted layers within the cell walls of wood. It is a type of brown rot and is also known as carroty rot. Affected timber cracks across the grain, but the cubes are mostly smaller than those of other brown rots and the timber is of a darker colour than before it was attacked. Prior to failure, soft rot is the more difficult of the three decay types to recognise by way of external appearance of the decaying timber.

TABLE 20.1
Categories of fungi capable of growing in association with wood

Class of fungal species	Properties in respect to timber
Moulds	On wood surface only Cannot destroy wood Look unsightly Produce mass of spores quickly (Potential respiratory problem to humans)
Sapstain (= bluestain)	Grow into sapwood but not into heartwood Consume sugars Cannot destroy wood Have dark cells that stain timber
Decay fungi proper	
Brown rot fungi	Rods (ie cellulose) attacked and broken Cracks across the grain giving large cubes of wood Exposed plastic (ie lignin) oxidises and turns brown
White rot fungi	Both cellulose and lignin attacked Remaining exposed cellulose is white, fibrous (ie stringy)
Soft rot fungi	Cellulose only attacked, but only within certain layers of the wood cell walls Brash fracture across grain together with small-scale cuboidal cracking Affected wood darkened (often to grey or black)

Source: J.D. Thornton, *Corrosion Australia*, vol. 16, no. 3/4, 1991
NOTE. The abovementioned *Corrosion Australia* article was also the main information source for Appendix B of the Australian Standard AS 4349.3 (Timber Pest Inspection Reports). However, Appendix B of AS 4349.3 contains colour illustrations which the reader of this chapter may find additionally informative.

Frequency of rot types in service

As a generalisation, decay of flooring timbers (excluding external decking) is almost exclusively due to brown rot. While decay in window joinery externally may be due to either brown or white rot, the most extensive decay of external wooden weatherboards is usually due to white rot.

While painting of external timber has an effect on rate of decay, in itself the paint cover does not appear to influence whether white or brown rot predominates.

Timber in-ground is inevitably attacked by soft rot unless white or brown rot fungi have caused earlier attack. However, both natural durability (see 'Durability of timbers' and Appendix IX) and preservative treatments influence the type of decay. Timbers of low durability will be attacked by brown rot fungi (mostly softwoods) or white stringy rot (mainly hardwoods). Timbers of high durability in-ground in Australia are mainly hardwood species and these will eventually fail to soft rot unless they have been slightly earlier attacked by white stringy rot (or in the case of timbers such as forest red gum, by white pocket rot). On the other hand, wood that is treated with currently registered preservatives and used in in-ground contact in Australia is only rarely attacked by white rot fungi. In thoroughly preservative-treated sapwood of hardwoods, the eventual decline is due to soft rot. For preservative-treated softwoods, the eventual failure will be to soft rot unless there is any poorly treated heartwood, which in this case would have decayed earlier due to brown rot. Decay of a timber component in service will often be most severe at (if not restricted to) a certain position (often a uniform height, eg: around ground line in a pole or post) that coincides with a moisture level in the wood, which proves to be the optimum moisture content for fungal decay to occur.

Requirements of decay fungi

The decay fungi require a wood food source, oxygen, water and a suitable temperature range. Timber species vary in their susceptibility to particular fungi. Some timber species are more durable than others and heartwood is more durable than sapwood, but no untreated timber can be regarded as completely immune.

Figure 20.1 Droplets of moisture on the subfloor timbers — the precursor of wood decay

Figure 20.2 Fungal mycelial growth on timber

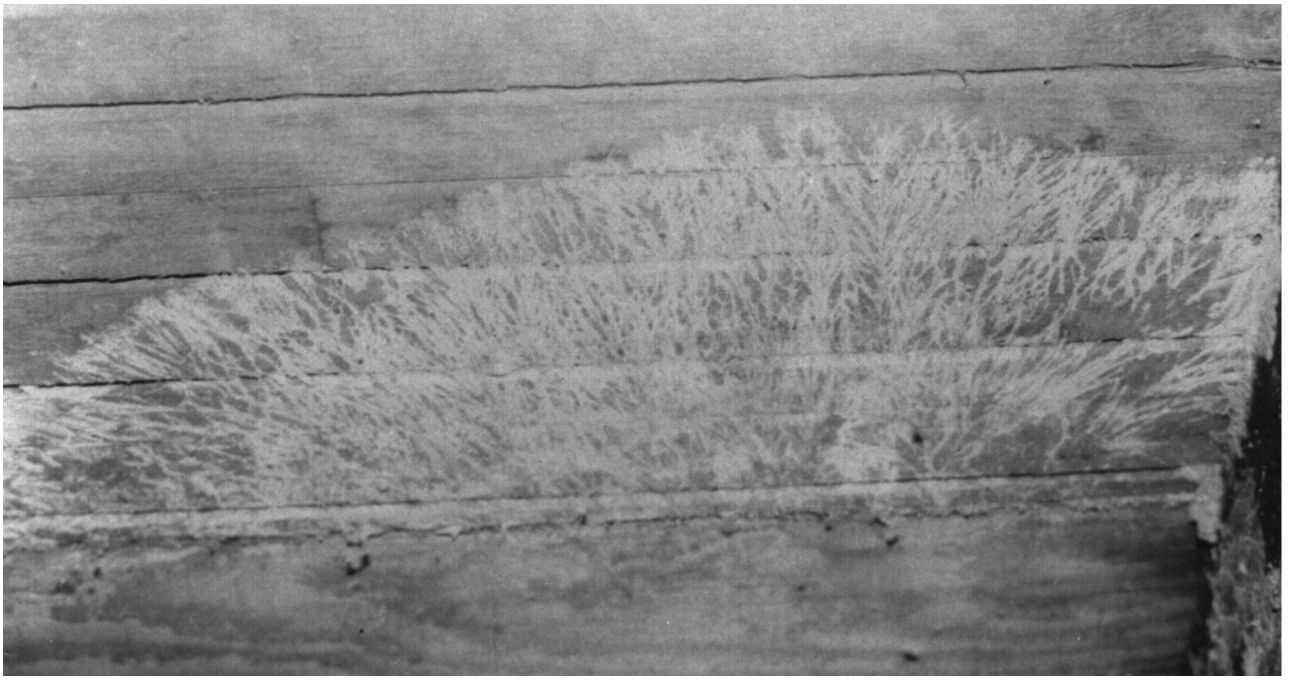

Figure 20.3 Fruit bodies of a decay fungus within a eucalypt tree stump

In most situations where decay occurs the oxygen requirement is met from normal air composition. Wood which is immersed in water or in water-saturated soil is not attacked, except on the surface, because oxygen is not available to it.

Water from various sources is an essential prerequisite for decay fungi, even for the 'true dry rot fungus', *Serpula lachrymans,* which needs moisture both to develop and to decay wood in service. In situations where wood is constantly dry, below 20%, neither fungal growth nor fungal decay can commence.

While the different species of decay fungi vary in their optimum temperature requirements for their growth, the range for most species in Australia is 25–30°C. However, as considered later, this temperature range is too high for *S. lachrymans* which favours approximately 20°C and is sensitive to higher temperatures, thus explaining its restricted distribution in Australia.

The role of water in fungal decay of wood

In considering the moisture relationships of the various wood-attacking fungi, J.D. Thornton, CSIRO, *Corrosion Australia* (1991), has summarised the moisture relationships of wood-attacking fungi and has given four basic scenarios which are extremely relevant to house and building inspections. This data appears in Table 20.2.

Sources of water

When freshly felled logs are converted to sawn timber the moisture content varies from 40 to 200% depending on the timber species. For instance, the more dense hardwoods contain less moisture while some of the softwoods could contain up to 200% moisture. Heartwood contains less moisture than sapwood.

TABLE 20.2
The moisture relationships of wood-attacking fungi as related to growth on (untreated) joists/bearers of a suspended wooden floor

Scenario no.	Moisture content of wood %	Relative humidity of air space %	Fungal growth	Condition of wood
1	<20	<90	No growth on or in wood.	Not decaying.
2	20–120	<90	Growth inside wood, surface mycelium flat and may not be too obvious.	Decaying.
3	30–120	>90	Growth inside wood, surface mycelium luxurious and growth very obvious.	Decaying.
4	>150	>90	Luxurious growth on surface: there would be little further growth within the wood itself.	Not decaying (because ‘waterlogged’).

Source: J.D. Thornton, *Corrosion Australia*, vol. 16, no. 3/4, 1991

As the wood loses its free water inside the cells air replaces it until only water of the cell walls is left. This stage is known as the 'fibre saturation point' (FSP) and for most timber species lies between 25 and 35% moisture content.

The water of the cell wall (combined water) then reduces until it reaches a level which is in equilibrium with the atmosphere in which it is placed. This is known as the 'equilibrium moisture content' (EMC). This moisture figure varies from place to place. For instance, the equilibrium moisture content in western New South Wales would be approximately 8–12% of the weight of the wood while the same timber on the east coast would range from 12 to 15%. The equilibrium moisture content also varies within a small range from one timber species to another.

Timber that has reached its equilibrium moisture content is usually stronger than when green and since the moisture content is below 20% it will not decay if it is maintained below this moisture content. Wood at equilibrium moisture content will fluctuate during wet and dry periods, but usually only within 2–3% so that decay will not occur unless other factors are present. These factors are considered below.

Ground water

Water from the soil, mainly in subfloor areas, evaporates and may condense on the cooler surfaces of the floor. Condensation is increased by poor subfloor ventilation and if this condition continues flooring timbers gain in moisture and also increase in volume causing distortion of the floor boards which may in turn affect the walls.

Fungi, as distinct from plants, require carbohydrate material (cellulose) and oxygen to sustain their energy and release carbon dioxide and water from their process of respiration. This water evaporates, except in environments of high humidity and poor ventilation, and in such cases the fungus continues its destructive life.

Damp-proof courses prevent water rising from the soil into the walls. Where these damp-proof courses have deteriorated, have been incorrectly applied or have not been installed at all, moisture will rise and affect timbers which are in contact with the walls thus providing decay fungi with a suitable medium and environment for the fungal spores to germinate and produce hyphae which then enter the wet wood.

Faulty plumbing can produce sustained moist conditions in subfloor areas and in walls, particularly where ventilation is poor.

Moisture from kitchens and bathrooms can also produce moist subfloor environments.

The proper directional disposal of storm water from roof areas prevents drainage problems which add to soil water in the subfloor area thus causing dampness problems.

The use of some types of floor coverings which do not permit evaporation of moisture from the floor boards can lead to decay problems especially in houses where subfloor ventilation is inadequate.

All the causes of dampness also form part of a pest report as well as a building structure report, for decay fungi can do significant damage in 12 months.

TABLE 20.3
Moisture content values relating to timber in defined situations

Situation	Moisture content %
Laboratory, oven-dried and desiccated timber	Nil
Equilibrium moisture content for timber in buildings, protected from the weather	
Melbourne	10–12
Melbourne, air-conditioning — evaporative cooler	12–14
Inland Queensland	7–12
Coastal Queensland	10–15
Lowest level at which decay can continue	18–20
Lowest level at which corrosion of metal fastenings occurs, in wood	18
Fibre saturation value, ie level above which decay can commence	30
Waterlogged wood	150 or greater depending on timber species
Moisture content of decaying wood	20–120
Water as free water present in cell voids	30–150 or greater
Timber changes dimensionally	
In theory	0–30
In practical situation	7–30
Moisture meter gives accurate reading	9–30

Source: J.D. Thornton, *Corrosion Australia*, Vol. 16, No. 3/4, 1991

DETECTION OF DECAY IN SUBFLOOR TIMBERS

When making pre-purchase and annual inspections the detection of fungal decay or high moisture levels in timber and walls, particularly in the incipient stages, is important when making these reports. The following characteristics of the presence of fungal activity or conditions favouring fungal growth alert the observant and experienced inspector to investigate, locate and report on the cause.

1 Even before entering a building the vegetation impinging on the outer walls and the build-up of soil and landscaping materials around the walls, often obstructing the function of the ventilators, are factors which may indicate poor ventilation and possible decay problems in the subfloor.
2 On entering a building a musty odour may betray a subfloor or wall moisture problem.
3 Movement of flooring when walked upon may be due to many causes, but the bearers and joists as well as the flooring require close examination to ensure they are free of decay and have a low moisture content.
4 Floor boards which have distortion such as cupping and splitting is often caused by sustained high moisture levels and possible fungal decay of the structural timbers beneath. Moisture from walls can also affect wood and produce these floor characteristics.
5 Probing wood, preferably with a knife, or with a screwdriver will reveal soft wood due to decay. The knife is particularly useful in determining decayed and decaying wood and an experienced inspector can often identify the type of decay.
6 Exterior, painted surfaces such as weatherboards and window sills may show bubbling and splitting due to decay beneath.

Brown to red dust (spores) when located on surfaces in enclosed situations is often produced by fungal fruit bodies. However, the spores of many species of wood decay fungi are unfortunately cream, white, or even clear, and thus cannot be seen by the naked eye when deposited in large quantities.

Further inspection of a subfloor area may reveal fungal growth in the form of fruit bodies and mycelial growths of variable colours, shapes and sizes. In many cases where the high moisture factor has been relieved the knife is particularly important in the detection of decayed wood as distinct from decaying wood.

SOME SPECIFIC FUNGI

Mould fungi

The spores of the mould fungi are airborne like the others, but are the cause of many allergies in humans. The spores of mould fungi germinate on the surfaces of moist wood, but their activity is superficial and they do not decay wood. When active they do betray a moisture level which may, if allowed to continue to rise, provide an environment for fungal decay. Usually the presence of mould fungi alerts the building inspector to a ventilation problem or a similar cause.

Sapstain fungi

Sapstain is often seen in pale-coloured timbers and is often referred to as bluestain. The spores of these fungi when they alight on suitable surfaces produce hyphae which enter the ray cells. These ray cells usually have a higher food value in the sapwood than heartwood cells and the fungal hyphae live on the contents of the cells and do not affect the cell walls. Sapstain fungi usually attack fresh logs and freshly sawn timber when poorly stacked. The moisture content for sapstain to occur is above 30%. The fungal hyphae enter the cells causing the characteristic, often blue or green, stain.

Rapid drying of sawn timber or placement of the timber in a dry atmosphere allowing air circulation reduces the incidence of bluestain.

The true dry rot fungus *Serpula lachrymans*

In many pre-purchase and annual inspection reports prepared by building inspectors and pest controllers the term 'dry rot fungus' is used. The fungus involved in the damage, particularly in the warmer parts of Australia, would not be the true dry rot fungus, *Serpula lachrymans* but, as *S. lachrymans* has caused damage to buildings in Melbourne, the proper nomenclature for the decay fungi is important in reports. Even though the name of this fungus may imply otherwise, it will not attack dry wood, that is, when the moisture content is below 20%.

The term has created much confusion for those who must advise the potential purchaser of a property on the future action after evaluating the pest and building reports. It is therefore important that both reports contain information on the cause of the decay and the magnitude of the damage. In most cases the cause of the decay is not due to the true dry rot fungus, but to one of the more frequently encountered species of fungi which cause brown rot or white rot. Unless the person inspecting the building has had special training in the recognition of the activity of some groups of decay fungi,the general term 'fungal decay' with some qualification as to whether it is a brown or white rot may be used. However, it is important to indicate the areas affected and the degree of damage.

S. lachrymans is one of the main timber destroyers of buildings in Europe and requires the moisture content of timber to be above its fibre saturation point, usually about 30%, but once the infestation is established in the timber the fungus can continue its activity down to 20% moisture content. This is also the requirement of other species of decay fungi.

An important difference between *S. lachrymans* and other decay fungi present in Australia is that its optimum temperature for growth is 20°C while that of the others is 25–30°C.

J.D. Thornton records the main behavioural differences between the true dry rot fungus and the other decay fungi as:

1 The true dry rot fungus is 'almost exclusively associated with built structures'. This includes houses, boats and even mine timbers, but it is very rarely found to affect timber in soil or in forest areas.
2 The optimum temperature for fastest growth for the true dry rot fungus is 20°C while other decay fungi have a higher temperature requirement (25–30°C) for optimum growth.
3 Most timbers have an acid pH — that is, below pH7. However, *S. lachrymans* can grow on timber which has an alkaline pH — that is, above pH7.

S. lachrymans has been found in many areas of Melbourne, but not often encountered in Sydney (J.D. Thornton 1992). In Melbourne it is not found in weatherboard houses, but mainly in brick houses for it can grow over moist stone and brick walls to reach timber which is moist — usually from poor ventilation.

The prevention and control procedures for *S. lachrymans* are similar to those for other decay fungi.

CLARIFICATION OF FREQUENTLY USED TERMS

Some terms that appear in reports are not fully understood by those using them and by those who must interpret them. The following should clarify their usage.

Decaying wood This wood has a high moisture content, but usually retains its original shape. It still has some strength. It may have fungal growth on its surface and has a moisture content above 20%.

Decayed wood The wood has lost its moisture, is reduced in size and has no active external growth on its surface. It is usually beginning to fall apart, with cracking across the grain, or the fibres are separating and the surface is becoming stringy. It is at this stage that floorboards fail. The moisture content of decayed wood is less than 20%.

Dry rot This term causes much confusion, particularly among those who are recipients of pre-purchase and annual inspection reports. This term should not be used in reports or in communication.

RISING DAMP

Rising damp is different to water overflow from guttering or leaks from a roof, both of which cause walls to become damp. Rising damp has its origin in water from the soil and moves upwards from the walls of the foundations. As the water evaporates, usually from inside a dwelling, 'tide marks' are left on walls. These are due to salts which are left when the water that carries them evaporates. This characteristic serves to identify rising damp from other moisture sources such as roof leaks and plumbing problems. In South Australia the soil is salty and the problem is referred to as 'salt damp'.

The treatment of rising damp is best done by specialists in this field, but the detection of the condition is important in pre-purchase and annual inspections. The main aim of any treatment is to place a barrier between the water source and the walls. This is achieved in two ways:

1 **Physical** This method places a new physical barrier or damp-proof course in an appropriate place in the walls. This usually involves removing the mortar and installing the new barrier material, but the mortar must be replaced. This type of disturbance must be done carefully as some movement in the wall may result.
2 **Chemical** Damp-proof courses are applied to walls by drilling holes in the brick or masonry and injecting the holes with silicones and aluminium stearates. The solvent evaporates leaving a barrier of chemical which is not penetrated by rising moisture. This procedure is very specialised and requires equipment designed specifically for this type of work for a fire hazard exists during the operation and for some days afterwards, mainly due to the solvents used. In addition, the salt left in the wall affects the application and lasting properties of paints over such surfaces. The moisture will take several months to dry from the affected walls after the treatment.

PREVENTION OF DECAY

Durability of timbers

There is very little data available on the durability of timbers in service in buildings, but investigational work on this aspect is currently in progress, mainly by the CSIRO and other organisations throughout Australia. It would therefore be unwise to indicate particular species which are more durable than others. Durability tests have been in progress for many years on timber in service in the ground and some of this information is available, but it may have little or misleading correlation to durability of timber in service in houses and buildings. Nevertheless, CSIRO has recently issued a revision of natural durability ratings for in-ground contact in Australia (see Further Reading and Appendix IX). The classification gives separate listings of ratings for decay only and for termites in the presence of decay. This new information acknowledges that the heartwood of some timbers is so variable that they span more than one durability class. This performance data is readily available, but is yet to be incorporated in revisions of relevant Australian Standards.

Many timber species being used in Australia have a low durability in many situations unless treated with a preservative. Timber species such as those in the spruce, fir and pine groups are preservative treated in many outside situations, but not usually in roof and wall components of houses. The relevant points about durability are:

- heartwood is more durable than sapwood; and
- inner heartwood is less durable than outer heartwood.

Detection of the cause of dampness and decay

Timber in service in buildings will not decay if maintained below 20% moisture content. To achieve this, the following factors are important and it is also important that these issues are recognised during Timber Pest Inspections.

Subfloor ventilation

In houses that have suspended timber flooring, the type of soil, as well as the number, type, condition and position of ventilators determine the level of humidity of the air beneath the floor.

Properties built on free draining sandy soils often have a lesser need for subfloor ventilation compared to properties on heavier types of soils that are inclined to retain dampness.

The older style terracotta ventilators have a total opening of 30 cm^2 while the newer bronze wire mesh ventilators of the same external dimensions have an opening of 215 cm^2.

The placement of the ventilators should ensure that there are no 'dead spots' and that cross ventilation is achieved.

Ventilators must be kept clear of vegetation that may restrict air flow.

The various states of Australia have differing requirements in respect of ventilators in square millimetres of ventilators per square metre of floor space.

Rising damp

Dampness drawn from the soil upwards into masonry walls (eg brick or stone) will not only increase the subfloor humidity, but also the moisture content of timbers in contact with the damp masonry walls. During inspections, these conditions should be recognised so that appropriate recommendations can be made (eg treatment against rising damp so as to minimise damage to interior finishes and isolation of timber elements from contact with damp masonry so as to minimise localised fungal decay of the bearing points of timbers such as floor bearers). Properties with these conditions will often benefit from improvements to subfloor ventilation.

Subfloor drainage

Water run-off from higher ground levels, swimming pool runoff and plumbing problems sometimes cause ponding in the subfloor. Such conditions should be reported with recommendations for the appropriate remedial action.

Further issues relating to subfloor ventilation

Subfloor ventilation may be reduced owing to range of conditions:

- the configuration of ventilators not allowing for cross ventilation (as may occur in attached properties such as terraces and semi-detached houses where common walls are without ventilation);
- inappropriate surroundings (eg where solid walls or fences are close to ventilators limiting air movement; or
- high exterior ground levels in relation to interior floor levels.

In such cases, a range of options will need to be considered, for example:

- Soil covers — where subfloor soil is constantly wet, evaporation may be reduced by covering the surface with plastic sheeting thus significantly reducing the humidity and condensation on the cooler surfaces of the timber above.
- Fan-forced ventilation — such systems may be powered via solar panels on the roof or via mains electricity. Those operating on mains electricity may be controlled by a timer for intermittent operation or they may operate for 24 hours per day. Fireplaces are sometimes used to obtain vertical connection with subfloor areas which cannot be otherwise ventilated. In some cases, fan-assisted subfloor ventilation may involve reticulated ducting (usually 150 mm diameter) that is designed and installed so as to optimise air movement and eliminate any 'dead spots'.

(Note: care must be exercised in relation to the potential for a sudden 'dry-out' of floor boards that had reached a relatively high equilibrium moisture content as this may cause shrinkage and gaps)

Subfloor ventilation problems can be complex. With the significant advances in technology that are now occurring, it is usually worthwhile to seek specialist expert advice.

The use of preservatives and preservatised timbers

While the most effective method of preventing or even terminating fungal decay in buildings is to reduce the moisture content of the environment in which the wood occurs, chemical preservatives are used in situations where timber is exposed outside or partly or wholly in the ground.

Transmission poles, sleepers, natural rounds for landscaping, and fences, particularly where radiata pine is used, are usually treated with CCA salts. These are water soluble salts (copper sulphate, chromium sulphate and arsenic pentoxide) in particular proportions and when they are used to treat wood, a vacuum pressure process in tanks at about 1400 kPa is applied. In this process a vacuum is created to permit the maximum absorption into the cellular structure of the wood. This ensures the sapwood is completely impregnated, but the centre heartwood is often resistant to penetration by the salts. The CCA salts impart a green colour to the timber which is penetrated.

Where wood treated by this method is used in the ground its service life is significantly increased over that of untreated timber. The untreated heartwood may decay or be attacked by termites leaving a soft or hollow centre. This is sometimes seen in natural rounds of radiata pine.

Creosote also has been used for the pressure treatment of poles and natural rounds.

Surface treatments using fungicides such as copper and zinc naphthenate have only short-term value due mainly to their limited penetration of the cells. These materials are diluted with oil solvents for superficial application.

The sap displacement method has been used by farmers who cut and install natural rounds as fence posts. Young trees with a large percentage of sapwood are cut to size and as soon as possible, within hours, placed upright in a tank to absorb the water soluble CCA salts. The salts are taken up by the sapwood, but any heartwood present is untreated because the cells are non-conductive.

Diffusion rods

Diffusion rods which contain boron, disodium octaborate tetrahydrate and sodium fluoride are used in sensitive situations where dampness cannot be controlled, such as poles in the ground, decking members where moisture remains after rain, and other outside timber structures. Holes are drilled into the wood (10 mm diameter and 40–50 mm deep) in the most appropriate situations. The rods are inserted and the hole sealed by using precut-to-size wooden dowels. The chemicals dissolve and permeate into the timber.

Specially formulated materials are also available in cartridges for use in a caulking gun. Copper, chromium and boron salts are used in these materials and are placed in timber in a similar manner to the diffusion rods. As the timber becomes moist the materials diffuse into the untreated areas and those cells that have received the chemicals are more resistant to decay.

Equipment to assist during inspections

When inspecting buildings a good quality torch is necessary and a hand lens. However, a knife or screwdriver is essential to detect decayed or decaying wood and an electronic moisture meter will betray conditions which are conducive to the development of fungal decay.

The moisture meter In the case of either annual inspections or pre-purchase inspections collapse of flooring can occur within three months of the inspection due to fungal decay. The moisture meter will detect pre-conditions for decay and the moisture content of timber cannot be positively determined without the meter. This information can then be reported to the owner or the purchaser. The source of the moisture is important to the future of the building for this also is often located during the inspection by the use of the electronic moisture meter. The meter will detect a moisture condition favourable to fungal development for it will give accurate readings up to the fibre saturation point of about 30%.

The knife A knife (or screwdriver), used in detecting and differentiating between decayed and decaying wood is also an important piece of inspection equipment. Because the knife is preferred by those experienced in this field of decay detection, the procedures in the use of a knife in preference to a screwdriver are given here. Initially the knife is mainly to determine strength loss, but when experience is gained by the inspector the knife test will enable an identification of the type of decay such as white rot and brown rot as well as determining the depth to which the decay has spread. It is likely that fungal decay has spread beyond the more obviously decayed sections and this must be realised during inspections (even with the knife test).

The following points assist in the test.

1 Insert (jab) the knife blade at right angles to the surface of the wood to a depth of about 3–4 mm.

2 Bend the blade towards the face of the wood.

Sound wood has a distinctive sound and produces a long splinter of wood with jagged ends.

White rot is indicated if the piece falls apart in white fibrous lengths.

Brown rot and soft rot — the wood breaks across the point of the knife and there is no long splinter and no tearing sound.

Advanced decay — material will continue to come out easily in pieces. The knife can be inserted until sound wood is located, probably at some depth.

Practice is needed to become proficient at this technique.

FURTHER READING

Australian Standard AS 4349.3-1998 *Inspection of buildings Part 3: Timber Pest Inspections* Standards Australia Sydney

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Thornton, J.D. Johnson, G.C. and Nguyen. N-K. 1997 *Revised CSIRO Natural Durability Classification: In-Ground Natural Durability Ratings for Mature Outer Heartwood* A3 Wall Chart CSIRO Australia

CHAPTER 21

MISCELLANEOUS TIMBER PESTS & EFFECTS

Sound wood in service and at equilibrium moisture content may be attacked by such insects as the furniture beetle, powderpost beetles and the European house borer, but wood that is decaying or decayed may be attacked by insects which are not able to infest sound wood at equilibrium moisture content. These insects are also able to extend the decay deeper into sound wood by their borings provided the wood remains moist. The insects, mostly the larval stages, reduce the fungal affected wood to a fine dust or frass.

PESTS OF DECAYING AND DECAYED WOOD

The following insects infest decaying or decayed wood in service:

Dampwood borer *Hadrobregmus australiensis* (Anobiidae — Coleoptera)

This insect initiates its attack in moist and decaying timber, usually in subfloor areas of a building. It is often found in softwood flooring, but also attacks hardwood bearers and joists.

The beetle is dark brown with its head partly concealed beneath its prothorax and is about 6–8 mm in length. The emergence holes made by the beetles are round and 2.5–3.0 mm in diameter. The larvae have 3 pairs of legs and resemble furniture beetle larvae, but are larger. When infested wood is opened the pupal chambers are darker than the surrounding wood and are smooth on the inside.

Syndesus cornutus (Lucanidae — Coleoptera)

This insect belongs to a group of beetles known as stag beetles. Decaying timber in the ground, such as stumps of trees, is the natural environment for this insect. It has now been found in decaying wood in moist subfloor situations where the hardwood bearers and joists were reduced to dust with only the outside layer of timber remaining. It will attack both hardwoods and softwoods. As long as the wood remains moist (above 30%) and is decaying, these beetles will continue to reinfest until both the sapwood and heartwood are destroyed.

The beetle is about 8–10 mm in length, uniform brown and has long and characteristically shaped mandibles. The larvae are similar in appearance to scarab beetle larvae (Christmas beetle larvae) which are often found in the soil feeding on plant roots.

Figure 21.1 Eucalypt hardwood damage caused by lucanid decay borer

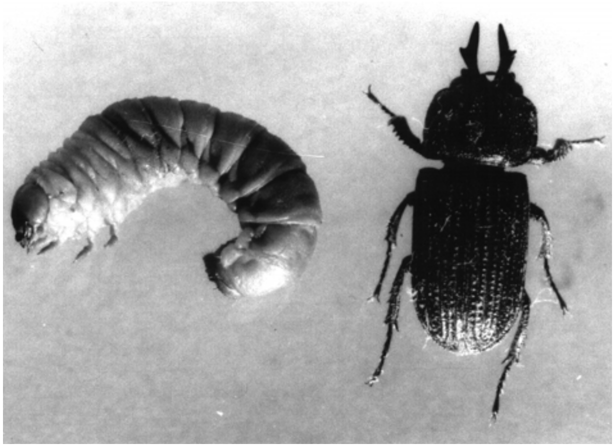


Figure 21.2 Larva and beetle of Lucanid decay borer (*Syndesus cornutus*)

Pentarthrum australe (Curculionidae — Coleoptera)

This insect is a small weevil which also attacks decaying timber, an essential condition for its infestation. It makes small round holes and its frass is fine. The larvae are legless. Like the dampwood borer and *S. cornutus* it does not attack dry, sound wood.

Decay moths, *Barea* spp. (Oecophoridae — Lepidoptera)

The larvae of these moths are found in decaying wood of fences and external verandah decking where they feed on the fungus-affected wood. The larvae of these grey moths are about 30 mm long when fully grown, pale in colour with a grey area towards the end of their abdomens. The larvae feed on fungi present in and on decaying wood. They bond their faeces and wood fragments together with silk and live and feed inside this. On casual examination these faecal/silk tunnels on the surface of wood may be confused with termite leads for they are found in similar situations.

Treatment of affected timbers with a fungicide such as copper naphthenate is effective for it kills the fungus and if it contacts the larvae or pupae they are also killed. By treating the fungus-affected wood the fungicide gets to the cause and also prolongs the life of the affected wood.

Carpenter ants, *Camponotus* spp. (Formicidae — Hymenoptera)

Carpenter ants are often found in decaying and decayed areas of trees and stumps. They will also nest in decaying timbers in wall cavities and in timber in the subfloor area of houses, particularly where wood is in contact with the ground. While the ants may be controlled using an organophosphorus insecticide such as chlorpyrifos it is important that the source of moisture be found and the cause remedied. The use of moisture meters is very useful in detecting the source of the moisture.

CASUAL TIMBER PESTS

Sawflies (Pergidae — Hymenoptera)

Some insects which feed in trees or on grain or flesh foods, when they have finished feeding seek a secure place in which to pupate. Timber in service in houses, fences and other outside uses are favoured by these insects as pupation sites.

Timbers usually chosen by sawfly larvae (*Lophyrotoma* spp.) are usually softwoods used either outside or in roof cavities accessible to these foliage-eating sawfly larvae. The colour of the larvae is usually green and this betrays their origin since true timber insect larvae are white to cream-coloured. The most frequently encountered larvae are those feeding on paperbarks and bottlebrushes.

Control of the foliage-eating larvae on their host trees is the most effective method, but this must be done during the time the sawflies are feeding.

Hide beetles (Dermestidae — Coleoptera)

The hide beetle (*Dermestes ater*) and the common hide beetle (*Dermestes maculatus*) are sometimes found damaging timber in houses. While the damage is mostly slight and does not require treatment, the identificaton of the damage and the insect is important in making the decision not to treat.

The wood is used as protection during pupation and not as a food source. Softwoods such as douglas fir and radiata pine are favoured wood species and the larvae generally select the softer growth ring to enter. Sometimes in food-handling facilities such as meat preparation, the softwood skirting can be extensively damaged as the larvae are numerous in such an area.

The entry holes of the larvae and the emergence holes of the beetles are round, devoid of dust and often contain the shed skin of the last larval instar. When this damage is found, particularly in roof cavities, the food source is usually dead rodents, possums and sometimes birds. When these larvae have finished feeding they enter wood to pupate and emerge through round holes about 3–4 mm in diameter.

Figure 21.3 Hide beetle (*Dermestes ater*) damage to a Douglas fir roofing member

Solitary bees (Colletidae — Hymenoptera)

Small solitary bees will excavate the early wood in the end grain of softwoods such as douglas fir and lay their eggs plus food for the young after they hatch. The young are fed in the recesses until they pupate when the ends are sealed. The adults break the seal when they are emerging.

This type of attack may be found on the end sections of roofing timber in open areas such as carports and garages.

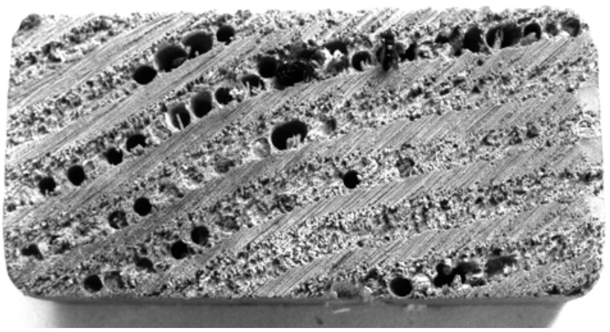


Figure 21.4 Solitary bee — damage to the softer growth rings of a Douglas fir roofing member

DEFIBRATION OF TIMBER

Wood consists mainly of cellulose, hemicellulose and lignin. In general terms, wood is about 45% cellulose, about 20–25% hemicellulose and about 25–30% lignin. The proportions of these materials vary and are different for softwoods and hardwoods.

Timbers which are used for tile battens and rafters in roof structures sometimes exhibit masses of orange-coloured fibres over their surfaces — mostly on the undersurface. This type of deterioration of timber is encountered in coastal areas, particularly those areas closer to the sea. Usually the houses in which the timber is affected in this way are more than 20 years old.

The same effect has been noticed in buildings where chemical gases or fumes are liberated in some manufacturing processes. Vapours from combustion stoves when allowed to discharge into roof cavities have caused this defibring effect more rapidly than that produced by salt air. The timbers most often affected in this way are douglas fir and radiata pine.

Defibration is the chemical breakdown and separation of the cell walls and it occurs in both pored and non-pored woods. The cell walls eventually disappear from the cell structure.

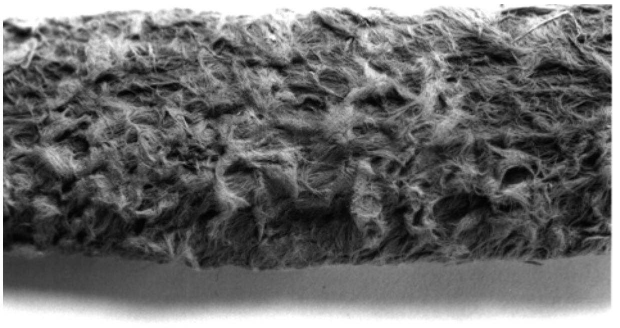
While defibration can result in the collapse of timber in the long term, the recognition of the early stages of its breakdown is important in pre-purchase and annual inspections. A study by Wilkins and Simpson (1988) revealed the following:

1. Defibration in roof cavities is more rapid at higher temperatures, but does occur at low temperatures.
2. In defibred wood the moisture content is higher than the equilibrium moisture content.
3. Sodium is very high in defibred wood when it occurs along the coast and around Sydney.
4. The affected wood is hygroscopic, probably due to the sodium chloride content.
5. The increase in moisture content favours defibration and this is further aided by high temperatures.

During the last 20 years, douglas fir has been used extensively in roof structures and tiling battens and as a result the occurrence of defibration is expected to rise significantly during the next 30 years and beyond.

The incidence of defibration may be reduced by the use of sarking, improved roof ventilation and the reduction in moisture being discharged into roof cavities from bathrooms and kitchens as well as roof and plumbing leaks.

Figure 21.5 Defibration — fibres have separated and adhere to the surface



MARINE PESTS

Wood in contact with, or submerged in, salty or brackish water is often attacked by the marine organisms that occur in these situations. Wooden boats, old wooden ships and wharf piles may be so seriously damaged that they no longer serve the purpose for which they were intended. Wooden boats may be destroyed below the water line in the space of a few years. Wharf piles, often extensively covered with marine growth, may be seriously damaged beneath. The 'hourglass' effect often noticed at wharves is due to marine borer damage. A calcareous material associated with marine organisms acts as a protection for the creature inside the damaged wood.

The behaviour of marine organisms varies with the species and is influenced by water salinity; therefore it is difficult to predict what will happen to wood in water. Control of destruction is often difficult, particularly where marine piles and wooden barges are involved. Prevention is a normal procedure used by maritime authorities, for they are acutely aware of replacement costs.

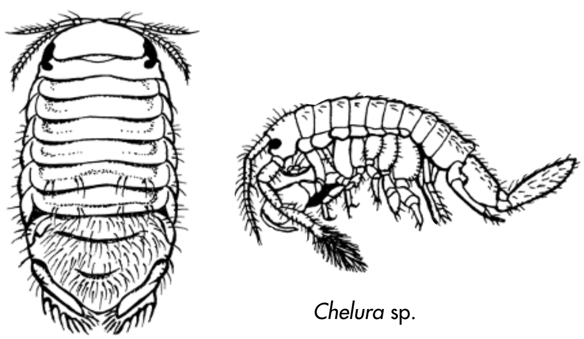
Commercial pest control operators are seldom called upon to control marine organisms, for this is usually such specialised work that it is done by persons experienced in boatbuilding and repairing or employees of maritime authorities.

Common pest species

Table 21.1 lists some common marine pests, together with data about their size, distribution, habits and so on. These marine pests belong to two phyla: Arthropoda and Mollusca.

Crustaceans

Crustaceans are invertebrate animals with jointed legs and segmented bodies. There are many species of crustaceans, but most are not pests of wood (eg prawns and lobsters). However, some do damage wood, either by initiating attack themselves or by extending attack by other marine pests. The final outcome of their damage is similar to that of the terrestrial wood borers, for in some instances the infestation is so severe that the wood in between the holes breaks away. *Limnoria* and *Sphaeroma* are important wood destroyers, but *Chelura* does little damage, living mainly on the faeces of *Limnoria.* When *Sphaeroma* attack occurs on marine piles, the piles assume an 'hourglass' appearance, and the damage is not concealed as in the case of mollusc organisms. They appear to breed throughout the year.



Chelura sp.

Sphaeroma sp.

Figure 21.6 Destructive and non-destructive crustaceans

Molluscs

The Aboriginal name 'cobra' is a general term that includes *Teredo*, *Bankia* and *Nausitora* species, and these have an unsegmented body similar to other better-known molluscs like slugs, snails and cuttlefish. The 'cobra' attack wood and extensively damage it, often before their presence is detected, for their only contact with the water is through a very small hole. This hole leads to a large cavity in which the organism feeds and extends. Seawater is siphoned in through this hole and along with it the animal's food, plankton. The organism has two siphons at one end of its body, and these arc at the small hole. Food and also male sperms are taken in through the inhalant siphon, while waste materials, sperms and eggs are released from the exhalant siphon. When the siphons are drawn in, the small opening is blocked by a pair of pallets. Identification of these animals is difficult and should he left to a specialist. The size of the organisms varies with species, population density and food supply.

Martesia, another mollusc, is often referred to as the 'shell borer', for it resembles a sand pippy. It occurs in partially enclosed shallow water. It is very widespread and destructive, being found in many waters along the eastern coast of Australia. By scraping wood with rough scales it bores holes that are pear-shaped in longitudinal section. While individual *Martesia* borers do not penetrate deeply, considerable damage is done, for they usually occur in large numbers, and successive generations ensure deep destruction of the wood. The siphons and parts of the shell appear through the holes, but these can be withdrawn. They feed on plankton, using wood for accommodation. They are also found in shale and soft rock within the tidal zone. Because they do not use wood as food, *Martesia* spp. are hardly affected by wood preservatives.

Logs are often stored in harbours and rivers prior to shipment or conversion to sawn timber at a mill yard. Marine organisms such as *Teredo* and *Bankia* attack the logs in these situations. When the timber is sawn and used in buildings some minor excavation of the wood may be present. However, this damage will be evident for the life of the timber in a building and it is therefore important during future annual and prepurchase inspections that this past damage is identified and the information passed on to those buying or selling the property.

The irregular-shaped holes or excavations are lined with a pale to white calcareous material and this feature is a characteristic of the past mollusc marine organism damage or past activity.

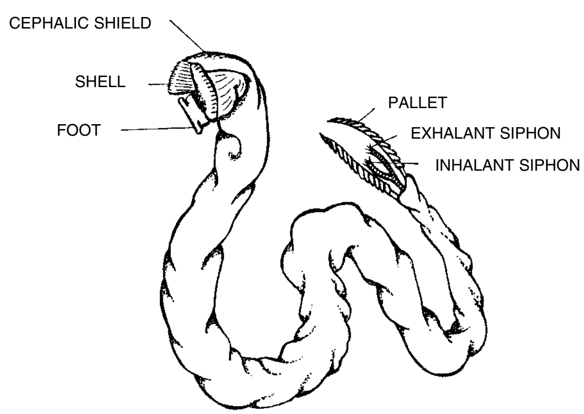


Figure 21.7 Shipworm (*Bankia* sp.)

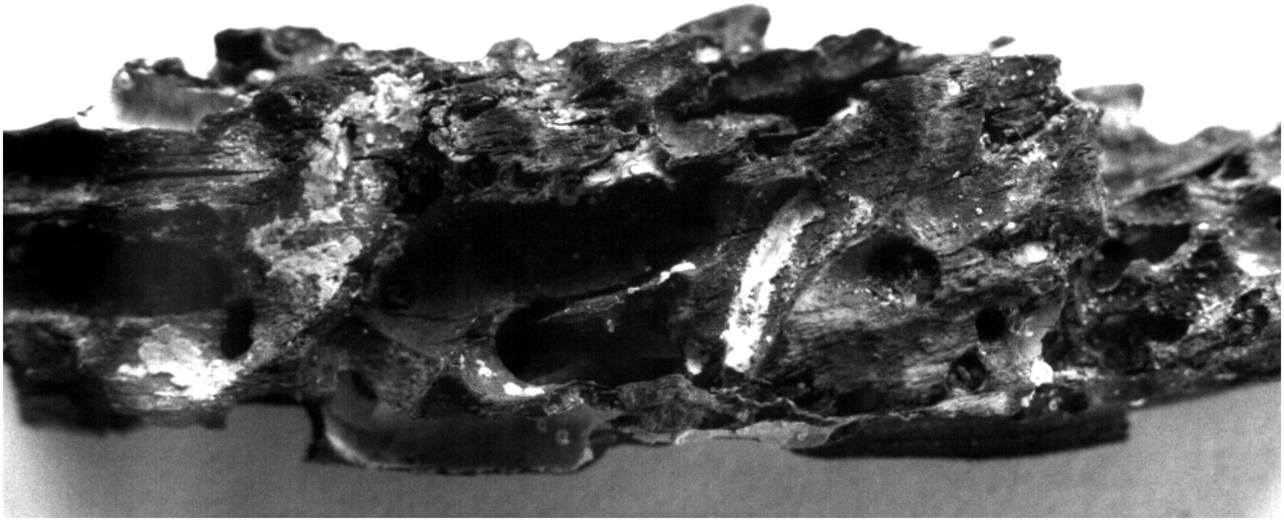


Figure 21.8 Mollusc marine borer damage. Note the holes lined with a calcareous material.

TABLE 21.1
Some common marine pests

Arthropoda	Class Crustacea	Order Amphipoda	*Chelura* spp.
		Order Isopoda	*Limnoria* spp. *Sphaeroma* spp. *Exosphaeroma* spp.
Mollusca	Familly Teredinidae		*Teredo* spp. *Bankia* spp. *Nausitora* spp.
	Family Pholadidae		*Martesia* spp.

TABLE 21.2
Some naturally resistant timber species

Turpentine	*Syncarpia laurifolia*
Swamp box	*Tristania suaveolens*
Satinay	*Syncarpia hillii*
Cypress pine	*Callitris* spp.
Prickly-leaved tea tree	*Melaleuca stypheliides*
Brush box	*Tristania conferta*

Prevention and control

Use of resistant timber Where possible, the most resistant timber species should be used for marine structures. This is sometimes confusing, for it depends where the timber is to be used and to what organism it is to be exposed. Turpentine is normally resistant below water level in Sydney harbour, but it is attacked by *Nausitora* in the upper tidal reaches of coastal rivers. There is no practical natural resistance of timber species to *Nausitora* or *Martesia*.

Natural resistance of timber to marine organisms is associated with silica content. The greater the amount of silica, the greater the resistance appears to be. Table 21.2 lists some naturally resistant Australian timber species.

Use of metal sheathing Metal sheathing of boats and structures prevents marine organisms from gaining access to the timber. Its main disadvantage, apart from added cost, is that fractures allow entry of marine animals. Copper or muntz metal is used extensively, and this inhibits marine growth, but in the case of small boats there is additional weight. An anti-corrosive paint over the metal, followed by an anti-fouling paint, is usual. Galvanised iron is often used for barges, and this is covered from time to time with hot coal tar.

Use of plastic coating Chemically cured resins reinforced with glass fibre cloth are often used to coat wooden boats and wood in contact with water. Better adhesion is obtained with light to medium density timbers, abraded with coarse sandpaper and thin initial coats of resin. If adhesion is not good, the wood may rot, causing damage to the hull.

Use of chemically treated timber The use of treated wood imparts considerable resistance to most marine organisms except *Sphaeroma*. Some chemicals are applied under pressure, and when in the wood become 'fixed' and not easily leached. Copper, chrome and arsenic salt formulations are mostly used, although creosote has been used in past years and was applied under pressure, but there are now environmental issues which have affected its use. However, not all wood species can be treated by these methods, as some resist pressure treatment. Plywood can be impregnated with the copper, chrome and arsenic formulations and successfully glued.

Use of paints A coat of paint is sufficient to prevent attack by marine borers, but usually attack occurs where the paint film has been broken. Wooden boats are usually protected from marine surface growth by anti-fouling paints. Most anti-fouling paints incorporate copper. Mercury-based paints are no longer favoured for use in water for environmental reasons.

TABLE 21.3
Marine pests

Organism	Size	Distribution	Water salinity	Economic importance	Food
		CRUSTACEANS			
Order Amphipoda *Chelura terebrans*	8–10 mm	Worldwide	High	Secondary pest; often follows *Limnoria* spp.	Plankton
Order Isopoda Gribble *Limnoria* spp.	2–3 mm	Worldwide	High	Attacks below mid-tide level.	Decomposed
Pill bugs or putty bugs *Sphaeroma* spp.	10–12 mm	Tropics and subtropics	High	Attacks at intertidal zone; honeycomb appearance; does not attack smooth wood surfaces; infests putty or caulking in seams.	Plankton and fungi (soft rot fungi)
Exosphaeroma spp.	10–15 mm	As above (upper reaches of rivers)	Low	As above	Plankton and fungi
		MOLLUSCS			
Family Teredinidae[1] *Teredo* spp.	Up to 1 m	Worldwide	High	Seriously damages wooden structures and boats.	Plankton and wood
Bankia spp.	Up to 1 m	Worldwide	High	As above	As above
Nausitora spp.	Up to 1 m	Worldwide (upper tidal reaches)	Low	As above	As above
Family Pholadidae Shell borer *Martesia* spp.	30–40 mm	Tropics and subtropics	High	Degeneration of wood by successive generations	Plankton

[1] Teredine borers are also called 'cobra' or shipworms

Anti-fouling paint is not necessary if a boat is taken out of the water frequently. The following painting procedure for wooden boats should be followed:

1 Sand back to bare wood.
2 Coat all wood with copper naphthenate, avoiding runs. Allow to dry for 2–3 days.
3 Lightly sandpaper. Apply pink primer that conforms to Australian Standard K109, and allow 2 days for drying. This primer contains red lead, whereas most pink primers are lead free.
4 Stop all holes, joints and so on with caulking compound and allow to dry. Sandpaper entire surface.
5 Apply an exterior undercoat and allow 24 hours to dry.
6 Sand surface and apply a coat of anti-fouling paint to surface below the water line. Use marine enamel only above water line.

Use of a floating collar The floating collar technique enabled a coating of creosote to be applied to marine piles. The method was developed by the Maritime Services Board of New South Wales. The floating collar is a cylindrical galvanised-iron or plastic casing supported on the water by floats. Creosote is put in the space between the collar and the pile. The Maritime Services Board now uses other less polluting methods.

Changing the environment Boats removed from the water regularly are not troubled by marine borers or shipworm. Under hot dry conditions, only a few days' removal is sufficient to kill the animals. Cool humid conditions require the period of removal to be extended to about one month. High salinity shipworms are killed by exposure to low salinity conditions; low salinity borers are killed by exposure to water of high salinity. This type of control requires a knowledge of the borers and their habits and environments.

FURTHER READING

Creffield J.W. 1996 *Wood Destroying Insects, Wood Borers and Termites* CSIRO Melbourne

Wilkins A.P. and Simpson 1988 'Defibring of Roof Timbers' *Journal Institute of Wood Science* 11 (3)

CHAPTER 22

TIMBER PEST INSPECTIONS

INTRODUCTION AND SCOPE

A timber pest inspection is essentially an attempt to:

- assess how the forces of nature have impacted on the timbers within a property (the principal players being termites, borers, fungal decay and climate); and
- effectively communicate the findings of the inspection to the client (including the implications and any relevant recommendations for minimising timber pest problems and risk).

Timber pest inspections may be carried out for a number of reasons:

- **Pre-purchase**
  The majority of timber pest inspections are commissioned by the solicitor of an intending purchaser (or sometimes directly by the purchaser). On occasions, the inspection may be arranged primarily for the 'peace of mind' of the purchaser. More often, it is a requirement of the lending authority, seeking to ensure that the property is not adversely affected by timber pests.
- **Re-financing**
  Persons involved in re-financing may find that their lending authority requires a timber pest inspection to be carried out on the property.
- **Specific concern**
  Homeowners sometimes have a specific concern that may generate the need for a timber pest inspection. Such concerns may arise from a number of causes, among them: a trades person reporting a hollowed timber; the homeowner finding evidence of insect damage in the house; the homeowner hearing that a neighbour has a serious termite problem; concern arising from a television item about severe termite damage.
- **Regular inspection (eg annual)**
  Many property owners recognise the importance of having regular timber pest inspections. The Australian Standard AS 4349.3–1998 (Inspection of Buildings Part 3: Timber Pest Inspections) recommends a competent Timber Pest Inspection at least on an annual basis. In some cases, there is a desire to lessen the chemical impact on the home environment and people who once had 'annual sprays' carried out (eg for termite prevention), now have an annual timber pest inspection. Such inspections must be just as comprehensive as a pre-purchase timber pest inspection and not just a cheaper 'quick look'.

All timber pest inspections should be thorough and comprehensive. For the remainder of this chapter, timber pest inspections will be considered largely in the context of pre-purchase inspections. However, regardless of the reason for which it is carried out, the conduct and thoroughness of the inspection should be the same.

THE MAIN OBJECT OF TIMBER PEST INSPECTIONS

Timber pest inspections are usually carried out in order to identify and report on:

- evidence of timber pest activity and/or damage (eg caused by termites, borers, fungal decay or delignification);
- evidence of a previous timber pest problem (eg drill holes in concrete paving)

- conditions that make the property more susceptible to timber pests (eg timbers in contact with the ground); and
- restrictions to inspection access (eg insulation in the roof void).

Any further investigations that are deemed necessary, in relation to any of the above issues, must be clearly communicated to the client.

Timber pest activity and/or damage

The main objective of a Timber pest inspection is to determine whether or not the biological agents causing timber deterioration (including termite, borer and wood decay) are present (or have been present) and whether they have caused damage.

If such activity and/or damage is found, then the inspection report should outline:

- which pest or pests are likely to have caused the damage;
- the location of the damage;
- a broad indication of the extent of damage; and
- an indication (when possible) of activity status.

In relation to the extent of damage, while persons who carry out pest inspections are not expected to do the work of qualified building consultants, architects or structural engineers, they should nevertheless give a broad indication of damage levels. Such assessments may include recommendations concerning the need for further investigations by those more qualified in such matters.

Indirect evidence of timber pest history

The identification of indirect evidence that suggests a history of timber pest infestation is important, because with the benefit of further investigations, it may be revealed that:

- there is significant concealed termite damage (that could not have been detected in a normal timber pest inspection); and/or
- an apparent attempt at termite control has failed and concealed activity is present.

Indications of a possible timber pest history may include evidence of chemical barrier treatment against termites, for example, drill holes in concrete slabs/paving, drill holes in trees/stumps, trenched soil around foundation walls and piers, notices in power box, receipts held by vendors.

Note: These signs are *not* reliable indicators of whether or not there is current termite activity and, in some cases, they may represent preventative measures rather than attempts at control.

Other evidence of possible timber pest history include improvements to subfloor ventilation, timber repairs and/or replacements, and removable skirting boards.

Timber pest susceptibility issues

In the current climate of increasing concern about unnecessary use of chemicals, it is evident that many clients appreciate advice on non-chemical strategies that lessen the likelihood of pest problems. The timber pest consultant can gauge the susceptibility of buildings and give the client specific advice that may reduce the likelihood of future pest problems (eg removal of old formwork timbers that are in contact with the ground). Such advice will, in some cases, incorporate strategies for improving inspection access.

Examples of common susceptibility issues include:

- timbers in contact with ground and/or concrete, such as door jambs, posts, steps, weatherboards, bottom plates (eg in garages), floor frame timbers, subfloor partition timbers, old formwork timbers, stored timber and timber debris in the subfloor;
- yard timbers in contact with ground, for example sleepers, retaining walls, garden bed edging, paver edging, other landscape timbers, fence palings, stored firewood, hardwood chip garden mulch, stored timber and timber debris, trees and stumps;
- excessive moisture sources, such as leaks from showers and other plumbing defects, hot water system overflow (especially when adjacent to a concealed slab edge), defective stormwater disposal, overly generous garden irrigation systems, roof and/or flashing leaks (eg around chimneys), penetrating damp in walls, poor site drainage, poor subfloor ventilation and rising damp in walls.

Restrictions to inspection access

All restrictions to inspection access should be noted during the inspection and outlined clearly in the report, so that those who read the report have a clear understanding of which parts of the building were inspected, which parts were obstructed, and which parts it was not possible to inspect at all. Careful attention to detail can minimise liability.

Examples of restrictions to inspection access include:

- Interior: furniture; stored goods; cupboards; window furnishings; wall linings/hangings; floor coverings; locked room(s); upper level flooring and floor frame.
- Roof Interior: dust; insulation; sarking; hot water system; air conditioning equipment; ducting; boarding; stored goods; low clearances.
- Exterior: plant material; soil, garden or paving levels concealing the slab edge; proximity of structures adjacent to fencing; stored goods and/or debris.
- Subfloor: low clearances; stored goods; ducting; debris (including hazardous materials); sections such as patios that are inaccessible.

In the context of pre-purchase inspections, the information provided in the report is often used to make the important decision about whether to purchase, so great care must be exercised in the conduct of the inspection and in the preparation of the report.

Where purchasers of an inspected property later find timber pest damage and/or activity that was not noted in the inspection report, it is possible that an independent assessment of the situation will find in favour of the consultant. That is, that visible evidence of pest activity and/or damage was unlikely to have been observable at the time of inspection. Such a situation may arise when, soon after moving in, the purchaser of a property undertakes renovations, including removal of wall linings, that substantially improve inspection access.

On the other hand, several matters of this kind have become extended legal battles, that have sometimes resulted in the settlement of damage claims in favour of the purchaser.

RESPONSIBILITIES OF STAKEHOLDERS

The timber pest consultant

Persons carrying out structural pest inspections should be knowledgeable in the areas of:

- timber pest biology, life cycles, habits and ecology;
- timber (including identification of main types, uses, pest susceptibility etc);
- building principles (naming building components and being familiar with various types of construction); and
- pest control and prevention methods (including both chemical and non-chemical approaches).

Normally, access to the property is made available by the vendor (or owner) and/or the real estate agent who is acting on the vendor's behalf. The consultant should make all reasonable attempts at examining as much timber in the property as possible. In cases where access to certain sections of the building is unavailable but feasible (eg where cutting a floor trap will allow access to subfloor timbers), the written permission of the current owner of the property, (ie the vendor), should be obtained.

Furniture is generally not included in the scope of pre-purchase inspections, unless special arrangements dictate otherwise. All built-ins (such as cupboards and closets) must, of course, be inspected as must all accessible timbers of the house and grounds.

The inspection of timber often involves probing and damaging its surface. Visible damage should be kept to a minimum, both as a mark of respect to the owner of the property and, in the case of termite damage, in order to minimise disturbance of the termites that may compromise attempts at control.

Some aspects of inspecting buildings can be dirty, eg exiting from roof voids and subfloors. Pest consultants have a professional obligation to employ clean work habits that are protective of the vendor's property.

Given the importance of the decision that is influenced by the findings of a timber pest inspection, it is strongly recommended that consultants always carry adequate insurance in the form of professional indemnity and public liability cover.

The vendor

The vendor or the vendor's agent should provide access to allow assessment of the condition of the building in relation to pest activity and/or damage.

In cases where access is poor (eg no access to subfloor area), the vendor may permit or prohibit obtaining access (by such means as cutting a floor trap).

It is usually advisable to obtain written permission from the vendor before undertaking alterations to improve access. Any such agreement should also serve as a contract that explains likely problems (such as damage to floor coverings) that may result.

In cases where permission to improve access is not forthcoming from the vendor, this may be interpreted as an attempt to hide timber pest damage or activity. In such circumstances, negotiations between the vendor's solicitor and the purchaser's solicitor may help obtain cooperation from the vendor.

The purchaser

Whether the purchaser him/herself requests the inspection, or the purchaser's solicitor does so on his/her behalf, the inspection can only be carried out with the consent of the vendor or vendor's agent. It is always advisable that a purchaser has a timber pest inspection carried out as soon as possible, but it is important that it be done prior to exchange of contracts. In cases where inspection access is poor, but improvable, the purchaser (or his/her solicitor) will need to negotiate access with the vendor.

In cases where unreported timber pest damage is found in a house after purchase, it is likely that, in legal evaluation, the expert witness will be asked whether there was visible evidence at the time of inspection. If it is not likely that such evidence was present, then the purchaser's legal representatives are likely to consider the case to be weak and not worth pursuing in the courts.

TOOLS AND EQUIPMENT — SOME IMPORTANT BASIC ITEMS

The following list of tools and equipment represents the basic requisites for carrying out an effective timber pest inspection:

- reliable powerful torches (a small 'reserve' pocket torch can be useful in extensive subfloors if the main torch fails);
- timber pest probe/sounding tool — (useful for sounding and probing timber — some consultants prefer a heavier, metal hammer head for sounding structural timbers such as hardwood floor frames);
- screwdriver and knife (for testing timber);
- moisture meters — pad and probe/pin types are useful for determining excessive dampness, including checking plasterboard for concealed termite activity/mud;
- binoculars;

- compass;
- magnifying lens (eg x 10), sample tubes and adhesive labels;
- ladder;
- access aids — a variety of tools eg screwdrivers;
- drop sheet — to protect interiors when exiting dirty roofs and subfloors;
- appropriate protective clothing and equipment (see Safety Issues below).

RECORDING INFORMATION DURING THE INSPECTION

The findings of a timber pest inspection should be recorded during the inspection rather than relying on memory. Whether the findings are written on a note pad, dictated into a mini-cassette recorder, or noted on a personalised 'check-sheet', it is important that a correct and comprehensive record of findings and observations be made and used for reference when writing the report. Employing the latter method, using a well-designed checksheet, will add in-built quality assurance to the process.

Findings and observations should be recorded immediately. Attempts at accumulating observations and making only infrequent notes is fraught with the risk of certain items being left out of the report.

Information that is recorded during the inspection should pertain to:

- pest activity and/or damage;
- history of pest infestation;
- access restrictions; and
- notes on susceptibility evaluation (ie. strategic advice on non-chemical preventative measures that reduce pest susceptibility).

Any recommendations regarding the need for further investigations or action (and these may be relevant to any of the above aspects) should also be noted.

Consultants have professional and legal obligations to produce a Timber Pest Report that is accurate and clear. The task of writing the report is made considerably easier with a well-designed and comprehensively annotated checksheet of the observations.

INSPECTION TECHNIQUES

Inspection procedures rely largely upon:

1. Visual examination of timbers and other building components for signs of pest activity or damage such as termite mudding, borer exit holes or fungal growth. The consultant will also be looking for signs of deflection or bowing of timbers that might have been caused by pest activity and damage.
2. Sounding timbers by striking them with a high density object eg handle of a large screwdriver or a specially designed tool. It is usually possible to determine, from the sound, whether or not the timber is in good condition. When struck, the timber may have a somewhat hollow sound (perhaps indicating the excavations of termites), or a 'dead' sound which may indicate fungal decay damage. Consultants usually carry a screwdriver or knife which will allow them, by probing the timber, to further investigate strength and soundness. Furthermore, movement in some timbers (eg flooring), may be an indication of pest damage.

THE MAIN SIGNS OF TIMBER PEST ACTIVITY AND/OR DAMAGE

Termites

- visible termite damage (eg wavy surface of timber or timber hollowed or fluted)
- termite mudding
- if active, mud or damaged timber will contain live termites (usually workers and/or soldiers)
- timber deflected, collapsed or crushed
- hollow sound when tapped
- termite flight cuts (eg in plasterboard, timber, trees)
- higher-than-normal moisture content (eg of plasterboard or wood)
- sound of falling mud when sounding linings such as plasterboard with the heel of one's hand.

Borers

- visible borer damage (usually small round holes)
- sometimes frass (dust)
- under floor coverings there may be a 'soft', slightly spongy depression or a collapsed section under foot.
- dead sound when tapped (more pronounced when damage is more advanced).

Fungal decay

- dead sound when tapped
- timber is soft, stained, spongy, broken into cubes, cupped or brittle
- fungal growth on timber (may or may not be present or visible)
- will not yield a sharp splinter.

If fungal decay is active, moisture content is high eg >25%, timbers are swollen and conditions are damp;
If fungal decay is inactive, moisture content is normal eg 8–15% and timbers have shrunk (eg when leak has been repaired or subfloor ventilation has been improved)

Delignification

- timber has a 'furry' appearance
- mostly affects roof timbers.

TYPES OF BUILDING STRUCTURE

The type of building structure, its age, style and design, can clearly have a significant impact on various aspects of the timber pest inspection:

How susceptible the building is to structural pest problems

An old, timber-framed, fibre-cement clad cottage, with exterior paving levels above interior floor levels, low subfloor clearance (with no subfloor access to rear rooms), no stormwater disposal system and surrounded by a yard landscaped with old, decaying hardwood sleepers, is considerably more susceptible to timber pest activity than a well-elevated, double brick structure that has good subfloor inspection access, proper stormwater disposal and treated pine landscaping timbers.

How long the inspection will take

A large, sprawling and old federation-style residence (with substantial amounts of timber to the interior, exterior roof and subfloor) will take considerably longer to inspect than a full brick, slab-on-ground, contemporary town house.

Potential for concealed pest activity and/or damage

Some types of construction allow the consultant direct access to the majority of the timber in the building, for example, full brick structures often allow reasonable inspection access for timbers in the interior, roof and subfloor areas. On the other hand, brick veneer and other timber framed structures contain substantial amounts of concealed wall frame timbers which cannot be inspected and may be susceptible to timber pest damage.

In cases where termite activity and damage are found in both subfloor and adjacent roof void timbers (in these types of construction), it is incumbent on the consultant to indicate the likelihood that pest damage may exist in concealed wall frame timbers, and that further investigations (including destructive investigations) may be required to establish the full extent of damage. In such cases, sections of bottom plate and top plate may be sufficiently accessible to allow testing for soundness.

INSPECTION PROCEDURE

Arriving at the property

When arriving at the property to be inspected, a number of preliminary observations are usually made. Such observations may include:

- What is the style, age and type of construction?
- Have there been any alterations or additions?
- Is it attached on both sides, semi-detached or free-standing?
- How does the house sit on the street? Is it on the high side or low side, and are there any implications in relation to seepage and drainage?
- How does the house sit on the block? Does it appear to be 'high and dry' or is it cut into the slope with possible bridging of dampcourses?
- Is it close to, or surrounded by many trees or bushland?

Consideration of issues such as these can provide the consultant with an overall view of the property and this will provide a useful introduction to a more detailed inspection and assessment.

Inspection sequence

Consultants usually have their own favoured approach to the order in which they inspect the various sections of properties. Some prefer to inspect the property in an order that represents a logical progression of termite evidence ie: first, the exterior and grounds are inspected (this may reveal, for example, a suspected termite nest in a tree or stump). Next an inspection of the subfloor (this may reveal termite entry points into the building). Following that, the interior is inspected (which may reveal termite damage to joinery timbers) and finally the roof interior is inspected (and this may also reveal termite damage eg to some top plates).

While there are advantages and a logicality to this approach, some would argue two disadvantages:

1. There is a danger of pre-supposing what will be found and where it will be found in the house interior and roof. Some consultants prefer not to have any pre-conceived ideas about what to expect, but rather to inspect the interior and roof in as much detail as is feasible (knowing that these areas can be revisited should the need arise).
2. Inspection of the subfloor is usually a very dirty business and this approach would require a change of clothes and a clean up in the middle of the inspection.

A widely favoured approach commences with an introductory overview of the entire property, ie a brief walk through the whole of the building interior and a walk around the grounds. The first area to be inspected in detail is the interior (and it is appropriate that, at this point, the consultant is cleanest). The next area inspected is often the roof void, and in cases where the manhole is in a very 'clean' part of the house, (eg in a hallway with light-coloured carpet), the consultant should take care (and preventative or remedial action if necessary) in relation to:

- not soiling the manhole cover
- not soiling the carpet or other floor covering with falling dust and dirty shoes — the use of a drop sheet is usually appropriate
- not marking or damaging wall finishes with a leaning ladder — the use of a protective cushioning (eg towel) on the ladder should avoid such problems.

The consultant would then proceed to the exterior of the property. This would include inspection of the house exterior (including any slab edges), fences, sheds and/or garages (interior and exterior), trees, landscape timbers etc. Finally, the subfloor, if there is one, would be inspected. Observations made in the subfloor area may prompt the consultant to wish to re-examine some part of the building interior and this often requires changing and clean-up. If access to the property was arranged by an agent who wished to lock up and leave as soon as possible, for instance, after the consultant inspected the interior and roof, then re-visiting the interior may present access problems.

If subfloor entry is via a floor trap inside the house, appropriate care must be exercised to minimise dirtying the house interior. This may involve the use of a drop sheet and having a dustpan and brush for clean-up. Some consultants prefer to change shoes and perhaps overalls when crawling in subfloors.

SOME COMMENTS ABOUT INSPECTING THE VARIOUS SECTIONS OF THE PROPERTY

The following is an overview of some common findings in relation to timber pest activity and/or damage in typical domestic dwellings. This is meant to be an overview only and is by no means meant to be comprehensive. There are many, less common timber pest situations that are not covered.

Introductory overview

Before commencing the detailed inspection of a property, it is always beneficial to have a quick walk through the interior of the building(s) and a brief walk around the grounds so as to familiarise oneself with the 'big picture'. For many consultants, this process begins when driving into the neighbourhood and up to the house. The prevailing topography, plant life, age and style of building will begin to give a context from which a more detailed assessment will evolve.

After noting the compass bearings of the building, a brief walk around and in the building will reveal much that may be useful in forming an introductory picture, for example:

- What is the predominant soil type? Is it heavy with poor drainage, or sandy and well drained?
- How well ventilated is the subfloor likely to be?
- How generous are the subfloor clearances likely to be?
- Do any exterior ground levels exceed interior floor levels?
- Is the slab edge concealed by paving, soil etc?
- Are there many trees and/or stumps or other potential termite nesting sites around the building?
- Are there many untreated timbers in contact with the ground (eg sleeper retaining walls)?
- What is the type of construction (eg weatherboard, full brick, brick veneer)?
- What is the layout of the interior?
- What is the best order in which to inspect the interior?
- Where are the wet areas (such as showers and baths) located within the building?
- Are there any obvious signs of excessive dampness (eg rising and/or penetrating damp)?
- Are there any indications of a timber pest history (eg borer holes in timber, evidence of drilling of concrete slabs)?
- What is the general age and nature of the building materials (eg Are the timbers relatively old or new? Are the foundations walls sandstone or brick?)
- Does the building include any extensions?
- Has the extension compromised the termite susceptibility of the building as a whole?

While full and complete answers to such questions are unlikely to be forthcoming from a brief 'walk through', nevertheless, such an overview will always provide a useful preliminary context within which to conduct a full and proper inspection and assessment of the timber pest issues within a property.

Experienced timber pest and building consultants generally develop a 'routine approach' to carrying out timber pest inspections. This involves not only the order in which the various parts of the property are inspected, but also the procedures used within each part of the property. An important part of the routine is remaining focussed on the inspection procedure. While some jobs can be accomplished while letting the mind wander, carrying out timber pest inspections is not one of those jobs. Having a set routine minimises the risk of missing defects or other timber pest-related evidence.

Interior

The inspection is best approached in a logical order, room by room, to ensure that all sections of each room are inspected. The following is an example of one routine approach to inspecting the interior of a building:

Upon entering a particular room, look around and identify all of the timber elements that must be inspected. This may include skirtings, window timbers, door timbers, built-ins, fireplace surrounds, picture rails, exposed floorboards, staircase timbers, exposed roof frame timbers, lining boards etc.

By a combination of visual inspection (with the aid of a torch) and sounding the timber by tapping, sequentially examine all of the timber for evidence of any pest-related defects. Torch light is important in this process because it also allows more reliable inspection of the joint between the timber and its substrate (eg plasterboard, fibre-cement or masonry), where tell-tale termite mudding may be the only evidence of a termite infestation — especially where the exposed joinery timbers, such as skirtings and architraves, are resistant to termites. Many interior timber surfaces are painted and this can make attempts at identification of the timber species difficult.

The sequence may involve travelling clockwise, first examining only skirtings and architraves then, when all of the skirting has been examined, turning anticlockwise to examine built-ins, windows etc. Next, if there are any, the exposed roof beams are checked, followed by the flooring.

In the case of plasterboard walls (especially in brick veneer-on-slab structures), some consultants will then, wall by wall (and including the ceiling), examine the surfaces (eg for evidence of termite mud). They may also (using the heel of the hand), sound the walls between studs listening for the sound of dislodged termite mud falling within the wall cavity. As well, they may run a pad-type moisture meter over sections of walls (eg typically just above skirting level) to look for any signs of higher-than-normal moisture levels that may indicate a timber pest problem that is subsequently identified (eg a leaking shower or an active termite infestation) or the need for further investigations.

Testing one's weight on floors (eg by shallow jumping at various points within each room) may indicate excessive movement that warrants further investigation. This check is especially important in cases where there is no subfloor inspection access.

Restrictions to inspection access inside a house may include furniture, stored goods (often more seriously in cupboards and below staircases), window furnishings and floor coverings, wall hangings and new patching/new paint.

Some examples of timber pest activity or damage that may be found include:

- **Termite activity and/or damage** This occurs possibly to skirtings, floors, architraves, window and/or door frames. In timber-framed and brick veneer-type constructions, concealed damage to wall frame timbers may be present.
- **Borer damage** This is more often encountered in older properties. Evidence of *Anobium punctatum* or *Calymmaderus incisus* may be found in exposed floor boards, built-in closets and fireplace surrounds, skirtings, architraves and occasionally doors. *Lyctus* borer damage is rarely encountered in the interior of houses, as finishing-type timbers are usually free of *Lyctus*-susceptible sapwood. Occasionally, *Lyctus* damage may be found in timbers such as skirtings and architraves.
- **Fungal decay damage** This may be found at the base of door frames, window frames (and mullions), in flooring adjacent to exterior doors, in wet areas such as around and under kitchen sinks, and in various timbers in bathrooms and laundries. Evidence of the use of sealants around the base of shower recesses may indicate a history of leaking (that may require further investigation). Skirting boards on walls adjacent to a leaking shower may also sustain fungal decay damage (as might the concealed timber frames within). In masonry properties that exhibit rising damp due to failure of damp-course materials and in basements with walls built below ground level, fungal decay damage to adjacent timbers such as skirtings is possible.

Roof interior

Upon entering the roof interior, it is wise to have an overall look at the entire space. This is useful for a number of reasons:

- one can identify the main types of timber (usually hardwood or softwoods such as oregon or radiata pine);
- the access restrictions can be identified (eg ducting, sarking, insulation etc); and
- the presence of gross defects such as deflection due to termite damage or repairs/replacements are sometimes more easily identified from afar.

The inspection is best approached in a logical order to avoid missing any sections (eg some consultants prefer working anti-clockwise around the entire perimeter followed by the ridge lines). The consultant should be mindful of the possibility that some timbers may be structurally unsound due to pest damage and consequently should always maintain good balance and footing and hold onto rafters, collar ties and the like.

Timbers should be examined visually for such evidence as signs of termite mudding, borer holes, or staining and/or cracking that may be associated with fungal decay and for signs of deflection and/or bowing.

Sounding and probing timbers can also be worthwhile, however, this can only be a sampling procedure as it would be impractical to test every square centimetre of timber.

Restrictions to access, may include: dust build-up on timbers, insulation materials (such as fibreglass batts and loose materials), ducting and air-conditioning equipment, sarking, boarding and stored goods and low clearance at eaves or other areas (depending on roof design). Flat or skillion roof sections are often not accessible for inspection. Where termite damage is widespread in roof timbers, the consultant should exercise care in moving around and this may constitute a restriction on inspection access.

Some examples of pest activity and damage that may be encountered in roof voids include:

- **Termite activity and damage** This can range from minor and localised to severe and extensive, including, most commonly, damage to top plates and ceiling joists and sometimes damage to rafters, underpurlins and hanging beams. In timber frame buildings (especially brick veneer-on-slab), the inspection of top plates (particularly over wet areas such as bathrooms) is worthwhile, even if the presence of insulation determines that it will be limited to a sampling procedure only.
- **Borer damage and activity** Timbers in roof spaces are often subjected to higher-than-normal levels of heat and dryness and this may lessen their susceptibility to borer attack. However, cases of borer damage to roof timbers do occur. In older buildings, *Anobium punctatum* or *Calymmaderus incisus* may be encountered occasionally (most commonly in softwood ceiling battens). *Lyctus*

borer damage is also encountered (eg in frame timbers and battens) and this may be active in newer buildings (eg less than 15 years old), but is unlikely to be active in older buildings.

- **Fungal decay** Fungal decay damage is sometimes encountered in roof timbers. Most typically it may be found in timbers associated with defective flashings, box gutters, valleys which may be leaking or which may have leaked (eg timber framing around chimneys) and timbers built into parapet walls.
- **Delignification** Evidence of delignification (where the timber has a furry appearance) is often encountered in oregon roof frame timbers of houses located close to sea and salt air.

Exterior

Inspection of the exterior of a property is best approached in a logical manner to ensure that no areas are missed. The inspection may proceed in the following manner:

1 the exterior perimeter of the house;
2 all untreated timber fences and gates;
3 all out buildings (interior and exterior);
4 all landscaping timbers; then
5 all trees and stumps.

Again, the use of a torch while visually inspecting and sounding can be a useful approach.

Restrictions to access may include plant materials (eg ivy growing over fences or buildings); soil build-up (eg to base of fence lines or to exterior perimeter of slab edge of building); stored goods in sheds and garages (these may be so plentiful as to warrant recommendation for re-inspection when cleared); low clearance below decks or balconies; no access to adjacent private property and proximity of structures.

Some examples of pest activity and damage encountered in the inspection of exteriors may include:

- **Termite activity and damage** This is often encountered in fence timbers, sheds and garages. Commonly, these structures are built in a termite-susceptible manner with frame timbers in direct contact with the ground and soil built up to walls. Close visual examination of bottom plates in sheds and garages often reveals a variety of pest damage. Structures built as slab-on-ground constructions are at risk of termites travelling over the slab edge and into the structure. Consequently, close examination of the exposed slab edge perimeter is warranted and recommendations for clearing (where feasible) may accompany comments on restrictions to inspection access. Close examination of untreated hardwood sleepers and other timbers used in landscaping and trees and stumps may reveal termite harbourage or activity. Evidence of termite mudding, damage or flight cuts in trees or stumps is common and usually requires further investigation. Untreated timbers in contact with the ground and/or concrete (such as posts and steps) are prone to concealed termite entry and damage.
- **Borer damage** This is sometimes encountered in fence and shed or garage timbers (for example old *Lyctus* borer damage in hardwood frame timbers and sometimes *Anobium punctatum* or *Calymmaderus incisus* damage in old softwood shelving or bench timbers).
- **Fungal decay damage** is probably the most commonly encountered type of pest damage to exterior timbers. Paying particular attention to cut ends and joints (where fungal decay is most likely) may reveal evidence of fungal decay damage in timbers associated with windows (especially sills), barges, cappings and fascias, trimming timbers, posts, fencing, decking, stairs, pergolas, sheds and garages. Timbers in contact with or penetrating the ground (eg door jambs, posts and steps stringers) are very prone to fungal decay damage. The use of non-durable softwood timbers (such as oregon) in weather-exposed situations such as decks and balconies, handrailing and pergolas is a relatively common practice that can have serious implications for the potential for future fungal decay damage. This sometimes results in expensive replacement costs. Careful assessment of such structures and appropriate reporting and warning of the susceptibility issue(s) is important (perhaps even in the absence of any current evidence of fungal decay damage).

Roof exterior

Inspection of the roof exterior usually involves checking fascias, barges, cappings, gable trimmings and linings, eaves linings, exposed rafter ends and roof windows. This usually entails visual examination (perhaps with the aid of binoculars) with some more direct sounding and probing where appropriate and/or feasible. A ladder may be required for closer investigations.

Restrictions to access may include height, obstruction by plant material, and perhaps a type of roof covering that is not safe to walk on, eg old slate or terracotta, asbestos cement sheeting or steeply pitched metal roofs.

Some examples of timber pest activity and damage that may be encountered include:

- **Termite activity and damage** Although relatively rare, termite damage is sometimes found in roof exterior timbers such as fascias, eaves linings and exposed beams and rafters.
- **Fungal decay damage** This is very common in exterior roof timbers. Damage ranges from minor to severe and is often located at corners, ends and joints of fascias, barges, capping and other external roof timbers. Leaking roof coverings and/or flashings may cause localised decay damage to eaves lining materials, bearing/insertion points of verandah roof support beams and pitching plates (eg for pergolas).

Subfloor

Inspection of the subfloor area should proceed in an organised routine manner that makes it unlikely that any section will be missed. The direction of crawling should ensure that the inspection allows for a view of all sides of all piers and dwarf walls, as well as all sections of floor and floor frame timbers at relatively close quarters (thus facilitating sounding and probing timbers as necessary).

A range of structural pest problems is commonly encountered in subfloor areas. If there is no access for inspection of the subfloor, this should be made very clear in the inspection report. The creation or improvement of access for inspection prior to exchange of contracts should be recommended in the report.

Restrictions to access in the subfloor may include low clearance, stored goods, build-up of debris, hazardous debris, extensive ponding or other obstructions.

Some examples of pest activity and/or damage that may be encountered include:

- **Termite activity and damage** This is commonly encountered in the form of mud leads (eg. over piers, bridging ant caps, on dwarf walls and over flooring timbers) and damage/hollowing of timbers. Damage levels can range from relatively minor and localised, to severe and extensive. Recommendations regarding the removal of old, unnecessary formwork timbers and timber debris from subfloor areas may be appropriate.
- **Borer activity and damage** *Anobium punctatum* and *Calymmaderus incisus* damage is often encountered on the underside of old pine flooring, and damage levels may vary from minor, to severe and widespread. Some sections of flooring may be resistant (eg cypress pine or hardwood). *Lyctus* borer damage is commonly encountered in hardwood bearers and joists. In older properties it is unlikely to be active, while in recent constructions it may well be active. It is unlikely to be of any real concern in most cases.
- **Fungal decay damage** This is commonly encountered in subfloor timbers. Damage may be widespread in subfloors with poor ventilation and high moisture levels, or it may be localised to points of contact with moist masonry, eg where floor bearer ends penetrate brick work.

Shower recesses are a potential source of regular and plentiful moisture. If they leak (as most commonly occurs at the junction of wall and floor), fungal decay damage to adjacent flooring and floor frame timbers, and possibly concealed wall frame timbers, is likely. Damage can range from minor to severe. In some cases, considerable structural damage to floor frame and adjacent wall frame timbers may occur. In such cases, the consultant usually recommends repair of the leak and/or waterproofing and any necessary structural repairs.

General dampness levels in some subfloor environments may warrant recommendations for ventilation and/or drainage improvements.

SOME COMMENTS ABOUT INSPECTING DIFFERENT TYPES OF CONSTRUCTION

The type of building construction can impact not only on its susceptibility to timber pests in general but, in particular, on its susceptibility to *concealed* termite entry and activity/damage. This can have important implications for timber pest inspections.

Attached brick terraces

Originally, terraces were built with solid masonry walls (often with soft lime mortar) and these are prone to rising damp (due to failure or absence of dampcourse materials) and penetrating damp (because exterior, weather-exposed walls are not waterproof). Dampness in walls can create conditions conducive to timber pest activity.

- Subterranean termites can travel within masonry walls, render or plaster and attack timbers in various parts of the building, eg ground floor flooring, first floor flooring, roof timbers (including pitching plates such as those found in or on parapet walls), verandah beams, skirtings/architraves, door jambs and staircase timbers. Such infestations often commence in a concealed fashion, and, in the case of areas such as flat roofs and first floor flooring, significant damage may occur before the infestation is evident to normal inspection procedures. Termites can travel within walls and move from one residence to an adjoining one. This susceptibility issue applies to the majority of fully attached and semi-detached buildings.
- Fungal decay damage is often an issue in timbers that are either in contact with or built into damp masonry (such as those mentioned above). Poor subfloor ventilation and drainage is often a problem in old terraces, and, in some cases, the excessively damp subfloor conditions that result, can cause extensive fungal decay damage to flooring and floor frame timbers.

The design and construction of old terraces often imposes severe restrictions on timber pest inspections. Such access issues include:

- Poor subfloor access, or no subfloor access is common.
- There is usually no access to inspect first floor level floor frame timbers and flooring may be inspected only partially if there are floor coverings.
- If there are timber-framed components of the building at the rear (eg laundry), the timbers are often in contact with the ground and/or concrete, with no access for inspection.
- There is often no access to inspect the rear skillion roof frame timbers.

Buildings with suspended timber floors and concealed timber wall frames (eg weatherboard, fibre-cement, brick veneer)

The wall frame timbers in these types of buildings are for the most part concealed, so inspection above (in the roof interior), below (in the subfloor) and around (in the interior of the building) must be thorough. The ant capping, if present at all, is seldom completely continuous. Even so, if there is a termite infestation in the building, a competent inspection of the subfloor will, in most cases, identify termite entry (for example, as mud tunnels on a foundation wall or pier). However, care must be exercised with respect to the possibility of concealed termite entry which may occur in a number of ways:

- Where flooring timbers are close to, or in contact with the ground, and inspection access is poor due low clearances.
- Where foundations are sandstone and there is no ant capping, termites can enter via the sandstone mortar directly into the floor frame timbers.
- Where there is a concrete slab on masonry foundations, without effective ant capping (as may occur with bathrooms, laundries and porches). Whether the slab is on fill or suspended, the possibility of remnant formwork timbers increases the susceptibility to termite activity or history. If the slab is suspended with no inspection access below, and if there is a possibility of old formwork timbers being present under the slab, it is wise to suggest that access be sought, and an inspection be carried out.
- Where there are engaged piers, these can also offer a means of concealed termite entry into buildings, when ant capping is not continuous (for example not soldered).

It is important for the timber pest consultant to be mindful of the potential for concealed termite entry in these types of construction. Termite activity and damage inside walls is usually not visible, so particular thoroughness during the inspection of the interior and roof interior is paramount. Careful searching for evidence of termite mudding (for example at the joint between timbers and plasterboard), tapping the walls with the heel of the hand (and listening for dislodged termite mud), and the use of a moisture meter, may assist in the inspection of such properties.

Brick and tile buildings

Brick and tile buildings have the advantage that, in many cases, much of the timber framing of the building is able to be inspected; ie if the subfloor clearance is adequate, much of the flooring can be examined, and (except for the rear skillion roofs), much of the roof framing can usually be checked. Older brick and tile buildings that have no ant capping are susceptible to concealed termite entry by the following means:

- Where foundations are sandstone (usually with soft, damp mortar), timbers in direct contact with such foundations are prone to fungal decay damage and concealed termite entry, via the soft mortar or weak veins within the rock itself.
- Where foundations are brick, and in the absence of effective ant capping, concealed termite entry remains possible (as does fungal decay damage at points of bearing of frame timbers on damp masonry).
- When floor frame timbers are close to or in contact with the ground and inspection access is poor or unavailable, regardless of what type of foundations they are, concealed termite activity is possible, and sometimes likely.
- Concealed termite entry via cavity walls is possible, and may on some occasions extend the infestation and damage into the roof frame timbers.
- Where flat, inaccessible roofs are present, the potential for concealed damage must be considered in relation to possible routes of entry.

Brick veneer on slab floor construction

This type of construction is arguably the most susceptible to serious concealed damage by termites. Much of this damage is attributable to termite entry via the slab edge that is concealed by paving, garden beds, soil or other obstructions. While termite entry may sometimes occur via pipe penetrations, the majority of infestations occur via concealed slab edges. It is very difficult to inspect these types of construction effectively, because in many cases, the concealed wall (and sometimes roof) frame timbers (often comprising oregon or radiata pine) are much more palatable to termites than the accessible joinery timbers (which are often maple or cedar).

The consultant is faced with assessing a building in which:

- concealed termite entry is easy;
- the timbers most likely to be damaged are concealed;
- inspection of the roof interior is often severely hampered by insulation, sarking, ducting, awkward truss configurations and low clearances; and
- the house is often built in areas that were previously populated by trees (possibly with high endemic populations of termites) and the former position of potential termite harbourages such as tree stumps and roots is often uncertain.

The effective inspection of such buildings is a demanding task. Consultants may employ a range of inspection techniques (eg close examination of all interior surfaces for signs of termite mud, sounding wall linings, running a moisture meter over certain areas of plasterboard and lifting sections of insulation in the roof interior).

Regardless of the findings, it is very important that the consultant communicates to the client:

- the possibility of concealed termite activity and damage; and
- the range of strategies that can help to minimise the termite risk (eg the installation of removable skirtings).

Risk minimisation tips

In this increasingly litigious world, missing a significant timber pest issue during a pre-purchase timber pest inspection can be a very costly oversight. Not surprisingly, termite related issues are probably the most commonly missed and the most costly to rectify. This is entirely consistent with their secretive habits, especially when many buildings continue to be constructed with concealed, termite-palatable frame timbers that are easily accessed by termites.

Other timber pest issues can also be potentially problematic if an oversight occurs. Failing to observe a small patch of *Anobium punctatum* damage in floorboards can be a more serious issue if the holes are in a cork-tiled floor of a kitchen that has been recently upgraded with new cabinets. Missing just a few patches of fungal decay damage in cantilevered softwood joists of a balcony has the potential to generate a substantial claim.

The following tips may assist in reducing the risk of claims:

- Overview always precedes close examination. Whether it be a room interior, a roof void or a subfloor space, always take a general overview before inspecting in detail.
- Be methodical and systematic; have a routine approach that provides a measure of quality assurance (for example, for a room interior it might be inspecting skirtings and architraves full circle in a clockwise direction; then anticlockwise, doing picture rails and windows, then built-ins, then flooring, and *always* in that order).
- Tap frequently — especially the base of door jambs, window frames, skirtings and the bearing points of frame timbers. If a termite infestation is relatively new, there may only be a few small patches of timber that are sufficiently hollowed as to be detected by sounding. The more timber you tap, the more likely it is that you won't miss the damage.
- Use the torch often (not just in the dark). Ambient light in some rooms is poor and the tell-tale signs of termite presence can sometimes be very subtle — using a torch not only helps you see, but probably also helps you to focus on the task at hand.
- Check for termite mud at all joints between interior timber and linings such as plasterboard (or masonry). When inspecting a building in which the hidden frame timbers are much more palatable to termites than the joinery timbers that you can see, one of the most common (albeit sometimes subtle) signs of termite activity is the mudding that may fill cracks between timber and wall finishes. If you search hard for these signs, you significantly increase the chances of finding them.
- When opening damaged timber or mudding to determine activity status, if activity is evident, close up (perhaps with tape) and keep disturbance to a minimum. If termites are not immediately evident, continue the inspection but return occasionally to check again — sometimes it takes a while for termites to detect an intrusion.
- Use torchlight across the surface of timber. Some timber pest defects, such as borer holes that have been painted over, or fungal decay damage that has been patched, are much more obvious when torchlight is shone across the surface.
- View objects (eg timbers, piers etc) from different angles when feasible. When you have finished inspecting the subfloor area and are returning to the entry, don't 'turn off' mentally. By staying focussed you might just see some termite damage that is only apparent from that side of the floor joist (perhaps because of the presence of some localised sapwood).
- Record all relevant findings when observed. When inspecting the interior and exterior always note observations as soon as they are made and, as soon as you emerge from the subfloor or roof void make a note of all of your observations. This process leaves much less room for error than just haphazardly jotting down the occasional note.
- Never pass up an opportunity to examine a cavity. Whether it be the gaps around a sliding door, or the cavity of a brick wall as you enter a subfloor, with the aid of a good torch it may one day reveal something important.
- Inspect by sampling when access is obstructed. Even though a fully insulated ceiling presents a profound constraint on inspection access, (and despite the careful exclusion wording that will furnish the report), some sample testing/inspection of selected areas (eg sections of top plates over wet areas) may one day prove to be an enormously worthwhile investment of time.
- Never compromise your attention to detail because of the weight of default exclusion clauses that appear in the report. Owing to the increased incidence of litigation, the timber pest inspection reports of many companies are so heavily laden with protective exclusion clauses that it is sometimes difficult to find real information about the house that was inspected. The consultant should never take short cuts because 'the report wording should cover it'.

Carrying out pre-purchase timber pest inspections is a complex undertaking that is laden with heavy responsibility, and yet low competitive pricing abounds within the industry. If increased pricing allows consultants to spend more time on site, making a more careful and detailed analysis of the building, then perhaps the upward trend in litigation might experience a levelling off.

Remember:

- the more thorough the procedure
- the greater the knowledge about timber pests
- the better the understanding of how the building is built
- the more effective the communication of the findings
- and (within limits) the more time spent on site

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- the greater the client satisfaction
- the smaller the risk and liability

REPORT WRITING

The inspection report should be clear and concise so that both the client and the lending authority can easily understand the document. Pest control operators and/or building tradespeople may also consult the report if their services are called upon.

The information that is recorded during the inspection (eg on a checksheet or by dictation into a mini-cassette recorder or by some other reliable means) should be thorough, detailed and clear. Spending a little extra time on site to collect concise, complete information pays enormous benefits later when it comes to compiling the report, for it will be a more efficient and more accurate process.

The report should be in a form that is easily read and understood. There should be a 'summary' section so that the client, solicitor or lending authority can quickly determine the implications. There should also be detailed findings so that the client is well-informed about the pest history, the current pest issues, the restrictions to inspection access and any recommendations in relation to any control, remedial or pest risk minimisation measures that should be undertaken.

Timber pests should be named in such a way as to avoid possible confusion or misinterpretation. The use of correct common names (eg furniture beetle) is largely acceptable, or scientific names may be considered more appropriate (eg *Anobium punctatum*). In the case of termites (which for the most part have no common names), scientific names may be considered essential.

When using scientific names, they should always be formatted correctly (ie in *italics* or underlined). If there is some uncertainty about the species concerned, the inspector should name pests only according to what is confidently known (eg *Lyctus* borer, *Coptotermes* sp.).

The following Appendices may be useful for those carrying out timber pest inspections:
Appendix I is a glossary of building terminology;
Appendix II is an illustrated guide to building terms;
Appendix III is a list of the scientific and common names of some insect pests of timber; and
Appendix IV outlines some of the basic procedures for collecting and preserving insects (ie techniques that may be necessary when the inspector encounters insect specimens that will need to be identified by a specialist, such as an entomologist).

For further details about the requirements of timber pest inspection reports and other aspects pertaining to inspection procedure, refer to Australian Standard 4349.3 Inspection of buildings Part 3 Timber Pest Inspections.

Activity status of timber pests

Whether or not reported pest damage is still active, is an important issue for the client. Unfortunately, it is not always possible during an inspection, to determine activity status with confidence.

Termites

- Termite activity is identified by the observation of live termites (usually after the careful opening of damaged timber or mud workings). Damage and disturbance of the termites should be kept to a minimum once the presence of current activity has been determined. Disturbances can cause termites to retreat and this may hamper future attempts at control.
- In cases where extensive probing of termite damage and mudding reveals no activity, the apparent absence of activity may be attributable to a number of causes:
  - Recent disturbance by a previous pest consultant (or even yourself). Tapping and sounding for termites have caused them to retreat temporarily.
  - Disturbance has been caused an anxious vendor when trying to kill them by spraying with an aerosol insecticide. Usually the termites remain active close by.
  - The more obvious accessible timbers (eg damaged garage wall studs) may appear free of termite activity, when live termites are actually present in the inaccessible interface between the bottom plate and the concrete slab.
  - Previous termite control measures may have been successful and it may be that there is no termite activity whatsoever.

In cases where exhaustive searching reveals no termite activity, it is often appropriate to report that concealed activity is possible and that further investigations and/or follow up monitoring and regular inspections are recommended.

Anobium punctatum and *Calymmaderus incisus*

These borers generally attack old pine timbers. In most cases there is no reliable method for determining whether or not the borers are active during the inspection. Signs that suggest that floor boards have been sprayed are no guarantee of absence of activity.

Longer term monitoring programs, where floor boards are marked, existing borer holes circled, and follow up checks made after spring each year, may give some indication of activity status.

Chemical treatments for borer control, because they are only surface treatments, are generally considered unreliable, in terms of complete eradication.

Where it is practical and feasible, replacement of affected timbers with resistant timber species is the preferred option. On the other hand, monitoring damage levels may shed some light on activity status and the need for further action.

Lyctus borer

These attack only the sapwood of certain susceptible species of hardwood timbers and are usually active only in newer buildings (ie less than about 15 years old). In old buildings, damage to the corner of structural timbers is usually old, inactive and of no consequence. Borer activity in new buildings should also be of no structural consequence, as the amount of susceptible sapwood in building timbers is usually regulated. If found active, recommendations for monitoring damage levels are probably appropriate.

Fungal decay

Fungal decay damage is probably the most widespread and common cause of timber pest damage encountered in buildings. By and large, the activity of fungal decay is dependent on excessively high moisture levels in timber. If it is suspected that the moisture source causing the decay is still present (eg leaking shower tray), then it is reasonable to assume that the fungal decay is active and that affected timbers will have a high moisture content, eg >25%. If the moisture source has ceased and is no longer influencing the timber, then the timber is likely to have a relatively low ('normal') moisture content (eg 8–15%) and the decay fungus is probably no longer active.

SAFETY ISSUES

Timber pest inspections involve several potentially hazardous activities, ranging from the use of ladders, to crawling around in somewhat inhospitable environments that may be contaminated with various pesticides. Consultants should be ever mindful of the risks associated with inspecting the various parts of buildings.

Roof interior

- **Falls from ladders** Falls from ladders are a common form of accident in the building trades and they often cause serious injuries. Careful placement of ladders to ensure stability is the key. This is especially important when ladders are set up against a wall: ladders *must* be set with a stable footing no more than 0.5 m out from the wall for every 2 m in height. On slippery surfaces, such as polished floor boards or tiles, propping the foot of the ladder to a wall (or other stable support) is a must to prevent the ladder from slipping out and away from the wall.
- **Falls in roofs** Timber pest consultants can sometimes become very nonchalant about walking around on frame timbers within a roof and this can be a trap. One must always be mindful of the care that is required while moving around in roof spaces. Falls may occur due to tripping (eg on cables) or even by stepping onto severely hollowed timbers. One should always hold onto rafters or other stable frame timbers and check the soundness of timbers before stepping.
- **Respiratory contamination** Moving around in roof spaces inevitably kicks up dust and this dust may contain a variety of contaminants (eg asbestos, fibreglass, dust, lead, insecticides and the spores of a range of fungal pathogens that occur in bird droppings). Regular respiratory contamination by such materials may result in various chronic health effects including lung diseases. One should always wear a well-fitting, regularly cleaned respirator that is rated for exposure to agricultural sprays.
- **Electrocution** Roof interiors have electrical wiring and other components that may sometimes be faulty. Electrocution may occur by direct bodily contact with live wires and/or components, or via tools that may conduct electricity. One should always avoid contact with electrical wiring and other components and *never* lie on top of wiring. Use tools (eg dongers) that are non-conductive or insulated and always be careful to avoid contact with electrical components when probing or jabbing timbers for soundness.
- **Back pain onset** The complicated geometry of some roof frames, (especially certain truss configurations), can sometimes require extreme twisting or bending that may bring on an episode of back pain in those with a history of this affliction. Being physically fit can reduce the likelihood of back pain. Doing regular preventative flexibility and strength exercises can be an enormous help in tuning the body for this rigorous work. Consult with your health professional (eg physiotherapist or chiropractor) about a suitable program of exercises.
- **Damage to joints** Kneeling on ceiling joists can place inordinate loads on the knees. Wearing knee pads during roof interior inspection not only affords protection for the knees, but probably results in a more thorough inspection technique because of the increased comfort when moving around in tighter areas.

Subfloor

- **Respiratory contaminants** Subfloor spaces are very dirty places that may contain a number of contaminants that can become airborne as one moves around. Of particular concern is the possibility of pesticide-contaminated soil and dust particles, as these may contain the very persistent organochlorine contaminants from previous termite-barrier treatments. One must always wear a respirator in the subfloor
- **Electrocution** The risk of electrocution in subfloors is a very real one that should always be borne in mind. One should

never contact or lie over wires or other electrical components. Great care must be exercised if wires are lying on the ground, especially if there is water ponding in the area.

- **Disease transmission** Care must always be exercised in relation to the potential for disease transmission, for example: sharp objects such as broken glass and rusty nails may cause cuts that can become infected; unsanitary conditions such as sewer leaks or animal droppings can be a source of disease transmission; used syringes may cause needle stick injury which can lead to serious disease transmission (eg hepatitis and HIV). To reduce risk, examine areas before entering and crawling, and do not proceed if the risk is too great. Wear protective gear including heavy-duty elbow-length gloves. Keep tetanus shots up to date.
- **Other issues in the subfloor** Knee pads and elbow pads can afford good protection of joints. Some subfloor movements, such as crawling and looking up, can cause back pain onset. Regular preventative exercises can help to avoid pain and the loss of income that sometimes results. Potentially venomous spiders and snakes may be encountered in subfloors and care must be exercised to avoid bites. A sound knowledge of the first aid procedures is essential. When inspecting large subfloor areas, ensure that someone is aware of your activities and has an idea of what time you are expected to emerge.

Those who carry out timber pest inspections often work alone and in environments that are unfamiliar and unknown (for example, the condition of the electrical system is uncertain). It is very important for such workers to be ever mindful of workplace risks and how to minimise them.

Consultants should always carry a basic first aid kit in their vehicle.

Important items in relation to occupational health and safety include:

- respirator
- overalls
- elbow-length gloves
- knee pads (and elbow pads)
- hat
- appropriate footwear.

Respirator care is also important. Consultants should be sure to:

- keep the respirator clean;
- check valves regularly; and
- replace cartridges regularly.

ALWAYS WEAR A RESPIRATOR IN ROOF VOIDS AND SUBFLOORS

FURTHER READING

Australian Standard AS 4349.3—1998 *Inspection of Buildings, Part 3: Timber Pest Inspections* Standards Australia Sydney

Creffield J.W. 1996 *Wood Destroying Insects, Wood Borers and Termites* CSIRO Melbourne

Hadlington P. 1996 *Termites and other Common Timber Pests* UNSW Press Sydney

Milton H. 1994 *Glossary of Australian Building Terms* Sydney Building Information Centre Sydney

Peters B.C, King J. and Wylie F.R 1996 *Pests of Timber in Queensland* DPI Queensland

Wallis N.K. 1970 *Australian Timber Handbook*

CHAPTER 23

EXOTIC FOREST & TIMBER PESTS — QUARANTINE ISSUES

This chapter reflects information prepared by the Australian Quarantine and Inspection Service (AQIS), Product Integrity, Animal and Plant Health (PIAPH) and the Standing Committee on Forestry (SCF) for wharf workers, container depot staff, timber handlers, timber yard workers, forest workers and forest technical staff. The chapter aims to provide basic information on some high-risk exotic pests of forest and amenity trees and imported timber.

The pests featured here are only a few — though very important — examples of exotic forest pests that could cause damage in the Australian environment. The chapter also lists who to contact if you spot an exotic insect that might be of quarantine or forest health concern.

HOW DO AQIS, PIAPH AND SCF FIT INTO THE PICTURE?

AQIS and PIAPH are both part of the Department of Agriculture, Fisheries and Forestry – Australia and work closely to prevent and manage incursions of exotic pests, weeds and diseases. AQIS is responsible for minimising the risk of entry into Australia of diseases and pests affecting humans, animals and plants. PIAPH provides national and international leadership and co-ordination in managing animal and plant health emergencies, and minimising the effects of incursions of pests and diseases on Australia's agricultural producers and the community.

The Standing Committee on Forestry (SCF) is comprised of the heads of the Commonwealth, State, Territory and New Zealand forestry agencies. SCF is supported by a network of sub-committees and working groups including the Forest Health Committee and the research working group on Forest Health, both of which deal with pest and disease issues.

ISOPTERA (TERMITES)

Formosan subterranean termite
Coptotermes formosanus Shiraki

Identification Live in colonies, soldiers 12–15 mm long, pale yellow, exude drops of milky fluid from the head when disturbed. Yellowish brown winged forms produced early spring to midsummer, swarm in large numbers at dusk.

Hosts More than 50 species of timber including oak, citrus, cypress; timber in contact with ground, timber in service.

Distribution China, Taiwan, Japan, Sri Lanka, South Africa, USA, including Hawaii.

Detection:

Nests Built from a substance resembling paper; made in soil, wood, hollows or spaces between walls and floors — can be in places not in contact with ground. Most likely to enter Australia in nests in shipping containers or in timber.

Potential impact One of the most destructive termites in the world; can severely damage buildings and timber in service.

Western dry-wood termite
Incisitermes minor (Hagen)

Identification Live in colonies, soldiers 11–12.5 mm long, pale yellow body with an orange-brown head. Yellowish brown winged forms produced from early spring to mid-summer, swarm in large numbers at dusk.

Hosts Dry wood (moisture content >12%), wood in contact with ground, timber in service.

Distribution USA, Mexico and Canada.

Detection

Nests Built from a substance resembling paper. Nests are not made in the soil but are located inside the wood, which is the food source. Frass sometimes visible outside nests; usually hard, hexagonal pellets less than 1 mm diameter. Most likely to enter Australia aboard ships in containers or hidden in timber and on yachts.

Potential impact A serious timber pest that can severely damage timber in service.

COLEOPTERA (BEETLES)

Cerambycidae (longicorns)

Asian longhorn beetle
Anoplophora glabripennis (Motschulsky)

Identification Larvae elongate and cylindrical with reduced head and legs, 50 mm long at maturity. Adult beetles 50–70 mm long, shiny black with about 20 white dots on wing-covers. Antennae black with white rings, much longer than the body. Plate-shaped feet black with whitish blue upper surface.

Hosts Standing trees and timber of many species including elm, willow, poplar, apple, plum, maple.

Distribution Southern China, Korea, Japan, introduced to USA (some parts)

Detection

Eggs Laid under tree bark in oval to round darkened wounds.

Larvae Tunnel into the heartwood of the tree; feeding can cause branch breakage, branch and tree death.

Adults Emerge in summer from trees or timber from circular holes 9–11 mm in diameter, often leave piles of sawdust at base of trees or in branch crevices, live for 3–66 days, strong fliers. Probable means of entry into Australia is in imported timber and wood used for packing materials from Asia.

Potential impact Very destructive, and could potentially devastate Australia's hardwood forests, apple and pear plantations and parkland trees.

Burnt pine longicorn
Arhopalus ferus (Fabricius)

Identification Larvae elongate and cylindrical with reduced head and legs, 25 mm long at maturity. Adult beetles 12–30 mm long; male light brown, female dark brown to black. Antennae half as long as the body.

Hosts Burned or wind-thrown pine and spruce.

Distribution United Kingdom, Europe, Russia, introduced to New Zealand.

Detection

Eggs Laid in groups of 5–50 in bark crevices on freshly burned or felled timber.

Larvae Feed in cambium; tunnels oval in cross-section, up to 12 mm wide, loosely packed with frass and coarse wood particles.

Adults Emergence holes are oval and average 6 mm diameter; adults live for several weeks, can appear in large numbers, active dusk to dawn, attracted to light, shelter in crevices during the day. Probable means of entry is on imported timber and cargo loaded during the adult beetle's flight period (usually summer).

Potential impact Could cause severe economic loss of wind-thrown or fire damaged trees.

Dry-wood longicorn beetle
Stromatium barbatum Fabricius

Identification Larvae are elongate and cylindrical with reduced head and legs, to 38 mm long and 9.5 mm wide. Adult beetles 12–28 mm long, reddish brown to almost black, covered with fine, short buff hairs, antennae up to 1.5 times body length.

Hosts 350 species of seasoned hardwood and softwood timber and plywood including eucalyptus, pine, elm and oak. Unlike Australian longicorns, dry-wood longicorn only attacks seasoned timber.

Distribution India, Sri Lanka, Burma, Mauritius, Madagascar, Pakistan, Nepal and Tanzania.

Detection

Larvae Form irregular tunnels tightly packed with very fine powdery frass; in heavy infestations tunnels can interlace so interior of wood is reduced to powder and exterior surfaces are left intact; can take up to 10 years to emerge. Most often detected in packing material, dunnage, furniture and sporting goods such as cricket bats and stumps.

Adults Emerge during summer, active at night.

Potential impact Potentially of great economic importance in Australia because of its large host range and preference for seasoned timber.

European house borer
Hylotrupes bajulus (Linnaeus)

Identification Larvae elongate and cylindrical with reduced head and legs, 19–41 mm long and to 7.5 mm wide at maturity. Adult beetles 18–25 mm long, brownish black to black, slightly flattened in appearance. Antennae half as long as body, wing-covers usually completely black but may have distinctive white bands. This borer prefers temperatures of 28–31°C.

Hosts Attacks seasoned softwood timber including pine, fir and spruce. Roof timbers most often infested.

Distribution Europe, Middle East (Turkey), North Africa, South Africa, South America, USA, China and Asia Minor.

Detection

Larvae Form galleries parallel to grain, tightly packed with fine powdery frass and tiny pellets, tunnels 9–12 mm wide and 6 mm high.

Adults Emerge after 2–17 years from an oval-shaped hole 5 x 9 mm in size (emergence holes usually first sign of infestation); strong fliers, attracted to night lighting. Most likely to enter Australia on imports of seasoned timber or timber articles such as furniture.

Potential impact One of the world's most destructive pests of seasoned softwood timber.

Curculionidae (weevils)

Hoop pine weevil
Vanapa oberthuri Pouillaude

Identification Larvae pale yellow with brown head, C-shaped, up to 90 mm long. Adult black, up to 70 mm long, with longitudinally ridged wing covers and long curved rostrum with elbowed antennae at end.

Hosts Trees and timber of *Araucaria* species (such as hoop pine and klinki pine).

Distribution Papua New Guinea and Indonesia (West Irian).

Detection

Larvae Make J-shaped tunnels in wood, 10–15 mm in diameter, about 40 mm depth, may make audible crushing noise, often leave clean wood debris on bark. Pupal chamber plugged with wood slivers. Damage usually occurs clumped in groups of up to 10 trees, cause dead branches, and can kill tree within five months.

Adults Emergence hole round, 8–13 mm in diameter. Life span 6–8 weeks, feed on green bark of pine twigs, lay eggs in fresh resin on bark. This species most likely to enter Australia from PNG via items carried by people for traditional trade, or in timber from *Araucaria* species or souvenirs.

Potential impact Could have severe impact upon Australia's native *Araucaria* forests.

Scolytinae (bark beetles)

European spruce bark beetle
Ips typographus Linnaeus

Identification Mature larvae about 5 mm long, white, legless, with light brown head. Adults 4–5.5 mm long; cylindrical and dark brown to black, with long yellowish hairs on head and sides of body; head is visible from dorsal surface. Rear end of body concave, framed on sides by a raised margin bearing four distinct spikes.

Hosts Bark of damaged and healthy softwood trees and timber.

Distribution Europe, China, Japan, Korea, Far Eastern Russia.

Detection Galleries extend about 12.5 cm on the long axis of the trunk, visible when bark is removed, cause red-brown dust in bark crevices, emerge *en masse*. Emergence evidenced by circular holes 2–3 mm in diameter or by small tubes of resin protruding from the bark. This species is most likely to enter Australia on imported timber packaging or dunnage contaminated with bark.

Potential impact One of the most destructive pests of spruce in Europe, normally breeds in freshly fallen or weak standing trees but high populations will attack and kill healthy trees.

Mountain pine beetle
Dendroctonus ponderosae Hopkins

Identification Mature larvae about 5 mm long, white, legless, with light brown head. Adults 3.7–7.5 mm long; stout and cylindrical; rusty brown to black; head is visible when viewed dorsally.

Hosts Polyphagus in *Pinus* genus, can attack species such as spruce (*Picea*) if in large numbers.

Distribution Canada, USA.

Detection

Larvae Chew feeding galleries at right angles to parent gallery; often cause red-brown dust in bark crevices; emerge en masse from circular holes 2–3 mm diameter or small tubes of resin protruding from bark. Most likely to enter Australia on imported timber, packaging or dunnage contaminated with bark; associated with a bluestain fungus visible in wood.

Adults Construct egg galleries up to 90 cm long beneath bark and parallel to the grain of the timber.

Potential impact Population build up in freshly fallen or weakened trees but will vigorously attack and kill growing trees when populations are in large numbers. Bluestain fungi and risk of increased timber decay associated with beetle introduction.

Bostrichidae (auger beetles/powder post beetles)

Powder post beetle
Heterobostrychus aequalis (Waterhouse)

Identification Larvae to 15 mm long, C-shaped, white with brown heads. Adults 6–13 mm long, cylindrical, dark brown to black; head not visible from above; segment behind head is distinctly excavated in front.

Hosts Hardwood, freshly felled trees and green or seasoned timber.

Distribution Europe, India, Asia, Middle East, South Africa

Detection

Larvae Feed along grain, making circular tunnels up to 38 cm long and 6 mm in diameter, tightly packed with a fine floury frass often visible when adults emerge. Most likely to enter Australia on imported timber packaging, dunnage, furniture, souvenirs etc.

Adults Bore circular holes into sapwood and continue feeding until sapwood is gone; can reduce interior of timber to powder.

Potential impact Damage to exposed wood in houses, furniture and panelling.

LEPIDOPTERA (MOTHS & BUTTERFLIES)

Asian gypsy moth
Lymantria dispar (Linnaeus)

Identification Egg masses contain between 100–1000 eggs; covered with buff/yellowish scales, average 38 mm long, 20 mm wide. Larvae highly variable in colour with long hairs covering the body, two distinctive rows of large spots along the back, usually in five pairs of blue and six pairs of red from head to rear. Adult females white with black markings with wingspan 50 mm or more; adult males greyish brown with wingspan about 38 mm.
Hosts Larvae feed on the foliage of 600 plant species including oak, birch, willow, elm, eucalyptus, pine, fruit trees, urban ornamental plants.
Distribution China, Far Eastern Russia, Korea, Japan, USA.
Detection
Eggs and larvae Most often found on forest products, shipping containers, cargo and ship structures. Larvae can survive a week without feeding, spin silken threads and spread long distances in the wind.
Adults Females can fly up to 40 km and die after laying eggs, males die shortly after mating; both are attracted to light.
Potential impact Causes significant damage to forest, horticultural and urban trees. Of the several biotypes known, the Asian biotype is the most damaging, but all are a risk to Australia.

Nun moth
Lymantria monacha (Linnaeus)

Identification Eggs orange-brown, spherical, laid in clumps without covering of scales. Larvae 30–40 mm long; have dark grey, tan or green coloured bodies, orange heads with black freckles. Adults have white forewings with dark lines and patches; occasionally dark brown to black colour form occurs. Females have a pointed reddish abdomen with black spots and a 45–55 mm wingspan; males 35–45 mm wingspan.
Hosts Larvae feed on the foliage of ornamental and forest conifers, elm, oak, larch, maple, and fig.
Distribution Europe, Far Eastern Russia.
Detection
Eggs and larvae Most often found on forest products, shipping containers, cargo and ship structures. Eggs are laid randomly; larvae can survive a week without feeding, spin silken threads and spread long distances in the wind.
Adults Strong fliers, attracted to light.
Potential impact Defoliation by larvae can kill trees, causes enormous economic loss.

White spotted tussock moth
Orgyia thyellina Butler

Identification Eggs white to buff, laid in clusters (not covered by scales) about the size of a 10-cent coin. Young larvae black and very hairy; mature larvae about 30 mm long with four distinctive white tufts of hair, orange stripe down each side, two spots on tail. Adult females have creamy white wings with dark spot, males smaller, grey-black with a similar spot.
Hosts Larvae feed on the foliage of urban trees and plants, horticultural plants, exotic and indigenous forest trees.
Distribution China, Korea, Japan, Far Eastern Russia, Taiwan.
Detection
Eggs and larvae Eggs laid randomly on or near food plants, forest products, shipping containers, cargo and ship structures; or on brown, felt-like cocoon from which female moth has emerged.
Adults Strong fliers, attracted to light.
Potential impact Absence of natural enemies could allow this species to become a serious pest of timber species and ornamentals.

HYMENOPTERA (WASPS, ANTS & BEES)

Black carpenter ant
Camponotus pennsylvanicus (De Geer)

Identification Live in colonies, most prevalent are the workers which are black to reddish black, 11–18 mm long. Winged males and females produced early spring to mid-summer, swarm in large numbers.
Hosts Nest in living and dead trees, rotting logs and stumps, buildings, wooden structures. Hard and softwoods may be attacked: infestations recorded from white and pitch pine, balsam, elm, hickory, juniper, aspen, oak, Douglas fir and western red cedar.
Distribution USA, Canada (eastern and central states).
Detection
Nests In imported containers, in untreated imported timber and timber packaging and dunnage. Nests established in cavities in wood that has deteriorated or been exposed to moisture. Small piles of sawdust outside the colony entrance can indicate infestation. Galleries kept smooth and clean, not lined with moist soil (cf termite galleries).
Potential impact Can cause serious damage to timber in service; undetected infestations can lead to failure in structures and other timbers.

Wood wasp
Urocerus gigas (Linnaeus)

Identification Larvae 30 mm long, creamy white, with a dark brown spine at the posterior end. Adults to

35 mm long, with two pairs of transparent amber wings and a black abdomen with yellow-brown stripes. Females have an ovipositor up to 20 mm long. Adults can be confused with other large native Australian wasps and *Sirex noctilio*.

Hosts Wood of pines and conifers; recently cut, fallen or severely weakened trees; and green timber.

Distribution Asia, Europe, Chile, USA, Canada and Russia.

Detection

Larvae Feed on fungus growing on wood within timber, make longitudinal tunnels 15–75 cm long (usually tightly packed with frass) from sapwood to heartwood and back. Wood decay (white rot) may be also visible.

Adults Emerge in summer from circular exit holes up to 8 mm diameter (this size may vary), pale haloes often visible around holes; fly for considerable distances. Females usually lay eggs in weakened trees, often on freshly burned or cut logs. Adults occasionally emerge from timber used in houses or furniture; most likely to enter Australia in pine logs, packing material and unseasoned dunnage.

Potential impact Can kill weakened trees and degrade wood, leading to structural damage.

WHO TO CONTACT IF YOU FIND A SUSPECTED EXOTIC PEST OR DISEASE

Contact your nearest AQIS office or State Forestry Agency as soon as possible to report a suspected exotic pest or signs and/or symptoms of a forest disease and to seek further information on what to do.

AQIS	STATE FORESTRY AGENCIES	PRODUCT INTEGRITY, ANIMAL AND PLANT HEALTH (PIAPH)
National Office		
Australian Quarantine and Inspection Service (AQIS) GPO Box 858 CANBERRA ACT 2601 Ph: (02) 6272 3933 Fax: (02) 6272 5697 Email: importclear@aqis.gov.au		Chief Plant Protection Officer Plant Protection Branch AFFA GPO Box 858 CANBERRA ACT 2601 Ph: (02) 6271 6534 Fax: (02) 6272 5835 Email: plant.protection@affa.gov.au http://www.affa.gov.au/nat-offices
ACT		
AQIS ACT PO Box 7193 Canberra Mail Centre ACT 2610 Ph: (02) 6272 5131 Fax: (02) 6239 7351	ACT Forests ACT Forests HQ 113 Cotter Rd WESTON ACT 2611 Ph: (02) 6207 2486 Fax: 02 6207 2544	
NSW		
AQIS NSW PO Box 657 MASCOT NSW 1460 Ph: (02) 9364 7222 Fax: (02) 9364 7340	Forest Health Section Forest Research and Development Section State Forests of NSW PO Box 100 BEECROFT NSW 2119 Ph: (02) 9872 0111 Fax: (02) 9871 6941	
Northern Territory		
AQIS Darwin NT Quarantine and Inspection Branch GPO Box 2268 DARWIN NT 0801 Ph: (08) 8999 2075 Fax: (08) 8999 2108	DPIF Forestry GPO Box 990 DARWIN NT 0801 Ph: (08) 8999 2316 Fax: (08) 8999 2043	
Queensland		
AQIS Brisbane GPO Box 778 BRISBANE QLD 4001 Ph: (07) 3246 8755 Fax: (07) 3839 9313	Queensland Forest Protection Group Forestry Research Institute PO Box 631 INDOOROOPILLY QLD 4068 Ph: (07) 3896 9713 Fax: (07) 3896 9628	
South Australia		
AQIS SA PO Box 63 PORT ADELAIDE SA 5015 Ph: (08) 8305 9700 Fax: (08) 8305 9825	Forestry SA PO Box 162 MT GAMBIER SA 5290 Ph: (08) 8724 2888 Fax: (08) 8724 2870	

Tasmania

AQIS Tasmania
PO Box 347
NORTH HOBART TAS 7002
Ph: (03) 6233 3626
Fax: (03) 6234 6785

Forestry Tasmania
GPO Box 207 B
HOBART TAS 7001
Ph: (03) 6233 8219
Fax: (03) 6233 8292

Victoria

AQIS Melbourne
PO Box 60
World Trade Centre
MELBOURNE VIC 3005
Ph: (03) 9246 6777
Fax: (03) 9246 6800

Natural Resources and Environment
Centre for Forest Tree Technology
PO BOX 137
HEIDELBERG VIC 3084
Ph: (03) 9450 8666
Fax: (03) 9450 8644

Western Australia

AQIS Perth
PO Box 1410
CANNING VALE WA 6970
Ph: (08) 9311 5333
Fax: (08) 9455 3052

Department of Conservation and Land Management
Locked bag 104
Bentley Delivery Centre
WA 6983
Ph: (08) 9334 0333 (Operational Headquarters)
Ph: (08) 9334 0299 (Science Division)

APPENDIX I

GLOSSARY OF TIMBER & BUILDING TERMS

agricultural pipe (or drain) flexible or rigid pipe with perforations or slots used for below ground-level drainage, usually set in trench filled with gravel (eg blue metal) and directs subsurface water away from buildings.

ant cap sheet metal shield (usually galvanised iron) installed during construction of timber floor and wall frames near ground level, placed between floor bearers and piers/dwarf walls/stumps to reveal the passage of termites from ground up into building; sometimes can be installed in existing buildings.

architrave moulding (usually timber) that surrounds window and door openings, covering jointing between frame and wall lining; sometimes base of door architrave penetrates ground (eg concrete floor/path) increasing susceptibility to moisture/fungal decay and undetected termite entry.

awning roof-like cover providing shelter or shade over windows and doors; may be constructed of a variety of materials, sometimes timber framed.

balcony a platform (or deck) projecting from the wall of a building; may be balustraded or railed, covered or uncovered.

balusters usually turned or square infill members between staircase treads or balcony/verandah floor and handrail.

balustrade framework of handrails and uprights (balusters and newel posts) that forms a protective barrier at the open side of a staircase or balcony/verandah.

barge board usually timber, fixed to visible sloping edge of a roof (usually parallel to roof rafters, cf fascia board); prone to fungal decay, particularly at ends/joins.

barge capping timber (or metal) cap that covers the top of a barge board and edge of the roof, prone to fungal decay, particularly at ends/joins.

batten small timber member, usually rectangular in cross section, used to fix linings, claddings or roof materials to timber frames, eg ceiling batten, tiling batten.

bay window window or group of windows that forms a bay or recess in a room and projecting beyond the line of the wall.

beam horizontal, load-bearing structural member supported at two or more points.

bearer subfloor structural member, commonly 100 mm x 75 mm hardwood spanning between piers and walls and supporting the floor joists; where masonry is moist, point(s) of contact prone to fungal decay; in the absence of ant capping, prone to undetected termite entry; may show *Lyctus* borer damage to sapwood edge/corner.

bottom plate horizontal member (often 100 mm x 50 mm softwood) forming base of structural wall frame; often obscured from inspection by wall linings/skirting; may sustain concealed fungal decay damage if adjacent to leaking shower tray.

bowing a bend or curve in an otherwise straight length of timber, perhaps caused by underspecification or other factors (including pest damage).

box gutter concealed roof gutter used between roofs, behind parapets or in valleys; blockages can lead to fungal decay damage to adjacent roof and wall frame timbers.

brick ties galvanised steel wire or strip built into brickwork at regular intervals to link internal and external sections of wall in either brick veneer or cavity brick construction.

brick veneer type of construction in which a structural timber frame is tied to a single brick external wall which is usually non-load bearing; as with timber frame construction, substantial amounts of wall frame timber are obscured from normal inspection by wall lining materials.

cabana covered structure near swimming pool used for changing, entertaining etc.

cantilever(ed) beam/joist beam or joist with one unsupported end projecting beyond a point of support.

casement window window with one or more sashes hinged vertically to a frame; opens out like a door.

cathedral ceiling ceiling which follows the line of the roof structure sometimes with some roof frame timbers exposed.

caulking compound product used to make waterproof seal to joints, usually flexible, for example silicon.

ceiling joists structural members (often 100 mm x 50 mm softwood) to which the ceiling is fitted; in flat/skillion roof structures roof rafters may function as ceiling joists and these timbers are usually obscured from direct inspection.

clerestory window window in the upper part of a room admitting light from above an adjacent window.

collar ties horizontal structural roof frame members which tie opposite roof rafters together to prevent roof spread or deflection of rafters; usually above underpurlins.

compressed fibre cement sheet extra-high density sheeting made from cement and fibre often used for water-resistant flooring and wall cladding in wet areas, for example bathrooms.

conduit protective casing for electrical cables, especially for use in exposed and underground situations.

coping capping or covering on top of wall or pier as a decoration and to protect masonry from water penetration from above.

cornice ornamental moulding used to conceal join between ceiling and wall or column; often plaster based, occasionally timber.

curing process of improving the quality of concrete by preventing rapid drying out.

dampproof course continuous layer of impervious material placed in a masonry wall to prevent the upward (or downward) movement of moisture; deterioration can lead to rising damp which can facilitate fungal decay damage to adjacent timbers, for example skirting boards.

decking usually timber, material forming the flooring of a deck or balcony; often hardwood (eg tallowwood) or treated pine.

door frame the surround of a door opening, often timber comprising two vertical door jambs and the door head.

dormer window a vertical window in a sloping roof with its own gable projection through the main roof.

double hung window a window with two sashes which both slide vertically over one another and are balanced by cords and weights or springs.

downpipe usually metal or plastic pipe for conveying rainwater from roof guttering to stormwater drainage, ground, tank or other part of the building; when not connected to stormwater drainage and drains to ground, may contribute to excessive moisture in subfloor area.

drip groove groove or recess on underside of sill to prevent horizontal movement of rainwater.

dwarf wall brick wall from footing level to underside of floor framing; often inspected for presence of termite mud leads.

eave part of the roof that overhangs the exterior wall.

eaves gutter preformed gutter that is fixed to the fascia board for carrying rainwater from the roof to the downpipe; blockages and deterioration can lead to fungal decay damage to adjacent timbers.

eaves lining sheet material, panelling or boards fitted as lining material to eaves; can suffer localised fungal decay damage due to roof leaks.

end grain section of timber resulting from a cut across the grain thus exposing the ‘ends’ of the fine tubes or vessels that carried water upwards in the tree; this part of building timbers is usually the most susceptible to moisture absorption and fungal decay damage.

engaged pier pier built into masonry wall, usually attached to dwarf wall supporting floor frame.

expansion joint vertical or horizontal joint in a construction to allow for thermal expansion/contraction or creep.

fascia board fixed to lower ends of roof rafters; roof gutters often fixed to fascia; fungal decay often begins at cut ends (joins, corners) or sections affected by leaks.

fire wall internal masonry wall that divides a building into separate sections to resist the spread of fire.

flashing strip or sleeve of impervious material, for example, lead fitted to shed water or to cover a joint so as to prevent moisture entry; deterioration/failure can result in fungal decay damage to adjacent timbers.

floor framing structural timbers supporting the flooring, (eg panel flooring or floor boards) often comprising bearers (usually 100 mm x 75 mm hardwood) resting on piers/dwarf walls that support floor joists (usually 100 mm x 50 mm hardwood) to which flooring material is fixed.

floor plate a horizontal timber member, usually hardwood, that rests on brickwork or sandstone and supports the ends of floor joists; may sustain fungal decay damage if in contact with moist masonry.

flue a vent or chimney structure that provides an outlet for gases and products of combustion.

footing the structural base of a wall or pier supporting the mass of the building, transferring the load to the foundation.

formwork temporary mould including supporting framework constructed to shape fresh concrete until it hardens to become self-supporting; old unnecessary formwork timbers that are left in contact with the ground under buildings are prone to fungal decay and can facilitate termite entry.

foundation the section of ground that supports the mass of a building.

frass sometimes referred to as ‘borer dust’ the small pellet-like droppings of insects; the characteristics of some borer frass may be an aid in the identification of the borer, for example *Anobium punctatum* frass is often coarser and more granular than that of *Lyctus*.

freestanding a building that stands unattached to any others.

gable the vertical wall or panel that forms a triangular section under a pitched roof; may be brick or timber framed and clad in a variety of materials.

galvanising the bonding of zinc protective coating over iron or steel to prevent corrosion (rust).

green timber freshly felled timber that still contains a relatively high amount of moisture; also referred to as unseasoned timber; may have increased susceptibility to certain insect pests of timber, for example some species of Bostrichids (auger beetle).

hanging beam a structural beam that supports ceiling joists from above (usually spans the middle of a room).

hardwood a type of timber that comes from trees classified as angiosperms (flowering plants usually with broad leaves), for example eucalypts, tallowwood, maple; magnified cross-section reveals pores known as xylem vessels giving rise to the term 'pored timber'; the term does not refer to the strength or hardness of timbers cf. softwood.

head the top section of a frame within an opening (eg of a window or door).

hip roof roof shape in which the sloping surfaces are pitched on all sides of the building.

hob brickwork which is raised above floor level, (eg around shower or fireplace).

hopper window window in which the sash is hinged at the bottom and moves inward at the top.

insulation materials materials installed in buildings as thermal or acoustic barriers including fibreglass batts (inserted between ceiling joists and wall studs) and sarking (fixed under roof and wall coverings); presence in roof voids can restrict inspection access.

jambs vertical sides of frames of window or door openings.

joists structural timbers supporting the flooring material (floor joists) or to which ceiling linings are fixed (ceiling joists).

lagging thermal insulation material used around pipes and duct work.

lintel horizontal structural member spanning an opening, for example at top of windows and doors; some older buildings may have timber lintels hence termite damage to window/door frames may have structural implications.

masonry refers to structural units that are laid in mortar, for example brick, concrete block, stone, terracotta etc.

membrane thin pliable sheet material that is often impervious to moisture, for example as used beneath concrete slabs.

mullion a vertical member dividing a window or door frame into sections; exterior (and possibly interior) base of window mullions sometimes sustain localised fungal decay damage caused by rainwater ingress.

newel post stair post into which handrail is fixed.

nogging horizontal blocking fitted between studs to hold them straight and for fixing of linings.

parapet a low wall that rises above the edge of a roof, balcony or terrace.

particle board building board made from compressed fibres bonded together with an adhesive — available in low, medium or high density grades, some with waterproofing added.

pelmet timber or fabric cover to curtain rod or blind fittings, or to a sliding door to conceal the tracks.

penetrating damp the lateral movement of moisture from one side of a wall to the other, for example from exterior walls or leaking shower recess walls to interior surfaces; can cause staining and deterioration of wall finishes and possibly fungal decay damage to timbers in direct contact with excessive moisture.

pergola open timber framework structure over a path, terrace or patio; often covered with climbing plants; if constructed of low durability timber (eg oregon), may sustain fungal decay damage, particularly at base of posts if these are in direct contact with the ground.

pier vertical structural member of footings in concrete or brick.

plasterboard rigid lining board made of a core of gypsum plaster set between and bonded to outer coverings of heavy paper.

plywood fabricated timber panelling formed by bonding together, under heat and pressure, a series of timber veneers alternately at right angles to one another.

porch a roofed entrance to a building.

rafter structural roof member sloping down from ridge to eaves providing the principal structural support for the roofing material.

retaining wall wall built to hold back earth or other material and resist lateral pressure from the retained material; when constructed of hardwood sleepers, can facilitate termite harbourage. Masonry or treated pine are termite-resistant alternatives.

reveal the vertical sides of an opening (eg of window or door).

ridge horizontal apex of two roof planes, usually the highest point of a roof.

ridge tile concrete or baked clay tile used for covering the ridge or hip of a tiled roof, usually with flanged/overlapping joints and pointed with cement; if cracked or pointing deteriorates can lead to fungal decay damage to adjacent roof frame timbers.

riser the vertical face of a step in a flight of stairs.

rising damp the vertical movement of moisture up a masonry wall often causing staining and deterioration of wall finishes; usually caused by failure of original damp course; usually can travel as high as about a metre; can lead to fungal decay damage to adjacent timbers (eg skirting boards).

roof truss structural frame designed to carry the loads of a roof over the full span without intermediate support.

rot common reference to fungal decay of timber that results from high moisture content that may be caused by a variety of circumstances.

sarking pliable waterproof membrane that is fixed under roof coverings and/or wall claddings usually with foil layer to give thermal insulation effect.

sash the framed part of a window unit into which the glass is fitted.

sealant usually flexible, these materials are applied to joints between building materials (in liquid or plastic form) to prevent entry of moisture.

seasoned timber usually refers to timber from which most of the moisture has been removed as a consequence of air or kiln drying.

semi-detached two buildings/residences that share a common wall.

shingles thin pieces of timber, slate or other material, often oblong shaped and fixed in overlapping rows for covering roofs, walls and awnings.

shutter hinged or otherwise moveable cover or screen often fixed externally to windows (sometimes louvred).

sill the horizontal member at the bottom of a window frame.

skillion roof a roof that consists of a single sloping surface without a ridge; often with barge boards on each side.

skirting a moulding, often timber, that covers the joint between the wall lining and the floor; sometimes fixed with screws to allow regular removal for inspection for termite activity in otherwise concealed bottom plates and possibly base of wall studs.

skylight glazed opening in a roof or ceiling designed to admit daylight into the space below.

slab on ground type of floor structure consisting of reinforced concrete (usually with thickened edges) placed directly on suitable ground over waterproof membrane.

soffit usually refers to the underside of part of a building (eg eaves, archway, lintel etc).

softwood a type of timber that comes from trees classified botanically as gymnosperms (ie conifers/pines — usually with needle-like leaves), for example cypress pine, radiata pine, oregon; referred to as 'non-pored' timber; the term does not refer to strength or hardness of timbers cf. hardwood.

span the horizontal distance between points of support of load-bearing structural members.

storm mould small moulding (usually timber) fixed over the joint between a window (or door) frame and the reveal of an external wall.

string(er) stairs component, the inclined structural members that support the treads(/risers) on each side; in exterior steps, base of stringers may sustain fungal decay damage and/or concealed termite entry, if in direct contact with ground.

strut in roof construction, structural support to purlin which transfers roof load to wall frame or strutting beam;

strutting beam in roof construction, structural beam used to support struts where no internal walls are available.

stud vertical structural member in wall framing to which lining or cladding is fixed; generally concealed from direct inspection for pest damage eg termite damage.

terrace one of a row of buildings attached together by common/party walls.

timber frame construction type of construction in which the structural members are timber.

top plate horizontal structural timber member forming the top side of wall framing or timber member laid on (strapped to) top of masonry wall (to carry ceiling joists and support rafters).

town house strata titled two-storey attached building.

trap a drainage or plumbing fitting, usually in the shape of a P or S, which retains water to form a water seal to prevent movement of foul air into the building.

tread the horizontal section (which is stepped onto) of a staircase.

trim mouldings (usually timber) fixed around doors, windows, joinery etc

truss a frame designed to carry loads over a full span without intermediate support.

underpurlin horizontal structural roof member supporting the rafters (from underneath at right angles) and itself supported usually by struts.

valley the intersection of two sloping roof surfaces to form an open drain/gutter.

valley board timber boarding that supports the valley gutter.

verandah an open or partly open section of a building, usually at front or side, that is roofed.

villa a single-storey attached dwelling.

weatherboards boards (often timber) designed to function as an effective exterior overlapping wall cladding for timber-framed buildings.

weep holes holes or openings left in the vertical joints of a masonry wall above the level of a flashing or at the bottom of a cavity to permit the drainage of any water that may otherwise accumulate; also used at base of masonry retaining walls for drainage.

FURTHER READING

Archer J., Jackson A. and Day D. 1988 *Australian Do It Yourself Manual* Collins Sydney

Milton H. 1985 *Glossary of Australian Building Terms* Sydney Building Information Centre Sydney

Tyrrell J. 1992 T*he Pest Pack: A Consumer's Guide to Do It Yourself Pest Inspections* Choice Sydney

Tyrrell J. 1993 *House Hunting: A Consumer's Guide to Buying a Home in Australia* McPhee Gribble Victoria

Wallis N.K. 1970 *Australian Timber Handbook* Angus & Robertson Sydney

APPENDIX II

ILLUSTRATED GUIDE TO BUILDING TERMS

The following illustrations are reprinted here, with the kind permission of Jerry Tyrrell, from his *The Pest Pack: A Consumer's Guide To Do It Yourself Pest Inspections*, Choice, Sydney.

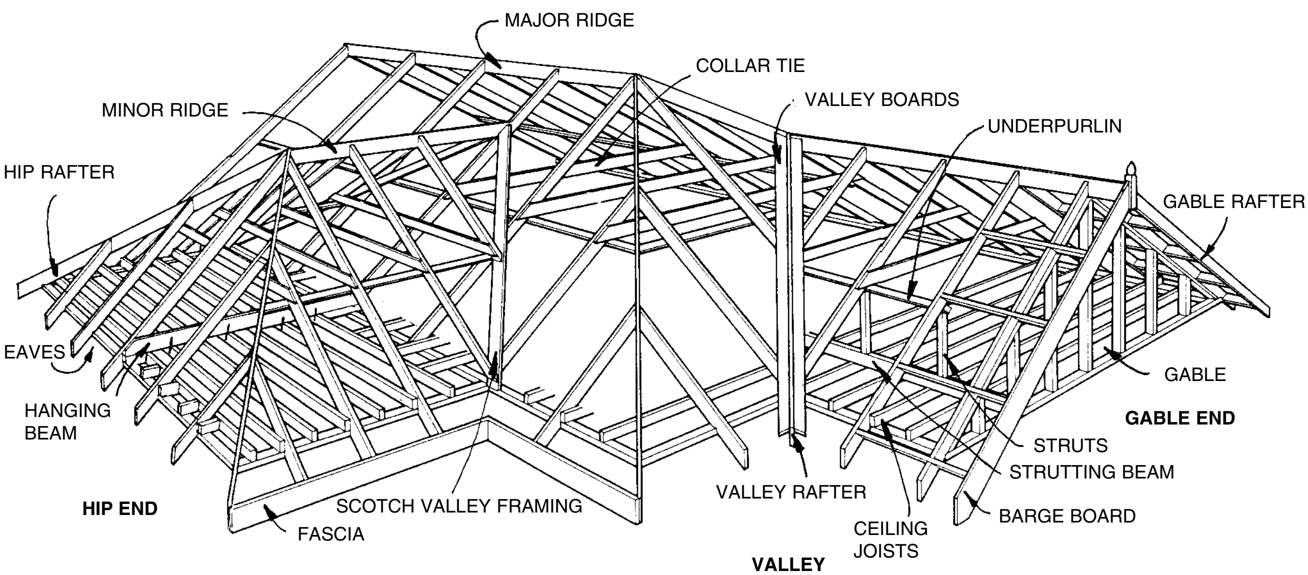

Figure 1 Roof

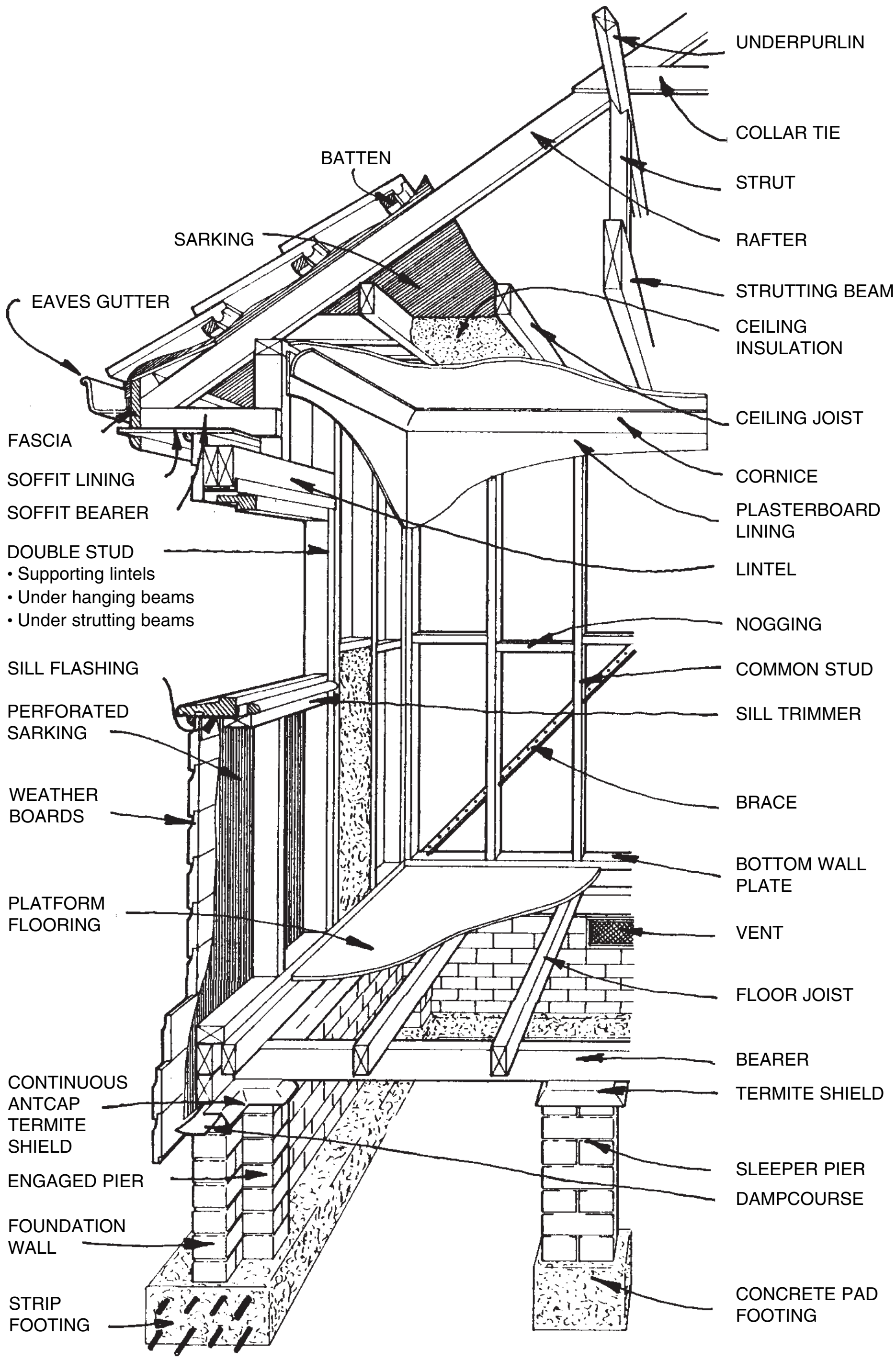

Figure 2 Timber framed construction

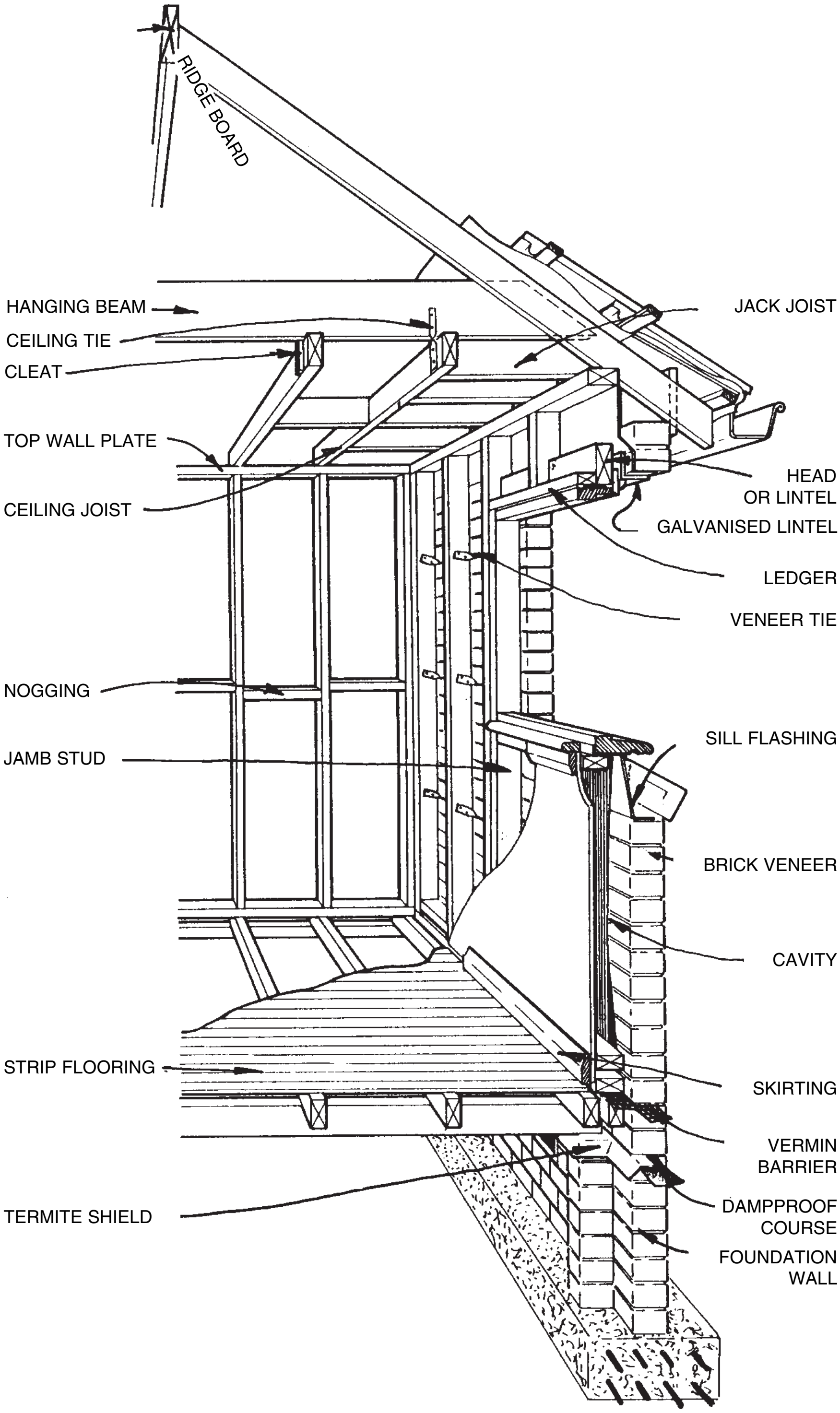

Figure 3 Brick veneer construction

SCIENTIFIC & COMMON NAMES OF SOME INSECT PESTS OF TREES & TIMBER

Borers

Ambeodontus tristis	two-tooth longicorn
Anobium punctatum	furniture beetle
Austroplatypus incompertus	horizontal borer
Barea spp.	decay moth
Bostrychopsis jesuita	large auger beetle
Buprestis aurulenta	Oregon jewel beetle
Calymmaderus incisus	Queensland pine beetle
Camponotus spp.	carpenter ants
Crossotarsus omnivorus	omnivorous pinhole borer
Dermestes ater	hide beetle
Diadoxus erythrurus	small Cypress jewel beetle
Diadoxus scalaris	Cypress jewel beetle
Ernobius mollis	pine bark anobiid
Family Bostrichidae	auger beetles
Family Buprestidae	jewel beetles
Hadrobregmus australiensis	dampwood borer
Heterobostrychus aequalis	lesser auger beetle
Hylotrupes bajulus	European house borer
Lophyrotoma spp.	sawflies
Lyctus brunneus	powderpost beetle
Lyctus discedens	small powderpost beetle
Lyctus parallelocollis	powderpost beetle
Mesoxylion collaris	particoloured auger beetle
Minthea rugicollis	hairy powderpost beetle
Pentarthrum australe	decay weevil
Phoracantha recurva	yellow longicorn
Phoracantha semipunctata	common eucalypt longicorn
Platypus australis	polyphagous pinhole borer
Platypus subgranosus	mountain pinhole borer
Prospheres aurantiopictus	hoop-pine jewel beetle
Scolytus multistriatus	elm bark beetle
Sirex noctilio	sirex wasp
Syndesus cornutus	lucanid decay borer
Xylion cylindricus	cylindrical auger beetle
Xyleborus perforans	island pinhole borer
Xylobosca bispinosa	two-spined auger beetle
Xylodeleis obsipa	auger beetle
Xylopsocus gibbicollis	common auger beetle
Xylothrips religiosus	northern auger beetle
Xylotillus lindi	yellow auger beetle

Termites

Coptotermes spp.	subterranean termites
Coptotermes acinaciformis	
Coptotermes frenchi	
Coptotermes lacteus	
Coptotermes michaelseni	
Coptotermes raffrayi	
Cryptotermes spp.	drywood termites
Cryptotermes brevis	West Indian drywood termite
Cryptotermes primus	native drywood termite
Heterotermes ferox	
Mastotermes darwiniensis	giant northern termite
Microcerotermes turneri	
Nasutitermes dixoni	
Nasutitermes extiosus	
Nasutitermes fumigatus	
Nasutitermes graveolus	
Nasutitermes longipennis	
Nasutitermes occasus	
Nasutitermes walkeri	
Noetermes insularis	ringant termite
Porotermes adamsoni	dampwood termite
Schedorhinotermes intermedius	
Schedorhinotermes reticulatus	

COLLECTION & PRESERVATION OF INSECTS & ALLIED FORMS

The work of a pest control operator, by its nature, gives rise to a rather close association with insects and other arthropods: their identification, knowledge of their habits and requirements, diagnosis of their activities and often, of course, procedures to control them. With such a close association, some pest control companies maintain a collection of pest insects which may be used as a means of introducing new trainees to insect identification. Collections of pest insects may also be consulted with clients in order to help in clarifying the nature of particular pest problems. As well, operators may encounter or be given specimens that require closer identification than is possible by the operator. In such cases it may be necessary to pass on the specimen to a specialist entomologist for accurate identification. Normally, when an insect dies, the chemical changes that occur lead to a gradual decaying of the specimen. Some knowledge of the basic techniques of preservation can ensure that collections are properly set up and maintained and that specimens sent off for identification remain in an identifiable and generally acceptable state. A thoroughly labelled, carefully stored insect collection can become a very useful tool for the pest control operator.

BASIC EQUIPMENT

In order to be able to collect and properly preserve specimens of insects and similar animals, pest control operators should have the following basic equipment:

Forceps — for picking up specimens when the use of one's hands is unsuitable.

Brush (camel-hair) — when moistened, for picking up and transferring very small specimens (eg mites and tiny insects).

Screwdriver or strong *scalpel* — for prying open timber, nests in soil etc.

Glass vials (of different sizes) — for containing specimens temporarily or permanently.

Preservative liquid — for permanent wet preservation of specimens.

Killing jar — for killing live specimens.

Killing agent (ethyl acetate or chloroform) — for charging the killing jar.

Labels (preferably stiff white card) — for recording information relating to each specimen.

Notebook and pencil — for note-taking at the time of collection.

Hand lens or magnifying glass — for closer observation and examination of small specimens.

Net (not essential but can be useful) — for capturing flying insects.

Aspirator (not essential but can be useful) — for collecting small insects individually (see Figure 1).

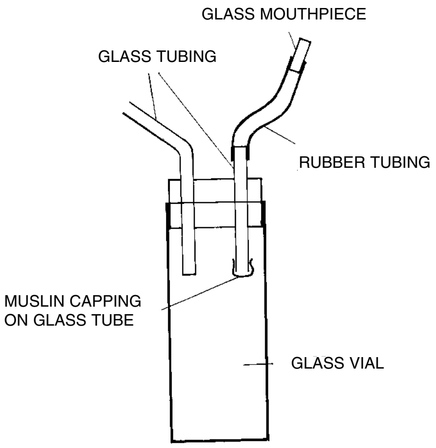

Figure 1 Aspirator

COLLECTING

Generally speaking, because warm conditions are most suitable for insect growth and development, spring and summer are usually the seasons when insects are most abundant.

Where to look

For the collector with a wide interest in insects, habitats that warrant attention include:

- various parts of dead or live plants (on foliage, on flowers, inside leaves, under bark, around roots, in leaf litter, and in or under rotting wood);
- under rocks;
- in soil;
- in and on streams and ponds;
- in and under animal dung:
- in animal carcasses;
- on animals that are hosts to parasitic insects; and
- in and around garbage tips.

For the collector with a more specific interest in specimens relating to urban pest control, other habitats may warrant consideration:

- Examination of structural timber in buildings may yield termites or borers. A screwdriver or scalpel may be useful for gaining access to specimens within the timber. When collecting termites, it is strongly advised that specimens kept include at least one soldier specimen, as these are the most suitable for identification.
- Examination of stored foods (eg grains and cereals) in domestic and commercial premises may yield a variety of stored-product pests (mostly small beetles and moths or their immature stages). Old grain-based rat baits in ceiling voids and subfloor areas also may sustain a population of stored-product pests.
- Insects that normally spend daylight hours hidden away in cracks and crevices (eg cockroaches, bedbugs) may be more accessible at night, when they are more active. Alternatively, such insects may be flushed out of their harbourages by a judicious spray from an aerosol containing a flushing agent (eg pyrethrins).
- Fabrics, particularly if stored in a less than clean state for some time, may facilitate the breeding of carpet beetles or clothes moths. Certain sections of carpet that are not regularly cleaned (eg under furniture) or clothes stored, uncleaned, between seasons may support such activity.
- Silverfish and booklice, although often fast moving, may be found among papers and books that are stored and seldom used.
- Examination of pets and their bedding, as well as bird nests, may yield specimens at different stages of growth of a variety of parasitic arthropods (eg fleas, lice, mites).
- Examination of damp locations in and around buildings may reveal a variety of arthropods (eg amphipods, slaters, millipedes, centipedes).
- Examination of garbage tips or other locations with rotting organic matter may reveal various stages of growth of flies, beetles and other insects.

Field notes and labels

The collector should always make a note of the important information about a specimen when it is collected. Reliance on memory should be avoided. A notebook or small white card label, should carry the following information about each individual specimen:

- place of collection — eg Hornsby, NSW
- date of collection — eg 26 Nov. 1995
- collector's name — eg J. Brown

Additional information (eg growing conditions of the specimen, type of timber attacked, type of stored food attacked) may be recorded, to be presented on a second label.

PRESERVATION METHODS

The primary objective of preserving insects is, of course, to have a specimen that for a long time will be representative of the original appearance of the live animal. Broadly speaking, there are two methods of preservation:

Dry preservation The insect must be relatively 'thick-skinned', because the process involves drying out the specimen. Cockroaches, beetles and grasshoppers are commonly dry-preserved merely by being pinned and allowed to dry out. Because the internal organs dry out, this method is not suitable for specimens that are to be examined internally.

Wet preservation This involves permanent immersion of the specimen in a preserving fluid. This method is most suited to soft-bodied insects (eg termites, caterpillars and other soft-bodied larvae), as the specimens retain their original shape and do not decay. Careful preparation can preserve the internal organs of insects. This method is also suitable for specimens that are too small for pinning.

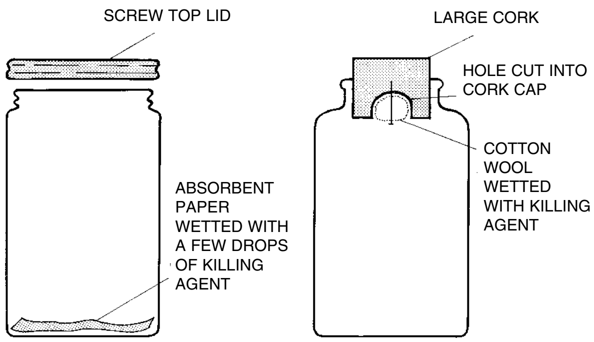

Figure 2 Killing jars

Dry preservation

Killing

Specimens collected live should be killed in a jar with a tight-fitting lid adapted as a killing jar. Absorbent paper on the bottom of the jar, or cotton wool secured in a cork top, may be wetted with a few drops of the chosen killing agent (usually ethyl acetate or chloroform). When tightly closed with the specimen inside, the jar becomes filled with toxic vapours, which kill the specimen. Insect specimens killed in this way are in a 'relaxed' state and ready to pin.

Should the collector wish to preserve an insect that, because it has been dead for some time, is 'unrelaxed' (i.e brittle and prone to breaking if handled), the specimen should be 'relaxed' before being pinned and set.

Relaxing

Specimens that have prematurely dried out can be relaxed for pinning by being placed in a relatively moist atmosphere. An airtight plastic container with moistened cloth or sand on the bottom, covered by tissue paper, will create an atmosphere moist enough to relax most dried insects within a few days. A mould inhibitor (eg chlorocresol) may be added to the water to prevent mould growth; and when the specimen is placed on the tissue paper and the container is sealed, it should be examined regularly until the specimen is sufficiently relaxed.

Pinning, setting and drying

Collectors should ensure that each specimen is identified with its correct label throughout the entire procedure of pinning, setting and drying. Pins used should be proper, stainless-steel entomological pins that are not so thin as to bend easily but not so thick as to damage the specimen (no. 3 pins are often regarded as a reasonable compromise for most insect specimens). It is customary to pin many types of insects in the centre of the thorax, with the pin travelling vertically. Some insects, such as beetles, owing to important identification features in the centre line, are pinned slightly to the right of centre, but again with the pin travelling vertically downwards. Robust insects can be held between finger and thumb for pinning; others can be placed on a 'pinning pad' (a piece of polystyrene foam will serve adequately). About one-third of the pin should project above the specimen .

The setting of insects during the pinning operation,

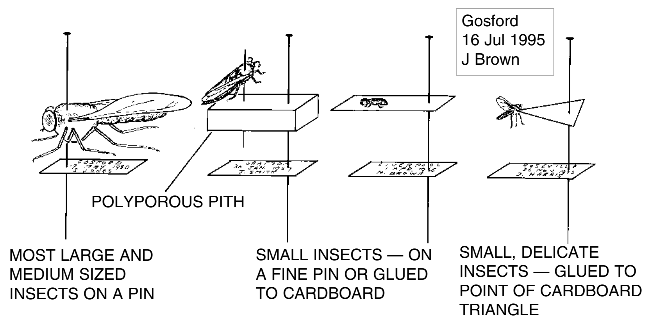

Figure 3 Pinning techniques

when the insect is relaxed, can allow for the arrangement of legs and wings into positions that will best facilitate future examination of the specimen when it is dry. Insects such as flies require little or no setting (perhaps extending the legs), while butterflies, for example, are most presentable with wings set out. Polystyrene foam can be shaped by cutting to facilitate most setting requirements. A setting board with a groove running along the centre is particularly useful in the setting of large winged insects such as butterflies and dragonflies.

Once set, specimens may be dried by placing them inside a cardboard box that has some ventilation. Days to weeks may be required for the drying process to be complete. In the meantime a sprinkling of naphthalene flakes (or other protectant) is advised to safeguard the drying specimens from the ravages of ants or other live insects that may discover such a smorgasbord.

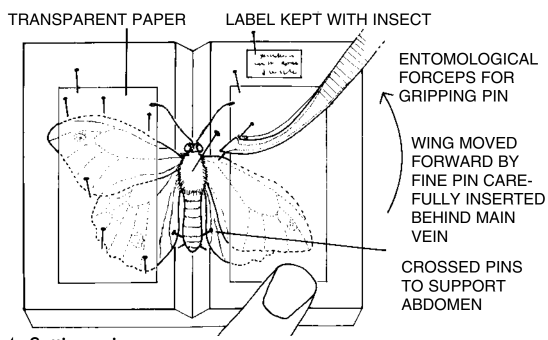

Figure 4 Setting wings

Very small insects that would be damaged by a normal entomological pin may be wet-preserved or double mounted. Double mounting is achieved by gluing the insect (using a small drop of a water-soluble glue) to the point of a small triangular card, or by pinning the insect with a headless micropin and staging the pinned specimen on a piece of polyporous pith, which is transfixed by the entomological pin.

Labelling

An aspect that is critical in any worthwhile insect collection is its documentation. Every insect specimen should have a small, preferably stiff, white card label placed below it (about halfway along the length of the pin) with the following information:

- place of collection eg Leura, NSW
- date of collection 12 Nov. 1995
- collector's name J. Brown

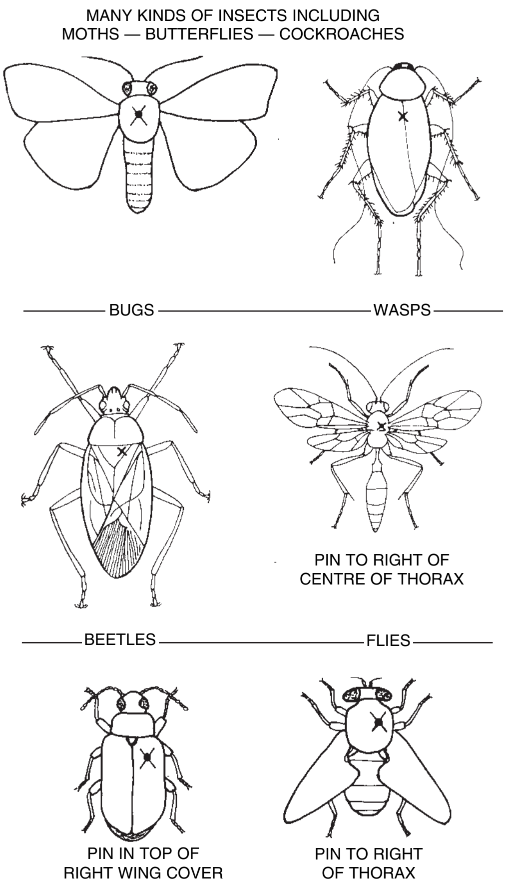

Figure 5 Pinning various types of insects

Labels should be written clearly and legibly using a very stable ink such as Indian ink. A second card, placed underneath this one, may serve to record further information that is relevant to the specimen. Such information may relate to the type of tree on which the specimen was feeding, the nature or extent of damage caused to timberwork, stored foods and so on.

Labelling relating to the identification or classification of the specimen is usually achieved by placing labels on the surface on which the specimens are pinned for storage. If this approach is unsuitable, the information may appear on another small card label that is transfixed by the pin.

Storage

Insects that have been pinned, set dried and properly labelled are ready to be stored permanently. Insect storage boxes are generally tight-fitting wooden boxes lined inside with cork or plastic foam into which the specimens are pinned. The collector may wish to make his or her own storage boxes by lining other types of boxes (even cardboard), with plastic foam. Tight-fitting boxes are preferred, as they are more likely to exclude live insects that may damage the stored specimens.

Naphthalene flakes or balls are often maintained inside the boxes to lessen the chances of insect attack. Cabinets specifically designed to house hundreds of specimens effectively, are available.

Wet preservation

Insects that are soft-bodied or too small to preserve by normal pinning procedures can be wet preserved. Insects such as silverfish, termites, lice, booklice and the larvae of moths, butterflies, beetles, flies, bees and wasps are all suited to wet preservation. Such specimens can be killed and preserved by dropping them into the preserving liquid, preferably 80% ethyl alcohol (80% methylated spirits will, in most cases, be adequate). A range of glass vials and jars will be useful in accommodating a variety of different-sized specimens.

Many larvae shrink, lose their colour or, if white, turn brown or black when placed straight into the preservative. If the collector wishes to avoid such reactions on the specimens, a fixing technique should be employed. While there are many fixatives and techniques suitable for different kinds of specimens, a generally useful fixative, especially for caterpillars and beetle grubs, is KAA. (To make up 100 ml, use 8 ml of kerosene, 77 ml of 95% alcohol and 15 ml of glacial acetic acid.) The preparation can be purchased ready mixed, and the larvae are killed in this fixative and left for several hours before being stored in 80% alcohol.

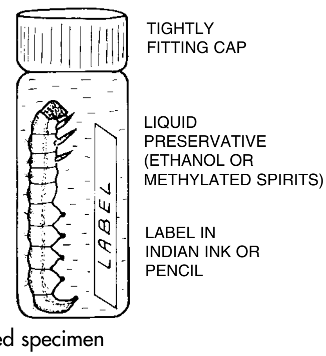

Figure 6 Wet-preserved specimen

Labelling

Labels carrying the important basic information for each specimen (place of collection, date of collection and collector's name), as well as separate cards or labels carrying other information, should be placed in the vial or jar with the appropriate specimen. Such labels should be written with a sharp lead pencil or Indian ink.

FURTHER READING

Smithers C. 1981 *Handbook of Insect Collecting* Reed Sydney
Upton M.S. 1991 *Methods for Collecting, Preserving and Studying Insects and Allied Forms* Australian Entomological Society Brisbane

SOME INSECTICIDE PRODUCTS USED IN URBAN PEST CONTROL

The inclusion of certain products in this table does not constitute their endorsement by the authors. Comments made in relation to uses and application are general ones that may not apply to all States. Also, other information supplied may vary. Specific product labels and State legislation should always be consulted before the use of any pesticide to ensure compliance. 'Trade names' includes registered trademarks of various companies.

Insecticide (Common name)	Trade name (Manufacturer/ Distributor)	Active constituent (Type of formulation)	Main uses and comments	Poisons Scheduling
Inorganic insecticides				
Arsenic trioxide	Aldi Arsenic Trioxide Termite Dust (Aldi G.C.)	659 g/kg arsenic trioxide (Dust)	For control of subterranean termites	Schedule: S7
	Garrard's Termite Powder Insecticide	379 g/kg Arsenic (present as arsenic trioxide)	For control of subterranean termites	Schedule: S7
Boric acid (Boron)	Drax Ant Kil Dual Syringe (Barmac Industries)	9 g/kg boric acid (Gel/bait)	Ready to use Dual Syringe gel formulation for the control of both sugar and protein/grease feeding ants.	Schedule: S5
	Drax Ant Kil Gel (Barmac Industries)	9 g/kg boric acid (Gel/bait)	Ready to use gel formulation for the control of sugar-feeding ants.	Schedule: S5
	Drax Ant Kil-PF (Barmac Industries)	9 g/kg boric acid (Gel/bait)	Ready to use gel formulation for the control of protein/ grease-feeding ants.	Schedule: S5
	Drax Ant Liquidator (Barmac Industries)	9 g/kg boric acid (Liquid outdoor bait station)	Ready to use liquid outdoor bait station for the control of ants around the perimeters of buildings.	Schedule: S5
	Magnetic Roach Food Cockroach Bait (Barmac Industries)	58 g/kg boric acid (Paste/bait)	Ready to use paste formulation for the control of cockroaches (including in food-handling establishments).	Schedule: S5
	Roach Prufe (Newill Industries)	173 g/kg boric acid (Dust)	For control of cockroaches and silverfish. Can remain effective for long periods.	Schedule: S5
Silica	Dryacide Sorptive Dust Insecticide (Dryacide)	900 g/kg silica (amorphous) (Dust)	For control of a range of insect pests of stored grain including the pretreatment of storage structures and handling equipment	Unscheduled

Botanical insecticides

Pyrethrins	Drift (Pestech)	4 g/L pyrethrins 24 g/L piperonyl butoxide (Ready to use mix for misting/fogging)	For control of flies, mosquitoes, midges, spiders, cockroaches and various insect pests of stored food in food-processing, industrial and domestic premises.	Schedule: S5
	Fog'n'mist Industrial and Domestic Insecticide (Pestech)	2 g/L pyrethrins 16 g/L piperonyl butoxide (Ready to use mix for misting/fogging)	For control of flies, mosquitoes, midges, spiders, cockroaches and various insect pests of stored food in food-processing, industrial and domestic premises.	Schedule: S5
	Pestigas Pyrethrins Insecticide (BOC Gases)	4 g/kg pyrethrins 20 g/kg piperonyl butoxide (High-pressure aerosol)	For control of flies, mosquitoes, ants, cockroaches, silverfish and some other insect pests in food handling, industrial and domestic premises. A range of application equipment allows manual dispensing with standard gun and hose or with self-contained Dose Gun (with normal or crack/crevice nozzles) or automatic systems for treatment of warehouses etc.	Unscheduled
	Preclude Insecticide (PCT International)	11 g/L pyrethrins 22 g/L piperonyl butoxide 37 g/L N-octyl bicycloheptene dicarboximide	For control of ants, bed bugs, beetles, cockroaches, fleas, flies, mosquitoes, moths, silverfish, spiders and wasps.	Unscheduled
	PY matic Metered Insecticide (C. Rudduck)	14 g/kg pyrethrins 60 g/kg piperonyl butoxide (Aerosol-metered Insecticide)	For use in dedicated dispenser for control of flies mosquitoes, moths ants, silverfish, fleas, cockroaches, spiders and earwigs.	Unscheduled
	PY Sect Metered Insecticide (Bramley Hygiene)	14 g/kg pyrethrins 60 g/kg piperonyl butoxide (Aerosol-metered Insecticide)	For use in dedicated dispenser for control of flies, mosquitoes, moths.	Unscheduled
	Rentokil Pyrethrum Insecticide Spray Mill Special (Rentokil Initial)	4 g/L pyrethrins 20 g/L piperonyl butoxide (Ready to use mix for misting/fogging)	For control of flies and some insect pests of industrial food-processing premises and some insect pests of stored grain.	Schedule: S5
	Rentokil Pyrethrum Spray No. 1 Special (Rentokil Initial)	1 g/L pyrethrins 8 g/L piperonyl butoxide (Ready to use mix for misting/fogging)	For control of flies and some insect pests of stored grain.	Schedule: S5
	Rudchem PY Spray Aerosol Insecticide (C. Rudduck)	10 g/L pyrethrins 50 g/L piperonyl butoxide (Aerosol)	For control of flies, mosquitoes, moths, ants silverfish, fleas, cockroaches, grain weevils, spiders and earwigs.	Unscheduled

Organophosphorus insecticides

Azamethiphos	Alfacron 500 Residual Insect Spray (Novartis Animal Health)	500 g/kg azamethiphos (Wettable Powder)	For control of cockroaches, spiders, flies, grain pests in storage areas and grain handling equipment, and certain pests of poultry.	Schedule: S6
Chlorpyrifos	Ant Out Granular Insecticide (PCT International)	50 g/kg chlorpyrifos (Granules)	For control of ants.	Schedule: S5
	Chlorpyrifos (Barmac Industries)	500 g/L chlorpyrifos (Emulsifiable concentrate)	For control of cockroaches, fleas, silverfish, spiders, ants and mosquitoes (larvae and adults).	Schedule: S6
	Chlorpyrifos Granules (Barmac Industries)	50 g/kg chlorpyrifos (Granules)	For the control of ants in gardens and outdoor areas.	Schedule: S5
	David Grays Antex Granules (David Gray + Co)	30 g/kg chlorpyrifos (Granules)	For control of ants.	Schedule: S5
	David Grays Micro-Lo Chlorpyrifos (David Gray + Co)	450 g/L chlorpyrifos (Emulsifiable concentrate)	For control of subterranean termites and cockroaches, spiders, ants, fleas, silverfish, mosquitoes (adults and larvae) and hide beetles (low odour).	Schedule: S6
	David Grays Pre-Construction Chlorpyrifos Termiticide (David Gray + Co)	450 g/L chlorpyrifos (Emulsifiable concentrate)	For pre-construction control of subterranean termites.	Schedule: S6
	Deter Insecticide (Aventis)	500 g/L chlorpyrifos (Emulsifiable concentrate)	For control of subterranean termites and cockroaches, fleas, silverfish, spiders, ants and mosquitoes (larvae and adults).	Schedule: S6
	Dursban Micro-Lo Termiticide and Insecticide (Dow AgroSciences)	450 g/L chlorpyrifos (Emulsifiable concentrate)	For control of subterranean termites and cockroaches, spiders, ants, fleas, silverfish, mosquitoes (adults and larvae) and hide beetles (low odour).	Schedule: S6
	Dursban PC Termiticide and Insecticide (Dow AgroSciences)	500 g/L chlorpyrifos (Emulsifiable concentrate)	For control of subterranean termites and cockroaches, spiders, ants, fleas, silverfish, mosquitoes (adults and larvae) and hide beetles.	Schedule: S6
	Dursban Pre-Construction Termiticide (Dow AgroSciences)	450 g/L chlorpyrifos (Emulsifiable concentrate)	For pre-construction control of subterranean termites.	Schedule: S6
	Empire Insecticide (Dow AgroSciences)	200 g/L chlorpyrifos (Micro encapsulated)	For control of ants, cockroaches, fleas (outdoors only), silverfish, slaters and spiders (no odour).	Schedule: S5
	Farmoz Strike-Out Termiticide and Insecticide (Farmoz)	500 g/L chlorpyrifos (Emulsifiable concentrate)	For control of subterranean termites and cockroaches, spiders, ants, fleas, silverfish, mosquitoes (adults and larvae) and hide beetles.	Schedule: S6
	Garrard's Ant Killer 50	50 g/kg chlorpyrifos (Granular bait)	For external control of ants around houses, buildings and vegetation.	Schedule: S5
	Killmaster II (Barmac Industries)	20 g/L chlorpyrifos (Lacquer)	For control of cockroaches, ants, spiders and silverfish (slow-acting, citrus formulation).	Schedule: S6

	Nufarm Chlorpyrifos (Nufarm)	500 g/L chlorpyrifos (Emulsifiable concentrate)	For control of subterranean termites and cockroaches, spiders, ants, fleas, silverfish, mosquitoes (adults and larvae) and hide beetles.	Schedule: S6
	Optem 500 Termiticide & Insecticide (PCT International)	500 g/L chlorpyrifos (Emulsifiable concentrate)	For control of subterranean termites and cockroaches, spiders, ants, fleas, silverfish, mosquitoes (adults and larvae) and hide beetles.	Schedule: S6
	Optem Pre-Construction Termiticide (PCT International)	450 g/L chlorpyrifos (Emulsifiable concentrate)	For pre-construction control of subterranean termites.	Schedule: S6
	Protem Termiticide & Insecticide (PCT International)	450 g/L chlorpyrifos (Emulsifiable concentrate)	For control of subterranean termites and cockroaches, spiders, ants, fleas, silverfish, mosquitoes (adults and larvae) and hide beetles.	Schedule: S6
Diazinon	Diacap Insecticide (Novartis Animal Health)	300 g/L diazinon (Micro encapsulated)	For control of cockroaches, silverfish, fleas, flies, ants, carpet beetles and bed bugs.	Schedule: S6
	Diazinon 800 Insecticide (PCT International)	800 g/L diazinon (Emulsifiable concentrate)	For control of ants, bed bugs, carpet beetles, cockroaches, fleas, flies, mosquito larvae, spiders, maggots, silverfish and skin and hide beetles.	Schedule: S6
	Diazinon (Barmac Industries)	800 g/kg diazinon (Emulsifiable concentrate)	For control of ants, bed bugs, carpet beetles, cockroaches, fleas, flies, mosquito larvae, spiders, maggots, silverfish and skin and hide beetles.	Schedule: S6
	Knox-Out Flowable Micro encapsulated Insecticide (Colin Campbell Chemicals)	240 g/L diazinon (Micro encapsulated)	For control of ants, cockroaches, fleas, flies and silverfish.	Schedule: S6
	Neocid 200P Insecticide (Novartis Animal Health)	200 g/L diazinon (Emulsifiable concentrate)	For control of cockroaches, spiders, fleas, ants, silverfish, flies, mosquito larvae, carpet beetles, maggots, bed bugs and skin and hide beetles.	Schedule: S6
	PCO Neocid 800 Insecticide (Novartis Animal Health)	800 g/L diazinon (Emulsifiable concentrate)	For control of cockroaches, spiders, fleas, ants, silverfish, flies, mosquito larvae, carpet beetles, maggots, bed bugs and skin and hide beetles.	Schedule: S6
Dichlorvos (DDVP)	Insectigas-D Insecticide (BOC Gases)	50 g/kg dichlorvos (High-pressure aerosol)	For control of flies, mosquitoes, moths, ants, cockroaches, silverfish and some insect pests of stored grain. A range of application equipment allows manual dispensing with standard gun and hose or with self-contained Dose Gun (with normal or crack/crevice nozzles) or automatic systems for treatment of warehouses etc.	Schedule: S6
	Vapona 500 Insecticide (Cyanamid)	500 g/L dichlorvos (Emulsifiable concentrate)	For control of flies, moths, mosquitoes, fleas, ants, cockroaches, spiders, silverfish, European wasp and a range of stored product insect pests.	Schedule S6

Fenthion	Baytex 550 Insecticide Spray (Bayer)	550 g/L fenthion (Emulsifiable concentrate)	For control of flies, mosquitoes (adults and larvae), fleas, spiders and ants outdoors.	Schedule: S6
Pirimiphos-methyl	Actellic Public Health Insecticide (Crop Care)	900 g/L pirimiphos-methyl (Emulsifiable concentrate)	For control of ants, cockroaches, fleas, flies, mosquitoes and mosquito larvae, silverfish, bed bugs, spiders and carpet beetles.	Schedule: S6
Temephos	Abate 100E Insecticide (Cyanamid)	100 g/L temephos (Emulsifiable concentrate)	For control of mosquito and midge larvae by treatment of breeding areas.	Schedule: S5
	Abate 10 SG Insecticide (Cyanamid)	10 g/kg temephos (Granules)	For control of mosquito and midge larvae by treatment of breeding areas.	Schedule: S6
	Abate 50 SG Mosquito Larvicide Granules (Cyanamid)	50 g/kg temephos (Granules)	For control of mosquito and midge larvae by treatment of breeding areas.	Schedule: S6
Carbamate insecticides				
Bendiocarb	Ficam D (Aventis)	10 g/kg bendiocarb (Dust)	For control of ants, bed bugs, carpet beetles, cockroaches, fleas, silverfish, spiders and European wasp.	Schedule: S5
	Ficam W (Aventis)	800 g/kg bendiocarb (Wettable Powder)	For control of ants, bed bugs, carpet beetles, cockroaches, fleas, flies, silverfish, spiders, millipedes and European wasp.	Schedule: S6
Propoxur	Blattanex Professional Crack and Crevice Aerosol (Bayer)	20 g/kg propoxur 2 g/kg tetramethrin 10 g/kg piperonyl butoxide (Aerosol)	For control of cockroaches, ants, bed bugs, carpet beetles, clothes moths, flies, mosquitoes, silverfish, earwigs, millipedes, spiders and European wasp (can be used with crack and crevice applicator).	Schedule: S5
	Starrdust Insecticide Dust (Bayer)	10 g/kg propoxur 5 g/kg triflumuron (Dust)	For control of cockroaches, fleas, ants, bed bugs, silverfish, European wasps and nuisance bees.	Schedule: S5
Methomyl	Dy-Fly Plus (Aventis)	10 g/kg methomyl 0.5 g/kg muscamone (Sugar-based granules)	For control of adult houseflies.	Schedule: S6
Synthetic Pyrethroids				
Allethrin	Wasp-Freeze Wasp Killer Insecticide (PCT Inernational)	1.3 g/kg d-allethrin 1.2 g/kg d-phenothrin (Aerosol)	For outdoor control of wasps.	Unscheduled
Alpha-Cypermethrin	Bestox pc 50 Residual Insecticide (FMC)	50 g/L alpha cypermethrin (Suspension concentrate)	For knockdown and surface residual control of cockroaches, spiders, silverfish, flies and ants.	Schedule: S6
	Fendona 15 SC Insecticide (Cyanamid)	15 g/L alpha cypermethrin (Suspension concentrate)	For control of ants, cockroaches, silverfish, fleas, flies and spiders.	Schedule: S5
Beta-Cyfluthrin	Responsar Beta SC Insecticide (Bayer)	125 g/L beta-cyfluthrin (Suspension Concentrate)	For control of cockroaches, spiders, ants, fleas, flies, silverfish, bed bugs, mosquitoes, clothes moths, carpet beetles and stored product pests.	Schedule: S6
Bifenthrin	Biflex Post-Construction Termiticide (FMC)	100 g/L bifenthrin (Emulsifiable concentrate)	For control of subterranean termites.	Schedule: S6
	Biflex Termiticide (FMC)	100 g/L bifenthrin (emulsifiable concentrate)	For control of and barrier protection against subterranean termites.	Schedule: S6

Bioresmethrin	Reslin (Aventis)	50 g/L bioresmethrin 400 g/L piperonyl butoxide (Emulsifiable concentrate for ULV spraying, misting and fogging)	For control of biting midges, moths, flies, mosquitoes, and American cockroaches.	Schedule: S5
Cyfluthrin	Responsar EW Professional Insecticide (Bayer)	50 g/L cyfluthrin (Liquid emulsion)	For control of cockroaches, spiders, ants, fleas, flies, silverfish and mosquitoes.	Schedule: S5
Cypermethrin	Cynoff wsb Insecticide in Water Soluble Bags (FMC)	500 g/kg cypermethrin (Wettable powder supplied in water-soluble bags)	For control of cockroaches, spiders, silverfish, houseflies, mosquitoes and ants.	Schedule: S6
	Demon Public Health Insecticide (Crop Care)	400 g/kg cypermethrin (Wettable powder)	For control of ants, cockroaches, fleas, houseflies, mosquitoes, silverfish and spiders.	Schedule: S6
Lambda-Cyhalothrin	Demand Insecticide (Crop Care)	25 g/L lambda-cyhalothrin (Capsule suspension)	For control of cockroaches, fleas, ants, houseflies, mosquitoes and spiders.	Schedule: S5
Deltamethrin	Blitz Insecticide (PCT International)	10 g/L deltamethrin 10 g/L tetramethrin-R 25:75 80 g/L piperonyl butoxide (Suspension concentrate)	For control of cockroaches, fleas, ants, spiders, silverfish, houseflies, mosquitoes, bedbugs, carpet beetles, clothes moths and bird mites.	Schedule: S5
	Cislin (Aventis)	10 g/L deltamethrin (Suspension concentrate)	For control of cockroaches, fleas, ants, spiders, silverfish, flies, mosquitoes, carpet beetles, clothes moths, bedbugs and bird mites.	Schedule: S5
	Crackdown (Aventis)	10 g/L deltamethrin 10 g/L d tetramethrin 80 g/L piperonyl butoxide (Suspension concentrate)	For control of cockroaches, fleas, ants, spiders, silverfish, houseflies, mosquitoes, bed bugs, carpet beetles, clothes moths and bird mites.	Schedule: S5
	Insectigone Insecticide (PCT International)	10 g/L deltamethrin (Suspension concentrate)	For control of cockroaches, fleas, ants, spiders, silverfish, flies, mosquitoes, carpet beetles, clothes moths, bedbugs and bird mites.	Schedule: S5
	Kordon TMB (Aventis)	1g/m^2 deltamethrin (Impregnated fibrous webbing sandwiched between two layers of plastic sheeting)	Termite Moisture Barrier for installation under 'slab-on-ground' buildings as a barrier against subterranean termites and moisture (chemical barrier – non-soil matrix sheet).	Unscheduled
Permethrin 25:75 cis:trans	Coopex Insecticidal Dusting Powder Industrial Strength (Aventis)	10 g/kg permethrin (25:75) (Dust)	For control of cockroaches, fleas, silverfish, ants, bedbugs, hide beetles, bird mites, European wasps and subterranean termites (in trees and stumps).	Unscheduled
	Coopex Residual Insecticide (Aventis)	250 g/kg permethrin (25:75) (Water-dispersable Powder)	For control of cockroaches, fleas, silverfish, carpet beetles, clothes moths, hide beetles, flies, mosquitoes, spiders, ants and bed bugs.	Schedule: S5
	Farmoz Permex Residual Insecticide (Farmoz)	250 g/kg permethrin (25:75) (Water-dispersable Powder)	For control of ants, bedbugs, carpet beetles, clothes moths, silverfish, cockroaches, fleas, spiders, housflies, mosquitoes and hide beetles	Schedule: S5
	Imperator Residual Insecticide (Crop Care)	500 g/L permethrin (40:60) (Emulsifiable concentrate)	For control of cockroaches, clothes moths, ants, fleas, silverfish, spiders and for use against certain timber borers and drywood termites.	Schedule: S6

Permethrin 25:75 cis:trans (cont.)	Imperator Smoke Generator (Crop Care)	47.5 g/kg permethrin (Smoke generator)	For control of ants, flies, fleas, silverfish, cockroaches, spiders and some pests of stored foods and plants.	Schedule: S5
	Perigen 500 Timber and Residual Insecticide (Aventis)	500 g/L permethrin (25:75) (Emulsifiable concentrate)	For control of ants, cockroaches, fleas, spiders, carpet pests, silverfish, bedbugs, mosquitoes, biting flies, timber borers and drywood termites. Also used in the processing/manufacture of various timber products.	Schedule: S6
	Pounce 500 Timber and Residual Insecticide (PCT International)	500 g/L permethrin (25:75) (Emulsifiable concentrate)	For control of ants, cockroaches, fleas, spiders, silverfish, mosquitoes, moths, beetles, biting flies, timber borers and drywood termites. Also used in the processing/manufacture of various timber products.	Schedule: S6
	Permethrin D Insecticidal Dust (Barmac Industries)	10 g/kg permethrin (25:75) (Dust)	For control of cockroaches, fleas, silverfish, ants, bed bugs, hide beetles, bird mites, European wasps and subterranean termites (in trees and stumps).	Unscheduled
	Target Dust Treatment for Insect Control (PCT International)	10 g/kg permethrin (25:75) (Dust)	For control of cockroaches, fleas, silverfish, ants, bed bugs, hide beetles and European wasps.	Unscheduled
Insect growth regulators				
Diflubenzuron	Integral (Aventis)	120 g/L diflubenzuron 10 g/L deltamethrin (Suspension concentrate)	For control of cockroaches, fleas, ants, spiders, silverfish, houseflies, mosquitoes, bed bugs and carpet beetles.	Schedule: S5
Fenoxycarb	Genus Insect Growth Regulator (BOC Gases)	6 g/kg fenoxycarb (High-pressure aerosol)	For control of immature cockroaches and fleas. A range of application equipment allows manual dispensing with standard gun and hose or with self-contained Dose Gun (with normal or crack/crevice nozzles) or automatic systems for treatment of warehouses etc.	Unscheduled
Hexaflumuron	Sentricon Colony Elimination System (Dow AgroSciences)	5 g/kg hexaflumuron (Bait)	For control of subterranean termite colonies.	Unscheduled
Hydroprene	Protrol Crack and Crevice Insecticidal Spray (Novartis Animal Health)	3 g/kg (S)-hydroprene 9.5 g/kg permethrin (Aerosol)	For control of cockroaches (with crack and crevice application facility).	Unscheduled
	Gentrol Point Source (Novartis Animal Health)	910 g/kg (S)-hydroprene (Plastic stations containing capsule)	For control of cockroaches. Used in conjunction with an adulticide (eg pyrethrum spay)	Unscheduled
Methoprene	Vet-Kem Siphatrol Insecticidal Mist (Novartis Animal Health)	0.75 g/kg (S)-methoprene 5 g/kg permethrin (Aerosol)	For control of fleas.	Unscheduled
Pyriproxyfen	Sumilarv (Aventis)	20 g/L pyriproxyfen (Soluble liquid)	For control of immature fleas and cockroaches (can be used as additive to an appropriate adulticide).	Unscheduled
Triflumuron	Starycide 480 Larvicide (Bayer)	480 g/L triflumuron (Suspension concentrate)	For control of silverfish, flea larvae and immature cockroaches (can be used as an additive to an appropriate adulticide).	Schedule: S5
	Intrigue Termite Dust (Bayer)	800 g/kg triflumuron	For control of subterranean termites	Schedule: S5

Miscellaneous insecticides				
Fipronil	Goliath Cockroach Gel (Aventis)	0.5 g/kg fipronil (Bait/gel)	For control of cockroaches	Unscheduled
Hydramethylnon	Amdro Cockroach Gel (Cyanamid)	20 g/kg hydramethylnon (Bait)	For control of cockroaches	Schedule: S6
	Amdro Granular Ant Bait (Cyanamid)	7.3 g/kg hydramethylnon (Bait)	For control of certain ant species	Schedule: S6
	Maxforce Ant Control System Insecticide Baits (Garrard's Pesticides)	10 g/kg hydramethylnon (Bait in station)	For control of ants	Schedule: S5
	Maxforce Cockroach Control System Household Insecticide Baits (Garrard's Pesticides)	16.5 g/kg hydramethylnon (Bait in station)	For control of cockroaches.	Schedule: S5
	Maxforce Professional Insect Control Roach Gel (Garrard's Pesticides)	16.5 g/kg hydramethylnon (Bait/gel)	For control of cockroaches.	Schedule: S6
Imidacloprid	Premise Cockroach Gel	21.5 g/kg imidacloprid (Bait/gel)	For control of cockroaches.	Unscheduled
	Premise 200 SC Termiticide (Bayer)	200 g/L imidacloprid (Suspension concentrate)	For control of subterranean termites (except *Mastotermes darwiniensis*).	Schedule: S5
Biological Control Agents				
Bacillus thuringiensis	Vectobac 12AS (Aventis)	1200 ITU/mg Bti *Bacillus thuringiensis* var. *israelensis*	For control of mosquito larvae.	Unscheduled

APPENDIX VI

ACTIVE INGREDIENTS AND TARGET PESTS

Insecticide Active ingredient (Type of formulation: see Key)	Cockroaches	Ants	Flies	Mosquitoes (adults)	Mosquitoes (larvae)	Fleas	Bedbugs	Clothes moths	Carpet beetles	Silverfish	Stored food pests	Spiders	European wasp	Termites (subterranean)
Surface-spray Insecticides														
alpha cypermethrin (SC)	✔	✔	✔							✔		✔		
azamethiphos (WP)	✔		✔								✔	✔		
bendiocarb (WP)	✔	✔	✔			✔	✔		✔	✔		✔	✔	
beta cyfluthrin (SC)	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔		
bifenthrin (EC)														✔
chlorpyrifos (EC)	✔	✔		✔	✔	✔				✔		✔		✔
chlorpyrifos (lacquer)	✔	✔								✔		✔		
cyfluthrin (LE)	✔	✔	✔	✔		✔				✔		✔		
cypermethrin (WP)	✔	✔	✔	✔						✔		✔		
deltamethrin (SC)	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔		
diazinon (EC)	✔	✔	✔		✔	✔	✔		✔	✔		✔		
diazinon (ME)	✔	✔	✔			✔				✔				
dichlorvos (EC)	✔	✔	✔	✔		✔				✔	✔	✔	✔	
diflubenzuron (SC)	✔	✔	✔	✔		✔	✔		✔	✔		✔		
fenthion (EC)		✔	✔	✔	✔	✔						✔		
imidacloprid (SC)														✔
lambda cyhalothrin (CS)	✔	✔	✔	✔		✔						✔		
permethrin (EC)	✔	✔		✔		✔	✔	✔		✔		✔		
permethrin (WDP)	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔		
pirimiphos methyl (EC)	✔	✔	✔	✔	✔	✔	✔		✔	✔		✔		

Insecticide Active ingredient (Type of formulation: see Key)	Cockroaches	Ants	Flies	Mosquitoes (adults)	Mosquitoes (larvae)	Fleas	Bed bugs	Clothes moths	Carpet beetles	Silverfish	Stored food pests	Spiders	European wasp	Termites (subterranean)
pyriproxyfen (SL)	✔					✔								
temephos (EC + granules)					✔									
triflumuron (SC)	✔					✔				✔				
Special purpose aerosols														
allethrin + phenothrin													✔	
fenoxycarb	✔					✔								
hydroprene + permethrin	✔													
methoprene + permethrin						✔								
propoxur + tetramethrin	✔	✔	✔	✔			✔	✔	✔	✔		✔	✔	
Space-spray insecticides														
bioresmethrin	✔		✔	✔										
dichlorvos	✔	✔	✔	✔						✔	✔			
pyrethrins	✔	✔	✔	✔		✔	✔			✔	✔	✔		
Insecticide dusts														
arsenic trioxide														✔
bendiocarb	✔	✔				✔	✔		✔	✔		✔	✔	
boric acid	✔									✔				
permethrin	✔	✔				✔	✔			✔			✔	✔
propoxur + triflumuron	✔	✔				✔	✔			✔			✔	
silica											✔			
triflumuron														✔
Insecticide baits														
boric acid		✔												
chlorpyrifos		✔												
fipronil	✔													
imidacloprid	✔													
hexaflumuron														✔
hydramethylnon	✔	✔												
methomyl			✔											

KEY

SC — Suspension concentrate
WP — Wettable powder
EC — Emulsifiable concentrate
LE — Liquid emulsion
ME — Micro encapsulated
CS — Capsule suspension
WDP — Water-dispersable powder
SL — Soluble liquid

FUMIGANTS — MAIN TYPES AND CHARACTERISTICS

METHYL BROMIDE

Methyl bromide has been a widely used fumigant — probably largely because of its good penetrating abilities. Much of its use has been concerned with the control of insect pests infesting timber, food commodities, plant material, furniture, clothing and bagged or bulk grain. Commonly, materials are exposed for up to 24 hours at a given concentration (note: these time/concentration ratios vary, depending on the conditions). Applications have involved the wrapping of a building with special tarpaulins for the control of dry wood termites or borers, or the placement of dense commodities and articles into a vacuum chamber, to assist in penetration of the fumigant.

Methyl bromide is usually available in two forms: one in which it is formulated with a small amount (eg 2%) of chloropicrin which acts as an odorant (or warning agent) and another which does not have an odorant present. The latter is used in more critical applications in which the phytotoxic effects of chloropicrin may adversely affect the product (eg plant bulbs).

Methyl bromide is a non-flammable, non-explosive, almost odourless liquid that boils at 4°C and behaves as a gas at room temperatures. It is highly toxic to humans, and a fumigation licence is required for its use.

Given recent concerns about the possibility that methyl bromide is contributing to ozone depletion (and its listing under the Montreal Protocol, which aims to reduce and ultimately eliminate the use of chemicals that deplete the ozone layer), the use of methyl bromide will decline and it will eventually be phased out of use.

HYDROGEN CYANIDE

Because of its high toxicity, the use of hydrogen cyanide has declined in recent decades. Its penetrating qualities are considered inferior to those of methyl bromide, so it has mostly been used for the fumigation of empty buildings such as warehouses, mills, ships' holds, greenhouses, and also for the fumigation of citrus trees under gastight tarpaulins.

Hydrogen cyanide may be obtained as a liquid that boils at 26°C and has an odour of bitter almonds. There are other means of generating the gas 'on site'. It is explosive above a certain concentration in the atmosphere, is highly toxic to humans, and a licence is required for its use. In some states and countries its use as a fumigant is prohibited.

CHLOROPICRIN

Chloropicrin, sometimes loosely referred to as 'tear gas', is a potent fumigant that has been used largely in the fumigation of soil to kill insects, worms and the like, and in burrows to kill rodents and rabbits.

It is a non-flammable liquid that boils at 112°C. It is highly toxic to humans, and a fumigator's licence is usually required for its use.

CARBON DISULPHIDE

Carbon disulphide is a rapidly acting fumigant with good penetrating characteristics. It is used mainly against pests in the grain-handling industry, for the fumigation of buildings (eg silos) or of sheeted stacks containing grain.

Carbon disulphide has a boiling point of 46.3°C. It is highly flammable, and its use must incorporate specific measures aimed at avoiding fire or explosion.

CARBONYL SULPHIDE

Carbonyl sulphide is a relatively new fumigant developed by the CSIRO. In its pure form, it is a colourless gas with a boiling point of –50.2°C. It has been tested against a range of stored product insect pests as well as termites and nematodes. Given the likely decline in use of methyl bromide (due to its implication in ozone depletion), carbonyl sulphide shows promise as a possible replacement in some applications.

PHOSPHINE

Phosphine is a highly insecticidal fumigant used mostly for the control of insect pests of stored foods and, to some extent, for the control of burrowing rabbits, rats and mice. It is a potentially hazardous material, so those using it should be entirely familiar with its action and the particular types of hazards that it may present (refer to State regulations, product labels and Material Safety Data Sheets). The wide use of phosphine in controlling insect pests of stored foods relies largely on two sources of phosphine gas for the purposes of fumigation:

1 Metallic phosphides

Fumigation tablets, pellets and sachets (Detia Degesch trade names include Phostoxin®, Gastoxin® and Gas-ex-B®) containing aluminium phosphide. The tablets or pellets are applied to grain and contact with moisture in the atmosphere creates a reaction, which leads to the liberation of phosphine gas. The tablets and pellets are used mainly in the control of insects in commercially stored grain, processed food and tobacco. In addition, they may be dispensed in burrows for the control of rabbits, rats and mice.

Fumigation strips and plates (Detia Degesch) containing magnesium phosphide represent another, more recently developed product for phosphine fumigation. The plates and strips are convenient in application and are used for the control of insect pests infesting raw cereal grains, processed food commodities, animal feeds, tobacco and empty warehouses and stores.

Care must be exercised in relation to residues (left by pellets and tablets), the need for deactivation procedures with used product, and hazards in relation to flammability (see safety directions).

2 Gaseous phosphine

Gaseous phosphine is dispensed from industrial gas cylinders (trade name ECO_2FUME® — BOC Gases) as a non-flammable mixture of phosphine and carbon dioxide. It is a 'ready-to-use' product dispensed directly from the cylinder via simple dispensing equipment into the sealed storage. Once installed, the dispensing system is operated from outside the storage area, avoiding any need for the operator to come into contact with the fumigant gas. Further advantages of this method of phosphine fumigation include ease of control over concentration and the absence of residues requiring clean-up.

SIROFLO® is a patented fumigation technique developed by the CSIRO that optimises the use of phosphine as a fumigant in stored product insect pest control. A low concentration of the phosphine/carbon dioxide mixture is incorporated into an air stream that is pumped into the base of a storage facility producing a small amount of pressure that facilitates an even spread of the fumigant throughout the grain mass. Advantages of this technique are that it is effective in storage bins that are not completely gas-tight and that long exposures can control phosphine-resistant insect strains.

As with other fumigants, a degree of gas-tightness of the structure treated is essential for the safe and effective use of phosphine as a pesticide.

APPENDIX VIII

SOME RODENTICIDE PRODUCTS USED IN URBAN PEST CONTROL

Rodenticide (Common name)	**Trade name (Manufacturer/Distributor)**	**Active constituent (Type of formulation/use)**
Multiple-dose anticoagulant rodenticide products		
Coumatetralyl	Racumin 8 Rat and Mouse Rodenticide (Bayer)	8 g/kg coumatetralyl (Dry baits or as a tracking powder)
	Racumin Mouse and Rat Blocks (Bayer)	0.37 g/kg coumatetralyl (Wax block baits)
	Racumin Mouse and Rat Bait (Bayer)	0.37 g/kg coumatetralyl (Pelleted bait Ready to use)
	Racupac Throw Pack Rodenticide (Barmac Industries)	0.38 g/kg coumatetralyl (Throw packs containing biscuit-meal bait)
Warfarin	Rentokil Bait for Rats and Mice (Rentokil Initial)	0.5 g/kg warfarin (Ready-to-use bait)
	Ratsak Ready to use Rat Bait (Hortico)	0.5 g/kg warfarin (Ready-to-use bait)
Single-dose anticoagulant rodenticide products		
Brodifacoum	Ditrac All-Weather Blox Rodenticide (PCT International)	0.05 g/kg brodifacoum (Wax block baits)
	Ditrac Rodenticide (PCT International)	0.05 g/kg brodifacoum (Ready-to-use pellet bait)
	Farmoz Rodex B Rat Blocks (Farmoz)	0.05 g/kg brodifacoum
	Farmoz Rodex B Rat Pellets (Farmoz)	0.05 g/kg brodifacoum
	Talon Rodenticide Pellets (Crop Care)	0.05 g/kg brodifacoum (Ready-to-use pellet bait)
	Talon Rodenticide All Weather Rodenticide Wax Blocks (Crop Care)	0.05 g/kg brodifacoum (Wax block baits)

Bromadiolone	Contrac Blox Rodenticide (PCT International)	0.05 g/kg bromadiolone (Wax block baits)
	Contrac Rodenticide (PCT International)	0.05 g/kg bromadiolone (Ready-to-use pellet bait)
	Rentokil Bromakil-P Rodenticide Pellets (Rentokil Initial)	0.05 g/kg bromadiolone (Ready-to-use pellet bait)
	Rentokil Bromakil Super Rat Drink Concentrate (Rentokil Initial)	0.5 g/L bromadiolone (Drink concentrate)
	Rentokil Bromakil Super Rat Bait (Rentokil Initial)	0.05 g/kg bromadiolone (Ready-to-use grain bait)
	Rentokil Bromakil Super Rat Blocks (Rentokil Initial)	0.05 g/kg bromadiolone (Wax block baits)
	Rentokil Bromakil Super Rat Bait Sachets (Rentokil Initial)	0.05 g/kg bromadiolone (Grain bait in sachets)
	Rentokil Bromard Rodenticide (Rentokil Initial)	0.1 g/kg bromadiolone (For use with caulking gun)
Flocoumafen	Storm Wax Block Rodenticide (Cyanamid)	0.05 g/kg flocoumafen (Wax block baits)

Note: 'Trade name' includes registered trademarks of various companies.

IN-GROUND DURABILITY RATES FOR MATURE OUTER HEARTWOOD

This table is taken from Thornton J.D., Johnson G.C. and Nguyen N-K 1997 *Revised CSIRO Natural Durability Classification: In-Ground Durability Ratings for Mature Outer Heartwood* CSIRO Australia. Adapted with the permission of CSIRO Publishing and John Thornton.

Durability ratings are intended for use by those wishing to choose between timber species. Although it is not possible to predict service life accurately from durability class, the key below gives a guide to what may be expected for outer heartwood. Two ratings are provided for the outer heartwood of each tree species. One should be used when termites are known to be absent, while the other should be used if termites are known to be present. When the user is uncertain of whether termites are absent or will continue to be absent from an area, it is advisable to select the ratings for decay in the presence of termites. Where two or more durability classes are allocated to the same species (eg 3/2 in one column), the two classes indicate the variable performance of the timber.

		DURABILITY CLASS	
Standard trade name	**Scientific name**	**Decay only**	**Decay plus termites**
Eucalypt species (hardwood)			
Ash, mountain	*Eucalyptus regnans*	4	4
Ash, silvertop	*Eucalyptus sieberi*	3/2	4
Blackbutt	*Eucalyptus pilularis*	3/2	3
Blackbutt, WA	*Eucalyptus patens*	2	4
Box, grey	*Eucalyptus moluccana*	1	2
Box, grey, coast	*Eucalyptus bosistoana*	1	2
Box, long-leaved	*Eucalyptus goniocalyx*	3/2	3
Box, red	*Eucalyptus polyanthemos*	1	1
Box, yellow	*Eucalyptus melliodora*	1	1
Brownbarrel	*Eucalyptus fastigata*	4/3	4
Bullich	*Eucalyptus megacarpa*	3/2	4
Candlebark	*Eucalyptus rubida*	4	4
Gum, blue, southern	*Eucalyptus globulus* ssp. *bicostata*	3	4
Gum, blue, Sydney	*Eucalyptus saligna*	3/2	3
Gum, grey, mountain	*Eucalyptus cypellocarpa*	3	4
Gum, Maiden's	*Eucalyptus globulus* ssp. *maidenii*	3	4
Gum, manna	*Eucalyptus viminalis* ssp. *viminalis*	4	4

Eucalypt species (hardwood) cont.			
Gum, red, forest	*Eucalyptus tereticornis*	2/1	2/1
Gum, red, river	*Eucalyptus camaldulensis*	2	2
Gum, rose	*Eucalyptus grandis*	3	3
Gum, salmon	*Eucalyptus salmonophloia*	2/1	3
Gum, scribbly	*Eucalyptus haemastoma*	3/2	3
Gum, spotted	*Corymbia maculata syn Eucalyptus maculata*	2	2
Gum, sugar	*Eucalyptus cladocalyx*	1	1
Gum, yellow	*Eucalyptus leucoxylon* ssp. *leucoxylon*	3/2/1	3/2
Ironbark, grey	*Eucalyptus paniculata*	1	1
Ironbark, red	*Eucalyptus sideroxylon* ssp. *sideroxylon*	1	1
Jarrah	*Eucalyptus marginata*	3/2	3/2
Karri	*Eucalyptus diversicolor*	3/2	4
Mahogany, red	*Eucalyptus resinifera*	2	2
Mahogany, southern	*Eucalyptus botryoides*	3/2	3/2
Mahogany, white	*Eucalyptus acmenoides*	1	1
Mallet, brown	*Eucalyptus astringens*	2/1	2
Marri	*Corymbia calophylla syn Eucalyptus calophylla*	4/3	4/3
Messmate	*Eucalyptus obliqua*	4	4
Messmate, Gympie	*Eucalyptus cloeziana*	1	1
Peppermint, black	*Eucalyptus amygdalina*	4	4
Peppermint, broad-leaved	*Eucalyptus dives*	3	3
Peppermint, narrow-leaved	*Eucalyptus radiata*	4	4
Peppermint, river	*Eucalyptus elata*	4	4
Stringybark, brown	*Eucalyptus capitellata*	3	4
Stringybark, red	*Eucalyptus macrorhyncha*	2	2
Stringybark, white	*Eucalyptus eugenioides*	3	3
Stringybark, Wilkinson's	*Eucalyptus eugenioides* formerly *E. wilkinsoniana*	4/3	4/3
Stringybark, yellow	*Eucalyptus muelleriana*	3	4
Tallowwood	*Eucalyptus microcorys*	1	1
Tingle, red	*Eucalyptus jacksonii*	4/3	4
Tingle, yellow	*Eucalyptus guilfoylei*	2	3
Tuart	*Eucalyptus gomphocephala*	1	3
Wandoo	*Eucalyptus wandoo*	1	1
Woollybutt	*Eucalyptus longifolia*	1	2
Yate	*Eucalyptus cornuta*	2/1	3
Yertchuk	*Eucalyptus consideniana*	2	3
Non-eucalypt species (hardwood)			
Beech, myrtle	*Nothofagus cunninghamii*	4	4
Bollywood	*Litsea reticulata*	4	4
Box, brush	*Lophostemon confertus*	4	4

Non-eucalypt species (hardwood) cont.			
Box, swamp	*Lophostemon suaveolens*	2	2
Brigalow	*Acacia harpophylla*	1	2
Jam, raspberry	*Acacia acuminata*	1	1
Kwila	*Intsia bijuga*	3/2	3/2
Mersawa	*Anisoptera thyrifera* ssp. *polyandra*	4/3	4
Oak, bull	*Allocasuarina luehmannii*	1	2
Oak, white, American	*Quercus alba*	4	4
Rosewood, New Guinea	*Pterocarpus indicus*	3	3
Satinay	*Syncarpia hillii*	3/2	3/2
Teak (Burmese)	*Tectona grandis*	2	2
Turpentine	*Syncarpia glomulifera*	2	2
Softwood species			
Cedar, red, western	*Thuja plicata*	3	3
Fir, Douglas	*Pseudotsuga menziesii*	4	4
Pine, black	*Prumnopitys amara*	4	4
Pine, celery-top	*Phyllocladus asplenifolius*	4/3	4/3
Pine, cypress, white	*Callitris glaucophylla*	2	2
Pine, Huon	*Lagarostrobos franklinii*	3	4
Pine, kauri	*Agathis robusta*	4	4
Pine, King William	*Athrotaxis selaginoides*	3	3
Pine, radiata	*Pinus radiata*	4	4
Redwood	*Sequoia sempervirens*	3	3

Key

Class	**Class name**	**Expected average life (median, in years)**	
		Southern Australia*	**Northern Australia**
1	highly durable	≥ 21	≥ 14
2	durable	12–24.5	5–14
3	moderately durable	8.5–15	2–7
4	non-durable (perishable)	1–9	1–3

*South of about 30° latitude

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