CHAPTER 4
Bedbugs, fleas, lice, ticks and mites

Ectoparasites that live on the body, in clothing and in beds

There are many different species of bloodsucking fleas, lice, ticks and mites. Lice live on humans or in their clothing, while fleas are frequently found taking blood-meals on people and domestic animals. Bedbugs, which can be found in beds or furniture, feed on humans to obtain blood-meals. Some mites live in people's skin, e.g. the mites that cause scabies. Other mite species and ticks may take blood-meals on humans. Fleas, bedbugs and lice are insects, whereas ticks and mites belong to another group of arthropods, the Acarina. Unlike adult insects they have only two main sections to their body, and the adults have four pairs of legs (as opposed to three pairs in insects).

Bedbugs, head lice and crab lice do not carry disease, but their biting can be a serious nuisance. However, important diseases of humans and animals are transmitted by other arthropods dealt with here, among them the following:

— epidemic typhus and epidemic relapsing fever (body lice);
— plague and murine typhus (certain fleas);
— Lyme disease, relapsing fever and many viral diseases (ticks);
— scrub typhus (biting mites).

BEDBUGS

Two species of bedbug feed on humans: the common bedbug (*Cimex lectularius*), which occurs in most parts of the world, and the tropical bedbug (*Cimex hemipterus*), which occurs mainly in tropical countries. They are a severe nuisance when they occur in large densities, being commonest in places with poor housing conditions. They are not important in the transmission of diseases, although they possibly play a role as vectors of hepatitis B virus.

Biology

Bedbugs have a flat, oval-shaped body with no wings, and are 4–7 mm long. Their colour is shiny reddish-brown but after a blood-meal they become swollen and dark brown in colour. There are three stages in the bedbug's life cycle: egg, nymph and adult (Fig. 4.1). The eggs are white and about 1 mm long. The nymphs look like adults but are smaller. Complete development from egg to adult takes from six weeks to several months, depending on temperature and the availability of food. Both male and female bedbugs feed on the blood of sleeping persons at night. In the absence of humans they feed on mice, rats, chickens and other animals. Feeding takes about 10–15 minutes for adults, less for nymphs, and is repeated about every three days. By day they hide in dark, dry places in beds, mattresses, cracks in walls and floors, and furniture; they are also found behind pictures and wallpaper; hiding places are also used for breeding. The bugs are frequently

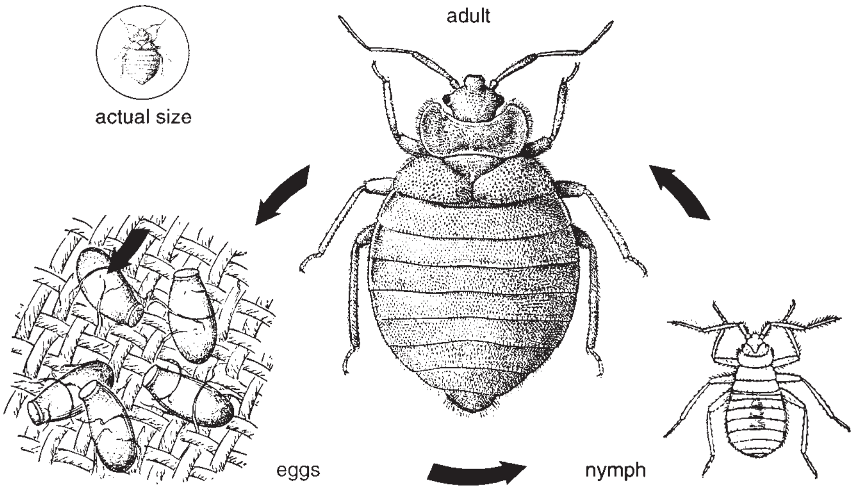

Fig. 4.1
Life cycle of the bedbug (by courtesy of the Natural History Museum, London).

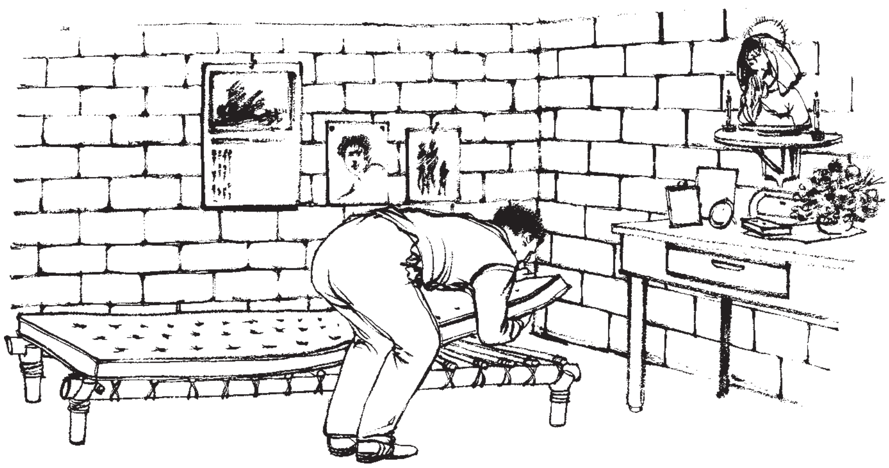

Fig. 4.2
Bedbugs are almost always found in bedrooms.

abundant in bedrooms in warm climates. Heated bedrooms in cooler climates are also favourable for the bugs, which cannot develop below 13 °C (Fig. 4.2). Adults can survive for several years without food.

Dispersal

Because they have no wings, bedbugs travel only short distances. In poorly built houses with many suitable hiding places they crawl from one bedroom to another; they spread from one house to another mainly in second-hand furniture, bedding and, sometimes, clothes.

Public health importance

Bedbugs are not considered vectors of disease. It has been suggested that they play a role as vectors of the hepatitis B virus (*1*, *2*) but this was denied in a recent study in the Gambia (*3*). They are mainly important as a biting nuisance. Some people, especially those exposed for a long time, show little or no reaction to the bites, which appear as small red spots that may not even itch. People never bitten before may suffer from local inflammation, intense itching and sleepless nights. The bite produces a hard whitish swelling that often continues to bleed. Scratching may cause secondary infections.

In heavily infested houses where people may receive one hundred or more bites a night it is possible that the blood loss causes mild anaemia in infants.

Control measures

Bedbugs can move rapidly when disturbed and are not easily detected while biting. Some people may not even be aware that they are bitten each night by large numbers of bedbugs. Control measures are therefore carried out only if there is evidence of the presence of the insects.

Detection

Infestations can be detected by the examination of possible hiding places for the presence of live bugs, cast-off nymphal skins, eggs and excreta. The excreta may also be visible as small dark brown or black marks on bed sheets, walls and wallpaper (*4*). Houses with large numbers of bedbugs may have a characteristic unpleasant smell. Live bugs can be detected by spraying an aerosol of pyrethrum into cracks and crevices, thus irritating them and driving them out of their hiding places.

Repellents

Deet and other insect repellents are effective against bedbugs. They can be used by travellers who have to sleep in houses infested with the insects. However, repellents applied to the skin are unlikely to last the whole night. It is likely that burning mosquito coils offer some protection (see Chapter 1).

Simple household measures

Small numbers of bedbugs can occur in any household, especially when second-hand furniture or bedding is used. Light infestations can be treated by thoroughly cleaning infested articles, pouring boiling water over them and exposing them to sunlight. Aerosol spray cans can be used to spray household insecticides on to mattresses, in crevices in walls, and in other possible hiding places. Among the effective insecticides are the pyrethroids, propoxur, bendiocarb and dichlorvos. The procedure should be repeated if bugs are still found after a few weeks.

Total release fogger

This device is similar to the aerosol spray can but is designed to release the total contents of the can in a single shot through a special valve. The fog contains rather large droplets that do not penetrate well into crevices. Cans containing an insecticide–kerosene mixture should not be used for fogging because of the risk of explosion.

Impregnated mosquito nets

Mosquito nets impregnated with a long-lasting pyrethroid insecticide are effective in repelling and killing bedbugs (Fig. 4.3) (*5*, *6*). Such nets are increasingly popular for the control of malaria mosquitos. A commonly reported incidental benefit of the use of these nets is the complete disappearance of bedbug and head louse infestations, which makes the nets highly popular among people in bedbug-infested areas.

Smoke generators

Smoke generators, which are commercially available and usually contain pyrethroid insecticides, can be used to fumigate the interior of houses. They burn for 3–15 minutes and can be used only once. A smoke of very small droplets of insecticide is produced which can penetrate into cracks and crevices to kill bedbugs, fleas, flies, mosquitos and tropical rat mites. Smoke generators do not always work well, as the insecticide may settle on horizontal surfaces without penetrating into deep crevices. They have a brief effect and do not prevent reinvasion from neighbouring, untreated dwellings. They are mainly used where quick action is needed. A fumigant canister developed in South America against the triatomine bugs is described in Chapter 3, together with general instructions on how to

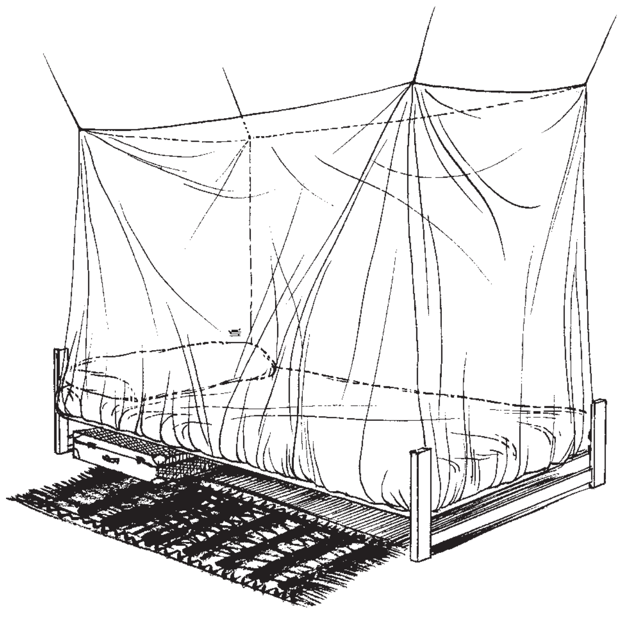

Fig. 4.3
The use of mosquito nets impregnated with a pyrethroid insecticide may result in the reduction or even eradication of bedbug and head louse infestations.

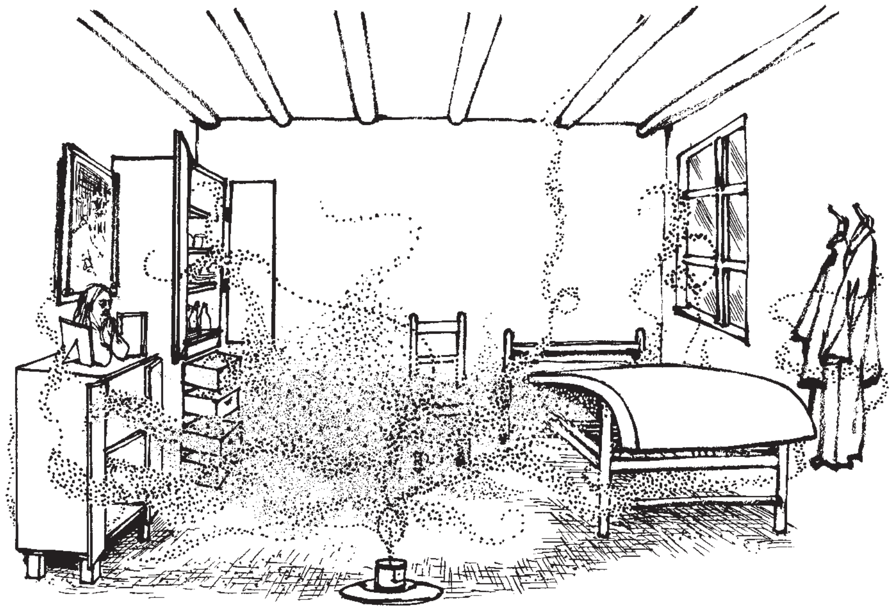

Fig. 4.4
The fumigant canister releases insecticide vapour for up to 15 minutes.

fumigate a house (Fig. 4.4). It contains an irritant insecticide that drives the bugs out of hiding.

Residual insecticides

Houses with heavy infestations need to be treated with long-lasting residual insecticide. One treatment is normally sufficient to eliminate bedbugs but, if an infestation persists, re-treatments should be carried out at intervals of not less than two weeks. In many countries, resistance of bedbugs to DDT, lindane and dieldrin is common. The insecticide selected should thus be one known to be effective against the target population (see Table 4.1). The addition of an irritant insecticide, e.g. 0.1–0.2% pyrethrin, helps to drive the bugs out of their hiding places, thus increasing exposure to the residual insecticide. Most pyrethroids are effective flushing and killing agents.

A residual spray is applied with a hand-operated compression sprayer (see Chapter 9). Special attention should be given to mattresses, furniture, and cracks and crevices in walls and floors (Fig. 4.5). In severe infestations, walls and floors should be sprayed until they are visibly wet (point of run-off). Usually this corresponds to 1 litre per 50 m^2 on non-absorbent surfaces and to 5 litres or more per 50 m^2 on absorbent surfaces such as those of mud-brick walls. Rooms in humid tropical countries must be treated in the morning so that they are dry and suitable for re-entry in the evening. Mattresses and bedding should be treated carefully to avoid staining and soaking, and should be thoroughly aired and dried before use. Hand dusters containing insecticide powder may be used to dust mattresses and bedding, to avoid wetting them. Bedding used for infants should not be treated with residual insecticide, but with a short-lasting insecticide such as may be found in most aerosol spray cans.

Table 4.1
Residual insecticides for use against bedbugs

Insecticide	Concentration in spray (%)
malathion	2.0
fenitrothion	0.5–1.0
propoxur	2.0
carbaryl	1.0
diazinon	0.5
bendiocarb	0.2–0.3
fenchlorvos	1.0
pirimiphos methyl	1.0
propetamphos	0.5–1.0
permethrin	0.5
cyfluthrin	0.01
deltamethrin	0.005
lambdacyhalothrin	0.005

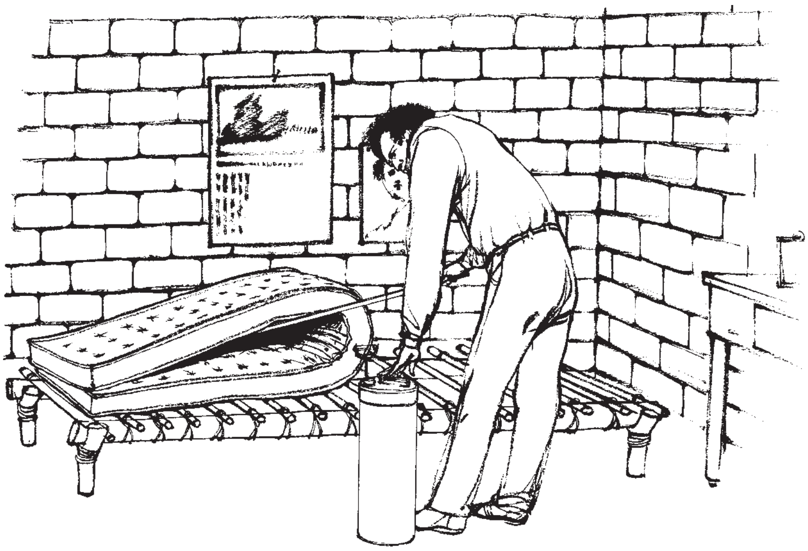

Fig. 4.5
Spray residual insecticide on to mattresses, cracks in walls, floors and other hiding places with a compression sprayer.

Bedbugs and malaria control

House spraying against malaria was very popular in many tropical countries, partly because it killed bedbugs. Unfortunately, the bugs quickly developed resistance to the insecticides, resulting in numerous complaints that spraying no longer controlled bedbugs, even though it still killed mosquitos.

Another possible explanation for the increase in the numbers of bedbugs observed is that the insecticide spray irritated the bugs, causing them to leave their hiding places. Seeing many more bedbugs than before, people believed that spraying caused an increase in the bug population (*7*, *8*).

As a result, many householders refused malaria spraying teams access to their homes. It is possible that in some areas the occurrence of bedbugs contributed indirectly to the ineffectiveness of malaria control programmes.

FLEAS

Fleas are small, wingless bloodsucking insects (order Siphonaptera) with a characteristic jumping movement. They feed mainly on mammals but also on birds. Of the 3000 species only a dozen commonly attack humans. The most important species are the rat flea, the human flea and the cat flea (Fig. 4.6). Their bites can cause irritation, serious discomfort and loss of blood. The rat flea is important as a vector of bubonic plague and flea-borne typhus. Cat fleas incidentally transmit tapeworms. The sand flea or jigger burrows into the skin of humans and may cause infections. Fleas that bite people occur in most parts of the world.

Biology

The life cycle of fleas has four stages: egg, larva, pupa and adult (Fig. 4.7). Adult fleas are 1–4 mm long and have a flat narrow body. They are wingless with well developed legs adapted for jumping. They vary in colour from light to dark brown. The larvae are 4–10 mm long and white; they have no legs but are very mobile. The cocoon (pupal stage) is well camouflaged because it is sticky and soon becomes covered with dust, sand and other fine particles.

Both female and male fleas take blood-meals. Fleas breed close to the resting and sleeping places of the host, in dust, dirt, rubbish, cracks in floors or walls, carpets, animal burrows and birds' nests. High humidity is required for development. The larvae feed on organic matter such as the faeces of the host, small dead

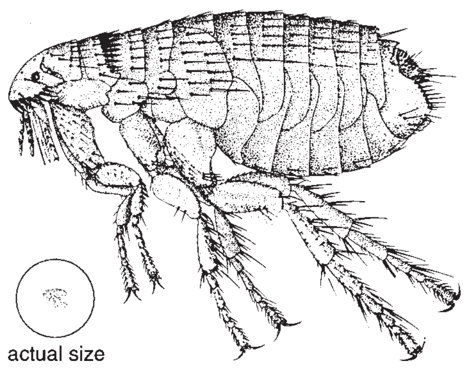

Fig. 4.6
A cat flea (*Ctenocephalides felis felis*) (by courtesy of the Natural History Museum, London).

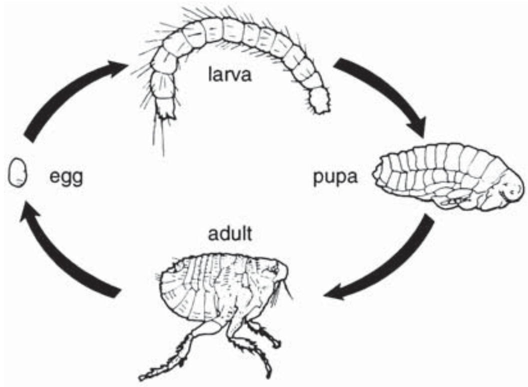

Fig. 4.7
The life cycle of the flea (by courtesy of the Natural History Museum, London).

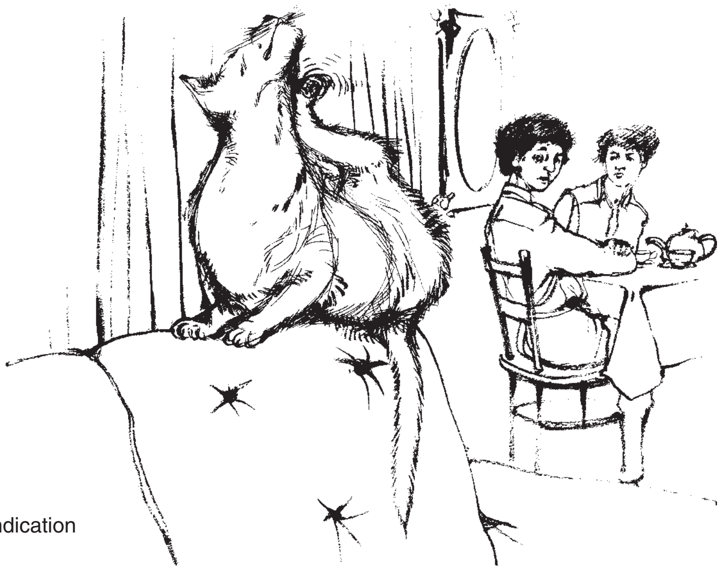

Fig. 4.8
A scratching cat is an indication of a flea infestation.

insects and undigested blood expelled by adult fleas. At the end of the larval period the larva spins a loose whitish cocoon within which it develops into a pupa.

The adult fleas are fully developed within 1–2 weeks but only emerge from the cocoons after receiving a stimulus, such as the vibrations caused by movement of the host. In vacant houses they may survive in the cocoons for up to a year. People moving into a vacant house can cause many fleas to emerge simultaneously from the cocoons and attack people or animals in large numbers. Under optimal conditions the development from egg to adult takes 2–3 weeks.

Behaviour

Fleas avoid light and are mostly found among the hairs (Fig. 4.8) or feathers of animals or in beds and in people's clothing. If possible, a flea will feed several times during the day or night. Heavy infestations with fleas are recognized by marks on clothing and bedding of undigested blood ejected by the fleas. Most flea species feed on one or two host species, but in the absence of their normal host they feed on humans or other animals. Adult fleas can survive several months without food. Fleas move around by jumping; some species can jump as high as 30 cm.

Public health importance

Nuisance

Humans are most commonly bitten by the cat flea, *Ctenocephalides felis* and, less commonly, the dog flea, *C. canis*. The so-called human flea (*Pulex irritans*) is, in spite of its name, less important. Fleas jump up from the ground and most frequently attack people on the ankles and legs, the easiest parts to reach, although sleeping people can be attacked anywhere on the body. Flea bites cause irritation and sometimes extreme discomfort. Heavy infestations may cause allergic reactions and dermatitis.

Plague

Plague is a disease caused by the bacterium *Yersinia pestis*. It occurs primarily in wild animals, such as rats and other rodents. Plague bacteria are transmitted by fleas, and humans may be infected by fleas that have fed on infected animals. In the past, plague was called the black death and caused disastrous epidemics.

Plague is still dangerous because it occurs widely in rodent populations. Rural or sylvatic plague may be contracted in the western USA, South America, Africa, the former USSR, parts of the eastern Mediterranean area, and central and south-east Asia. Human plague frequently occurs in several countries in Africa, Bolivia/north-eastern Brazil, Ecuador, Myanmar, Peru and Viet Nam (*9*).

Rural plague is acquired by people entering rural areas and handling wild animals. Most at risk are hunters who may be bitten by infected fleas while handling recently killed animals.

Urban plague may occur when rats living in and around human dwellings are infected. Rat fleas (*Xenopsylla* species) that normally feed on rats may occasionally feed on humans and thus spread the disease to them. When rodents infected with plague die the fleas leave their hosts and are then likely to attack and infect people. Other fleas, such as the human flea, may subsequently transmit the disease from person to person.

There are three clinical types of plague:

- *Bubonic plague*. Swellings (buboes) filled with bacteria develop in the lymph nodes, especially in the armpits and groin. This form is normally transmitted to humans by infected fleas. If left untreated, it causes death in about 50% of cases.
- *Pneumonic plague*. This is a secondary form in which the lungs become affected. It is highly contagious, the plague bacillus easily spreading from person to person in sputum or droplets coughed up or sneezed by sick people. Pneumonic plague occurred in epidemics in past centuries, killing millions of people. If left untreated it very often results in death.

- *Septicaemic plague*. The bloodstream is invaded by the plague bacillus, resulting in death before one of the above two forms can develop.

Prevention and control

Partial immunity is acquired after an infection. A vaccine is available which provides protection for a period of only a few months. Treatment with streptomycin, tetracycline or its derivatives or chloramphenicol is highly effective if used within a day after the onset of symptoms.

Urban plague is controlled by rapidly applying insecticide dusts in rodent burrows and on to rodent runways where it will be taken up by the animals on their fur, thus killing the vector fleas. Dusting against fleas should be followed by measures to control rodents.

People working in the field may protect themselves by dusting their clothing with insecticidal powder, using impregnated clothing, and using repellents on a daily basis.

Flea-borne typhus

Flea-borne typhus, also called murine typhus fever, is caused by *Rickettsia typhi* and occurs sporadically in populations of rats and mice. It is transmitted mainly by rat fleas and cat fleas, and humans can become infected as a result of contamination from the dried faeces and crushed bodies of the fleas. The disease occurs worldwide and is found in areas where people and rats live in the same building. Its symptoms are similar to those of louse-borne typhus (see p. 257) but milder.

Prevention and control

Immunity is acquired after the first infection. The treatment of sick people is similar to that for louse-borne typhus (see p. 257). Control is carried out by applying residual insecticides to the runs, burrows and hiding places of rats. If these measures are successful in killing fleas, rodent control measures can be taken (see p. 250, box).

Other diseases

Fleas occasionally transmit other diseases and parasites from animals to humans, for instance tularaemia caused by the bacillus *Francisella tularensis*, and the parasitic tapeworms that occur in dogs and cats. Children playing with domestic pets may become infected by swallowing fleas that carry the infective stage of the worms.

Control measures

The recommended control methods depend on whether the intention is to deal with fleas as a biting nuisance or as vectors of disease.

Fleas as a nuisance

Individual self-protection

An effective repellent, such as deet, applied to skin and clothing, prevents fleas from attacking. A disadvantage is that repellents applied to the skin last only a few hours (see Chapter 1). Longer-lasting protection is obtained by dusting clothing with insecticide powder (see p. 262) or by using insecticide-impregnated clothing (see Chapter 1).

Simple hygienic measures

Fleas and their eggs, larvae and cocoons can be effectively removed by keeping houses well swept and floors washed. Removal with a vacuum cleaner is also effective. When people enter an infested house that has been vacant for some time, large numbers of newly emerged fleas may attack. The treatment of floors with detergents, insecticides or a solution of naphthalene in benzene is recommended; care should be taken to avoid inhaling benzene fumes.

Application of insecticides

Heavy infestations can be controlled by spraying or dusting insecticides into cracks and crevices, corners of rooms and areas where fleas and their larvae are likely to occur. Insecticides can also be applied to clothing and the fur of animals. Fumigant canisters that produce aerosols of quick-acting insecticides (e.g. the pyrethroids, propoxur and bendiocarb) kill fleas directly and are convenient to use (see p. 240 and Chapter 3). However, the insecticidal effect is brief and reinfestations may appear quickly.

Cat and dog fleas

Fleas can be detected in the hair around the neck or on the belly of cats and dogs. Treatment involves applying insecticidal dusts, sprays, dips or shampoos to the fur. Dusts are safer to use than sprays because the insecticides are less likely to be absorbed through the skin in the dry form. Dusts also produce less odour and do not affect the skin as much as sprays. Carbaryl and malathion should not be used on kittens and puppies under four weeks of age. Pets can be provided with plastic flea collars impregnated with an insecticide. Flea collars are effective for 3–5 months, whereas other treatments give only short-term control.

Recently, lufenuron tablets have been used to control fleas in cats and dogs. The tablets are administered once monthly at a dose of 30 mg per kg of body weight to cats and 10 mg per kg of body weight to dogs and are safe for use in pregnant and nursing animals. Lufenuron is taken up by the female flea during feeding and acts by inhibiting egg development (*10*).

Dusts must be rubbed thoroughly into the hair and can be applied by means of a shaker (Fig. 4.9). They must not be allowed to get into the eyes, nostrils and mouths of animals. Heavy applications should not be made to the abdomen as the material will be licked off. Application should begin above the eyes and all the areas backward to the tail and haunches should be covered, ensuring thorough treatment around the ears and underneath the forelegs. A small animal can be

Fig. 4.9
Dusting a dog with insecticide powder to control fleas.

treated with one tablespoonful of dust, while 30 g may be required for a large dog. Sprays must wet the hair completely and can be applied with a hand-compression sprayer. It is also possible to spray with an insecticide aerosol from a pressurized spray can.

Re-treatment may be necessary if reinfestation occurs. Important sources of reinfestation are the places where animals or humans sleep or spend much time, such as beds, bedding and kennels. Where possible, animal bedding should be burned or laundered in hot soapy water. A vacuum cleaner may be used to remove accumulations of dust that contain flea larvae and pupae, and infested premises can then be treated with a residual insecticide. Treatment with insecticidal powders or solutions is possible (*11*). Because flea cocoons are much less susceptible to insecticides than the larvae and adults, treatments should be repeated every two weeks over a period of six weeks to ensure that all emerging fleas are killed (*12*).

Human flea

This flea species does not usually remain on the person after feeding and by day it rests in cracks, crevices, carpets and bedding. Regular cleaning of houses, and of bedrooms in particular, should prevent large infestations.

More effective control is achieved by dusting or spraying insecticides on to mattresses and cracks and crevices in floors and beds. Bedding left untreated should be washed and cleaned during insecticide application. Fleas in many parts of the world have developed resistance to DDT, lindane and dieldrin (*13–15*). Suitable insecticides for spraying or dusting are indicated in Table 4.2.

Table 4.2
Insecticides and application methods effective against fleas

Type of application	Pesticide and formulation
Residual spray	malathion (2%), diazinon (0.5%), propoxur (1.0%), dichlorvos (0.5–1.0%), fenchlorvos (2%), bendiocarb (0.24%), natural pyrethrins (0.2%), permethrin (0.125%), deltamethrin (0.025%), cyfluthrin (0.04%), pirimiphos methyl (1%)
Pesticide power (dust)	malathion (2–5%), carbaryl (2–5%), propoxur (1%), bendiocarb (1%), permethrin (0.5–1.0%), cyfluthrin (0.1%), deltamethrin (0.05%), temephos (2%), pirimiphos methyl (2%), diazinon (2%), fenthion (2%), fenitrothion (2%), jodfenphos (5%), (+)-phenothrin (0.3–0.4%)
Shampoo	propoxur (0.1%), (+)-phenothrin (0.4%)
Fumigant canister	propoxur, dichlorvos, cyfluthrin, permethrin, deltamethrin, (+)-phenothrin
Flea collar for dog or cat	dichlorvos (20%), propoxur (10%), propetamphos, diazinon
Repellent	diethyl-toluamide (deet), dimethyl phthalate, benzyl benzoate

Retreatment is probably not needed if all infested places in a house are treated or cleaned. Infants' bedding should not be treated but should be thoroughly washed.

Fleas that transmit diseases

Control measures during epidemics of plague or typhus must be effected in two stages:

(1) insecticidal dusting of rat habitats to kill rat fleas;
(2) rat control.

A control campaign with the sole aim of killing rodents could result in increased disease transmission to humans: the deaths of many rodents could cause large numbers of fleas to leave the dead hosts and seek alternative sources of blood.

Insecticidal powder

The most common and effective method of controlling rodent fleas has been to use DDT in a 10% dust formulation. Alternative insecticides in dust formulation are increasingly used (see Table 4.2) because of the resistance of fleas in many areas to DDT and also because of environmental concerns.

Dust is applied to burrows, runways and other sites where rodents are likely to pick it up. When the rodents groom themselves they spread the dust on their fur, thus killing the fleas.

Before control is begun, it is important to know where rodent burrows and runways are. To save insecticide, the burrows should first be closed off; only those

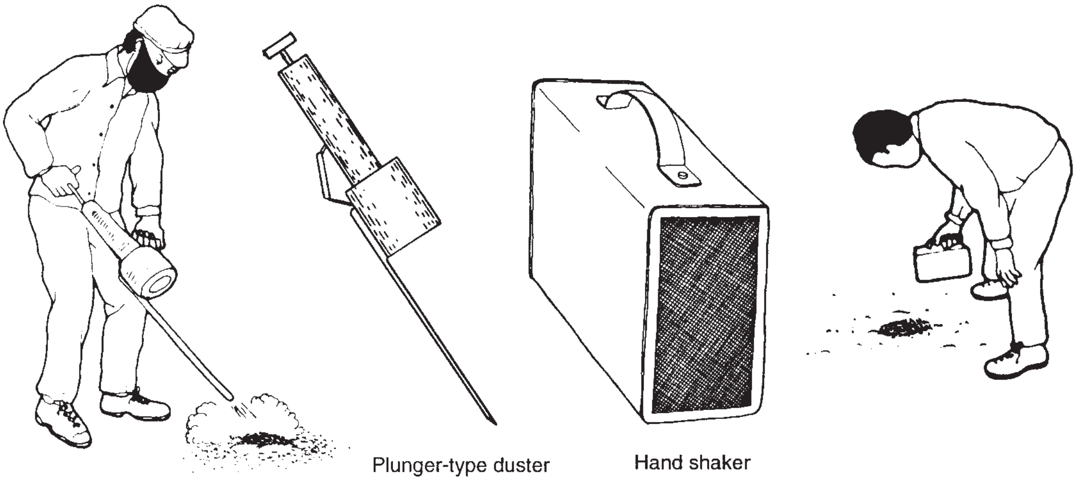

Fig. 4.10
Equipment for applying anti-flea dusts (© WHO).

that are subsequently reopened should be treated. Insecticidal dust should be blown into each burrow with a duster. A patch of dusting powder, 1 cm in depth, should be left around the opening. Patches of dust 15–30 cm wide should be placed along runways. Dust should be applied only where it will remain undisturbed by humans and the wind. Care must be taken not to apply insecticides to areas where they can contaminate food. Many insecticidal dusts remain effective for 2–4 months if used indoors in undisturbed places.

A plunger-type duster is suitable for fast applications of dust to rodent burrows and runways, in attics and spaces under buildings. It consists of an air pump like a bicycle pump to which a container for the dust is attached. The air from the pump is led into this container, agitating the contents and expelling them from an orifice (Fig. 4.10).

Alternatively, a hand shaker can easily be made from a can by fitting a 16-mesh screen at one end. A can with nail-holes punched in the top can also be used. Insecticidal dust of low toxicity can be applied to human clothing or the fur of animals with such equipment.

Integrated rat and flea control

To control urban outbreaks of plague or typhus, insecticides to kill rat fleas are applied at the same time as or a few days earlier than rat poisons. Suitable rat poisons are warfarin, coumafuryl, difenacoum, brodifacoum, coumatetralyl, bromadialone, chlorophacinone and zinc phosphide (*16*, *17*).

In places where food for human consumption is stored and in crowded areas, such as markets, it is safer to use bait boxes (Fig. 4.11) in which the rodents contaminate themselves with the anti-flea dust before they die from eating the toxic bait. Bait boxes can be placed along rodent runs at intervals of 60 metres. A suitable bait consists of 100 g of rolled oats mixed with rat poison.

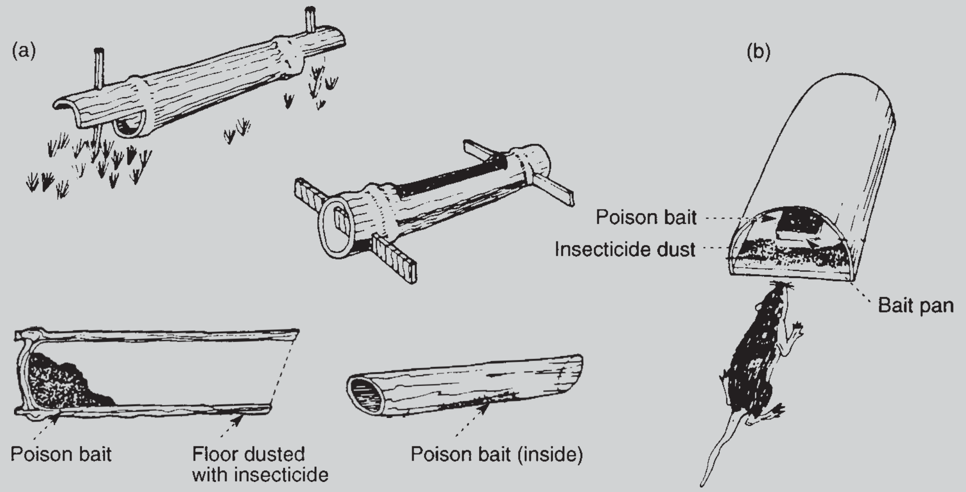

Fig. 4.11
Models of bait boxes. (a) Boxes made of bamboo. (b) A bait box made of floorboard (30 × 20 cm) covered by a metal roof (© WHO).

Sand fleas or jigger fleas

The sand flea, chigoe or jigger flea (*Tunga penetrans*) is not known to transmit disease to humans but, unique among the fleas, it is a nuisance because the females burrow into the skin. Sand fleas occur in the tropics and subtropics in Central and South America, the West Indies and Africa.

Biology

The larvae of sand fleas are free-living and develop in dusty or sandy soil. The adults are initially also free-living but, after copulation, the fertilized females attach themselves under the skin of humans, pigs, dogs, poultry and other animals, penetrating soft areas of skin, for instance cracks in the soles of the feet, between the toes, and under the toenails. Other parts of the body may also be affected.

Public health importance

Usually a person is infested by only one or two jiggers at a time but infestation with hundreds is possible. People who do not wear shoes, such as children, are most commonly affected. The flea burrows entirely into the skin with the exception of the tip of the abdomen. It feeds on body fluids and swells up to the size and shape of a small pea in 8–12 days (Fig. 4.12). The body of the female flea is completely filled with thousands of eggs which are expelled in the next weeks (Fig. 4.13). Most of the eggs fall to the ground where they hatch after a few days.

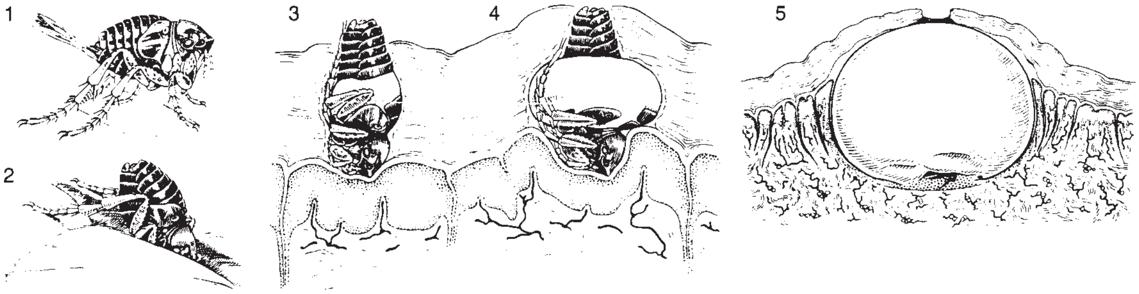

Fig. 4.12
The female sand flea attacks bare-footed persons by burrowing into soft skin on the feet (*18*).

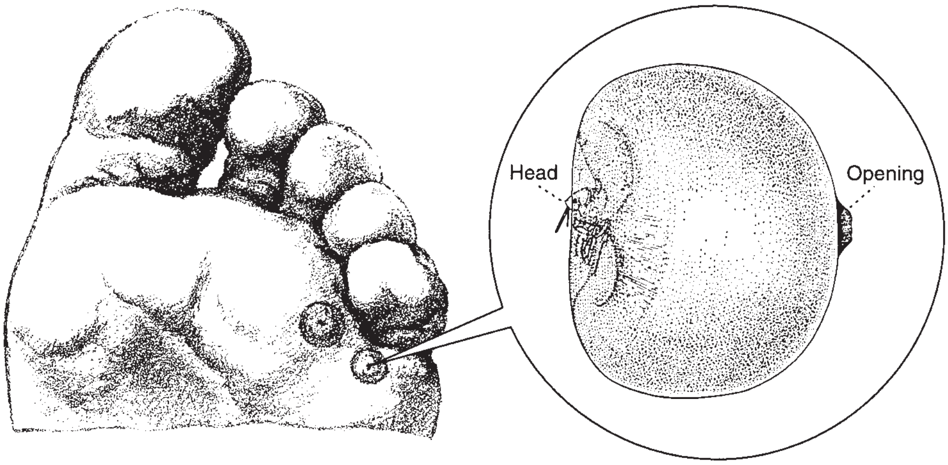

Fig. 4.13
Detail of foot with jigger infections. Eggs are expelled through the dark opening in the centre (by courtesy of the Natural History Museum, London).

Symptoms

An infestation begins to irritate and itch when the female is almost fully developed. Sometimes it causes severe inflammation and ulceration. If the female flea dies in the skin it may cause a secondary infection which, if ignored, could lead to tetanus, gangrene and even the loss of a toe.

Natural extrusion of the egg sac or removal of the jigger with a dirty pin or needle leaves a tiny pit in the skin which may develop into a sore. The sore may extend and develop into a septic ulcer. An infection under a toenail may cause pus to form.

Prevention, control and treatment

Jigger populations often maintain themselves in the domestic environment by breeding on livestock and domestic animals. Efforts should be made to remove the jiggers from these animals. Infections in dogs can be controlled by the administration of ivermectin (0.2 mg/kg of body weight) or by bathing the feet with dichlorvos

(0.2%) (*19*). The former treatment may kill other parasites, such as *Dermatobia* larvae, which causè skin infections. In infested areas, people should inspect their feet daily for freshly burrowing jiggers, which are visible as minute black spots and cause an itchy sensation.

Wearing shoes prevents attacks. The fleas may also be deterred by a repellent applied to the skin, although walking bare-footed in dirt quickly removes it. If it is possible to locate the area of soil where the jiggers originate it could be burnt off or sprayed with a suitable insecticide in an effort to kill the fleas.

Treatment

With some skill it is possible to remove the jigger with forceps or with a sharp object, such as a needle, a thorn or the tip of a knife (Fig. 4.14). The object and the site of infection should be cleaned, if possible with alcohol, to reduce the risk of infection. Removal can be done in a painless way but care should be taken not to rupture the egg sac. Infection may result if eggs or parts of the flea's body are left in the wound. After removal, the wound should be dressed antiseptically (with alcohol or iodine) and protected until healed.

LICE

Lice are small bloodsucking insects that live on the skin of mammals and birds. Three species of lice have adapted themselves to humans: the head louse (*Pediculus humanus capitis*), the body louse (*Pediculus humanus*) and the crab or pubic louse (*Pthirus pubis*) (Fig. 4.15). All three species occur worldwide. Lice infestations can cause severe irritation and itching. In addition the body louse can transmit typhus

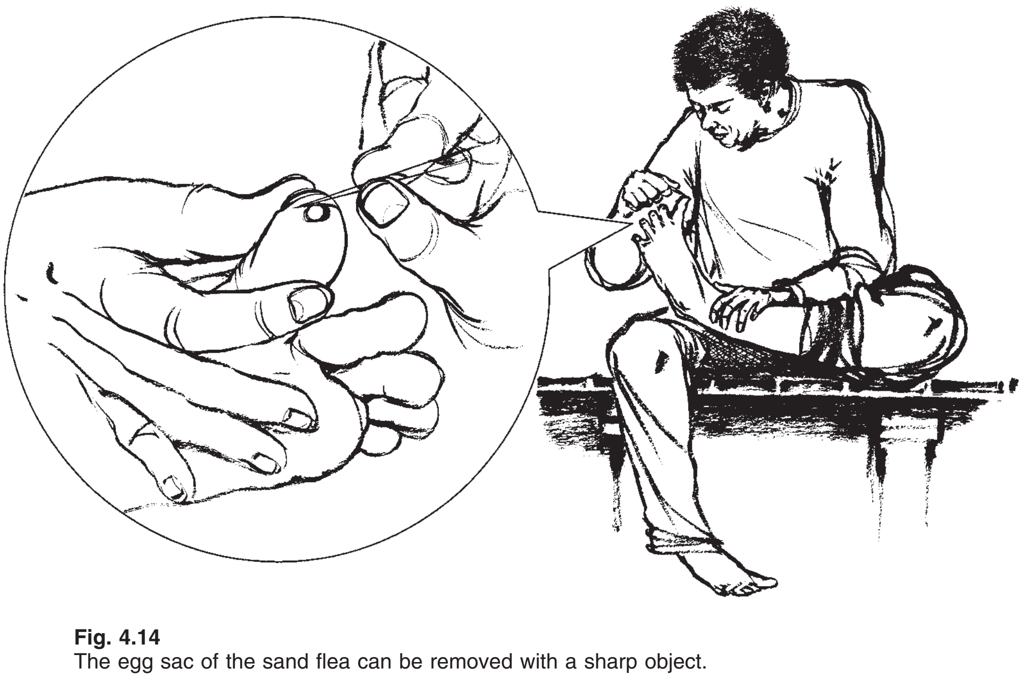

Fig. 4.14
The egg sac of the sand flea can be removed with a sharp object.

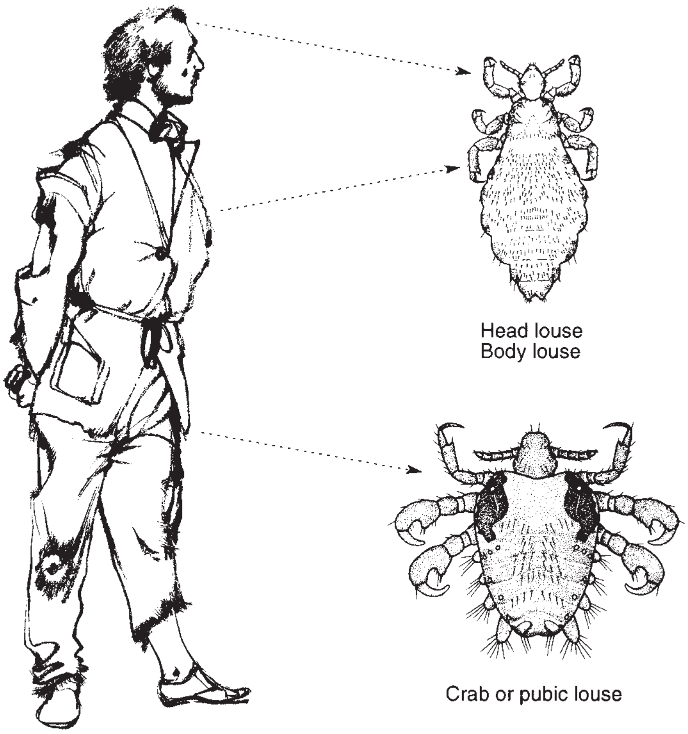

Fig. 4.15
Human sucking lice are flat wingless insects with legs adapted for grasping hairs (infested man © L. Robertson; Lice © WHO).

fever, relapsing fever and trench fever. Outbreaks of louse-borne typhus fever, sometimes claiming thousands of lives, have occurred in colder areas where people live in poor, crowded conditions, especially in some highland areas of Africa, Asia and Latin America.

Biology

The three species live only on humans (not normally on animals) and feed on human blood; the life cycle has three stages: egg, nymph and adult (Fig. 4.16). Development from egg to adult takes about two weeks. The white eggs (called nits) are glued to a hair or, in the case of the body louse, to fine threads on clothes. The nymphs are similar to the adults but much smaller. Fully grown lice are up to 4.5 mm long and feed by sucking blood. Feeding occurs several times a day. Lice can only develop in a warm environment close to human skin, and die within a few days if they lose contact with the human body. They are normally spread by contact, e.g. in overcrowded sleeping quarters and other crowded living conditions.

The three species of human lice are found on different parts of the body:

- the head louse occurs on the scalp and is most common in children on the back of the head and behind the ears;
- the pubic louse or crab louse is mainly found on hair in the pubic region but it may spread to other hairy areas of the body and, rarely, the head;
- the body louse occurs in clothing where it makes direct contact with the body; it is similar to the head louse but slightly bigger.

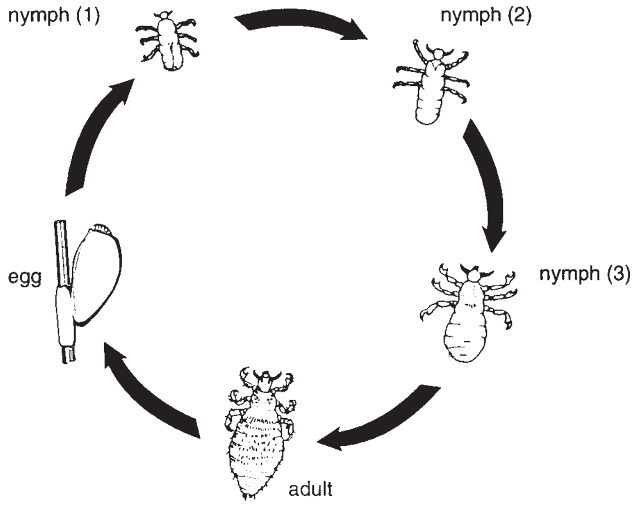

Fig. 4.16
Life cycle of the louse (© WHO).

Body lice

Body lice are most commonly found in clothing, especially where it is in direct contact with the body, as in underwear, the crotch or fork of trousers, armpits, waistline, collar and shoulders. They attach themselves to body hair only when feeding. The eggs are attached to thin threads of clothing. Body lice are most common in colder areas where people do not frequently wash or change clothes.

Body lice are spread by close contact between people. They are most commonly found, therefore, on people living in overcrowded, unhygienic conditions, as in poorly maintained jails, refugee camps and in trenches during war. They also spread by direct contact between people in crowded transport vehicles and markets. Body louse infestations may also be acquired through sharing bedding, towels and clothing or by sitting on infested seats, chair covers or cushions.

Head lice

The head louse is the most common louse species in humans. It lives only in the hair on the head and is most often found on children. The eggs (or nits) are firmly glued to the base of hairs of the head, especially on the back of the head and behind the ears (Figs. 4.17 and 4.18). Because the hairs grow about a centimetre a month it is possible to estimate the duration of an infestation by taking the distance between the scalp and the furthest egg on a hair. Infested persons usually harbour 10–20 adult head lice. The females lay 6–8 eggs per day. Head lice are spread by close contact between people, such as children at play or sleeping in the same bed. Head lice are also spread by the use of other people's combs that carry hairs with eggs or lice attached.

Crab or pubic lice

Crab lice, also called pubic lice, are greyish-white and crab-like in appearance. They are most often found on hair in the pubic region, and eggs are laid at the base

Fig. 4.17
Inspection of the hair for head lice. Girls tend to have heavier infestations than boys.

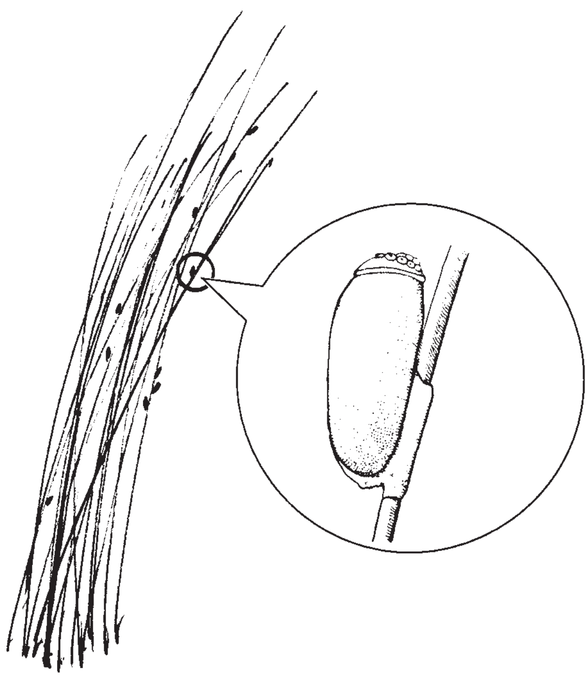

Fig. 4.18
Close-up of hair infested with lice and eggs (by courtesy of the Natural History Museum, London).

of the pubic hair. Heavy infestations may spread to other hairy areas of the body, such as the chest, thighs, armpits, eyelashes, eyebrows and beard. Crab lice are mainly spread through sexual or other close personal contact, and are most common in young, sexually active adults.

Public health importance

Only the body louse is a vector of human diseases. It transmits typhus fever, relapsing fever and trench fever.

Nuisance

Lice feed several times a day and heavy infestations can cause intense irritation and severe itching. Toxic reactions to the saliva injected into the skin may lead to weariness and a general feeling of illness.

Louse-borne typhus fever

This disease is caused by a microorganism, *Rickettsia prowazekii*, and is an acute, highly infectious disease with headache, chills, fever and general pains as symptoms. It may be fatal in 10–40% of untreated cases.

The disease has occurred on all continents except Australia. It is prevalent in cool areas where heavy clothing is worn and where the vector is most common. In the past the disease was most common during war and famine. Today, foci of transmission are found in mountainous regions of South America, in Central and East Africa and in the Himalayas.

Transmission

Body lice take the disease organisms up with the blood of an infected person and then expel it with their faeces. Since louse faeces dry to form a fine black powder they are easily blown about. The powder can infect small wounds, such as those caused by scratching, or the mucous membranes of the nose and mouth. Because the disease organism can remain alive for at least two months in dried louse faeces, it is dangerous to handle the clothing or bedding of patients with typhus.

Treatment

Effective treatment is possible with tetracycline, doxycycline or chloramphenicol.

Prevention and control

A vaccine has been prepared but is not yet commercially available. Infection can be prevented by controlling the body lice. Epidemic outbreaks are controlled by the application of a residual insecticide to the clothing of all persons in affected areas.

Louse-borne relapsing fever

This disease is caused by a microorganism, *Borrelia recurrentis*. Infected people suffer periods of fever lasting 2–9 days which alternate with periods of 2–4 days without fever. Usually, about 2–10% of untreated persons die but the mortality rate may be as high as 50% during epidemics. The disease occurs in limited areas of Africa, Asia and South America.

Transmission

Louse-borne relapsing fever occurs under similar conditions to those of typhus fever and the two diseases may appear together. Humans become infected by crushing infected body lice between the fingernails or the teeth. The disease organisms are thus released and can enter the body through abrasions, wounds or the mucous membranes of the mouth.

Treatment

Treatment is possible with tetracycline.

Prevention and control

Prevention and control are as described for typhus fever; no vaccine is available.

Trench fever

This bacterial disease, caused by *Rochalimaea quintana*, involves intermittent fever, aches and pains all over the body, and many relapses. Infection rarely results in death.

The disease can probably be found wherever the human body louse exists. Cases have been detected in Bolivia, Burundi, Ethiopia, Mexico, Poland, the former USSR and North Africa. Epidemics occurred during the First and Second World Wars among troops and prisoners living in crowded and dirty conditions, hence the name "trench fever".

Transmission

Transmission occurs through contact with infected louse faeces, as for typhus fever.

Treatment

Tetracycline, chloramphenicol and doxycycline are probably effective but, as the disease is rather mild, they have not been adequately tested.

Prevention and control

Prevention and control are as for typhus fever; no vaccine is available.

Control measures

The control methods used depend on the importance of the health problem. Individual or group treatment may be carried out where lice are merely a nuisance. Large-scale campaigns are recommended for the control of epidemic outbreaks of disease.

Head lice

Hygienic measures

Regular washing with soap and warm water and regular combing may reduce the numbers of nymphs and adults. However, washing will not remove the eggs, which are firmly attached to the hair. A special louse comb with very closely set fine teeth is effective in removing both adults and eggs (Fig. 4.19). Shaving the head is effective and this measure is sometimes adopted with young boys; however, it is often objected to and should not be insisted on.

Insecticides

Insecticide applications to the hair give the most effective control (*20–26*). They can be in the form of shampoos, lotions, emulsions or powders (Fig. 4.20; see also Table 4.3). Some pyrethroids are the most recommended products, since they do not cause the burning sensation of the scalp or other side-effects sometimes associated with other insecticides, such as lindane (*27*, *28*). Powder or dust formulations are usually less effective and less acceptable for use than lotions or emulsions. A soap formulation containing 1% permethrin can be applied as a shampoo (see box, p. 261).

How to make insecticidal dusts, shampoos and lotions

An insecticidal dust can be made by adding insecticide powder (wettable powder) to talcum powder to obtain the recommended dosage of active ingredient (in grams). An insecticidal shampoo is made similarly by adding insecticide powder or emulsifiable concentrate to hair shampoo with a neutral pH. An insecticidal lotion is made by mixing an emulsifiable concentrate with water or alcohol.

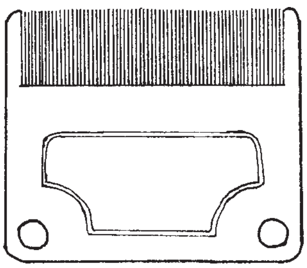

Fig. 4.19
A louse comb has very closely set fine teeth and is effective in removing head lice and their eggs.

Fig. 4.20
Hair can be treated with an anti-louse shampoo or lotion.

Table 4.3
Insecticides and formulations commonly used to control lice

Insecticide	Formulation and concentration (%)	
bioallethrin	lotion	0.3–0.4
	shampoo	0.3–0.4
	aerosol	0.6
carbaryl	dust	5.0
DDT	dust	10.0
	lotion	2.0
deltamethrin	lotion	0.03
	shampoo	0.03
jodfenphos	dust	5.0
lindane	dust	1.0
	lotion	1.0
malathion	dust	1.0
	lotion	0.5
permethrin	dust	0.5
	lotion	1.0
	shampoo	1.0
(+)-phenothrin	shampoo	0.2–0.4
	dust	0.3–0.4
propoxur	dust	1.0
temephos	dust	2.0

Insecticidal soap

The insecticidal soap bar is a recently developed inexpensive formulation of permethrin (1%) which is effective in killing head lice. It can also be used against the scabies mite (see p. 282).

How to use

The bar can be used as a shampoo. Apply to wet hair, work it into a lather and thoroughly massage into the scalp. Allow to remain on the head for 10 minutes, then rinse and dry the hair. Dead lice can be combed out over a towel. Repeat the procedure after three days. The hair will remain free of reinfestation for at least several weeks.

How to make

The bar, which is commercially available, can be produced locally for non-commercial purposes.

Ingredients	*%*
Crude raw coconut oil	57.0
Antioxidant	0.14
Permethrin	1.00
Mineral oil	8.86
Caustic soda solution	32.0
Natural clay	1.00

Premix the permethrin with the mineral oil at room temperature and add the mixture to the coconut oil in which the antioxidant has been dissolved. To this blend, add the caustic soda solution at ambient temperature, with rapid stirring. When all the caustic soda has been added, sprinkle the clay in and pour the emulsion into moulds, where the reaction continues for 12 hours.

The following day, cut the blocks into 40-g bars. If the bars are wrapped in polypropylene film and placed in an airtight box, the product will retain its effectiveness for more than two years. If they are packaged in a small plastic sandwich bag, or placed unwrapped in an airtight box, the shelf life is one year. If the product will be used up within a few weeks of manufacture, the lower-cost packaging is sufficient.

Impregnated mosquito nets

Head louse infestations disappear from people sleeping under mosquito nets impregnated with a long-lasting pyrethroid insecticide (*5*) (see Chapter 1 and p. 240).

Crab or pubic lice

Shaving the infested pubic hairs from the body has been replaced by the application of insecticidal formulations, as described for head louse control. In heavy infestations all hairy areas of the body below the neck should be treated.

Body lice

Individual treatment

Regular washing and changing of clothes usually prevents body louse infestations. In areas where water is scarce, washing facilities are lacking and people own only a single piece of clothing, this may be impractical. Another solution is to wash clothing and bedding with soap containing 7% DDT.

Soap and cold water are not sufficient to eliminate lice from clothing. Clothing must be washed in water hotter than 60 °C and should then be ironed if possible.

Group or mass treatment for disease control

The preferred method for mass treatment is the blowing of insecticidal powder between the body and underclothes. A suitable powder consists of talcum powder mixed with permethrin (0.5%), DDT (10%), lindane (1%) or another insecticide. Alternative insecticidal dusts, as shown in Table 4.3, can be used in the case of resistance. Because the dusts come into close contact with the body, it is important that the insecticides have a low toxicity to people and do not cause irritation.

An advantage of dusting powder is that it is easily transported and stored. Application can be made by any type of dusting apparatus, such as compressed-air dusters, plunger-type dusters and puff dusters (Fig. 4.21) (see p. 250), or by hand. It is important to explain the purpose of dusting to the people to be treated because the powder leaves clearly visible traces on clothing.

For individual treatment, about 30 g of powder can be applied evenly from a sifter-top container over the surfaces of clothing that are in close contact with the body. Special attention should be given to the seams of underwear and other garments. To treat large groups of people about 50 g of powder per person is needed. The powder is blown into the clothing through the neck openings, up the sleeves and from all sides of the loosened waist (Fig. 4.22). Socks, headwear and bedding should also be treated. One treatment should be sufficient but re-treatment may be needed at intervals of 8–10 days if infestations persist.

The impregnation of clothing with a pyrethroid emulsion may provide long-lasting protection (*29*), the insecticide possibly remaining effective after 6–8 launderings.

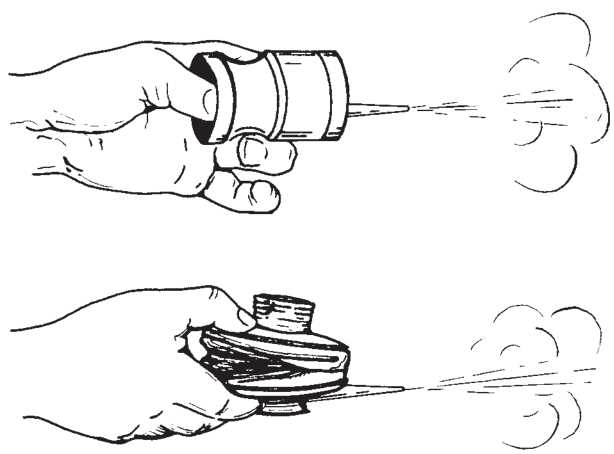

Fig. 4.21
Insecticidal dust can be applied to clothing with a hand-operated puff-duster (© WHO).

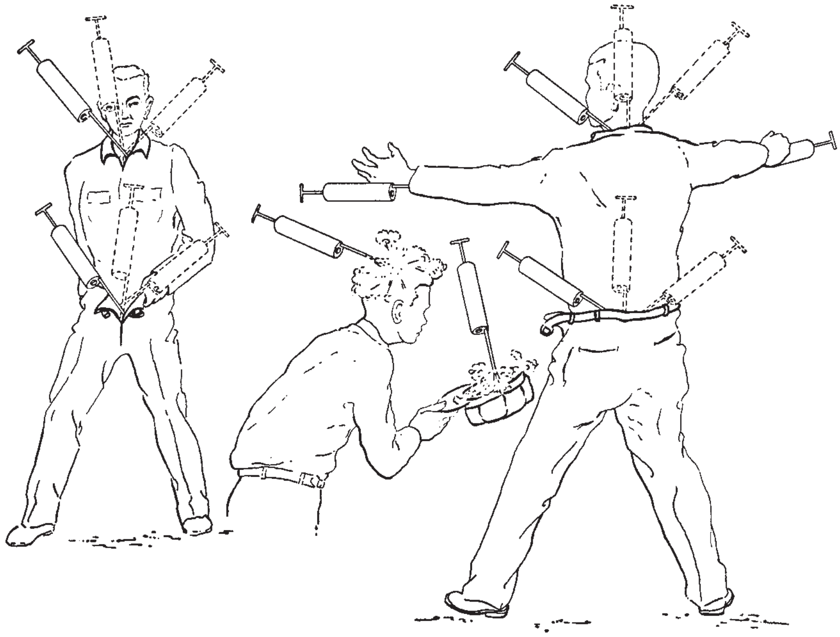

Fig. 4.22
Treating an individual with insecticidal dust using a plunger-type duster. (Reproduced from *Insect and rodent control*. Washington, DC, Departments of the Air Force, the Army and the Navy, 1956.)

TICKS

Ticks are arthropods that suck blood from animals and humans. They occur around the world and are important as vectors of a large number of diseases. Among the best-known human diseases transmitted by ticks are tick-borne relapsing fever, Rocky Mountain spotted fever, Q fever and Lyme disease. Ticks are also important as vectors of diseases of domestic animals and they can cause great economic loss. Two major families can be distinguished: the hard ticks (Ixodidae), comprising about 650 species, and the soft ticks (Argasidae), comprising about 150 species. Ticks are not insects and can easily be distinguished by the presence of four pairs of legs in the adults and the lack of clear segmentation of the body (Fig. 4.23).

Biology

Ticks have a life cycle that includes a six-legged larval stage and one or more eight-legged nymphal stages (Fig. 4.24). The immature stages resemble the adults and each of them needs a blood-meal before it can proceed to the next stage. Adult ticks live for several years, and in the absence of a blood-meal can survive several years of starvation. Both sexes feed on blood, the males less frequently than the females, and both can be vectors of disease. Disease organisms are not only passed from one host to another while blood is being taken: female ticks can also pass on certain disease agents to their offspring.

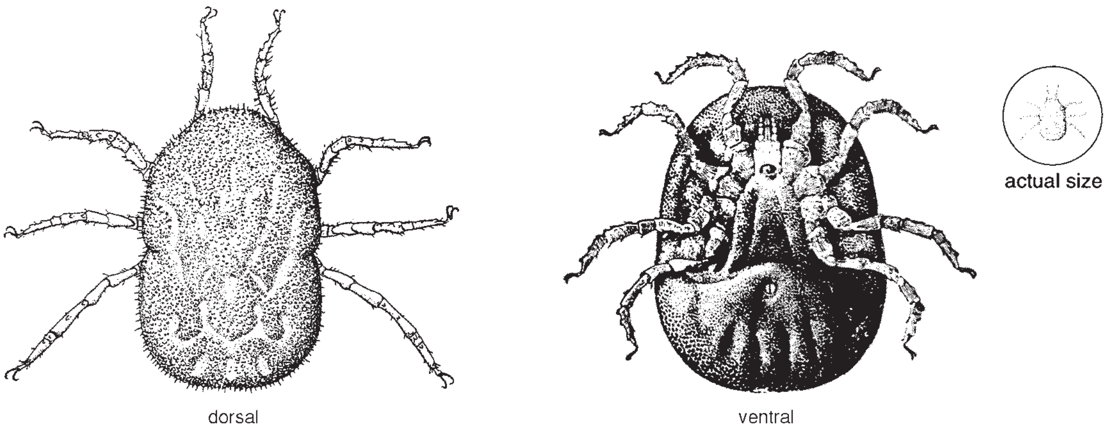

Fig. 4.23
A soft tick, *Ornithodoros moubata*, vector of relapsing fever in Africa (by courtesy of the Natural History Museum, London).

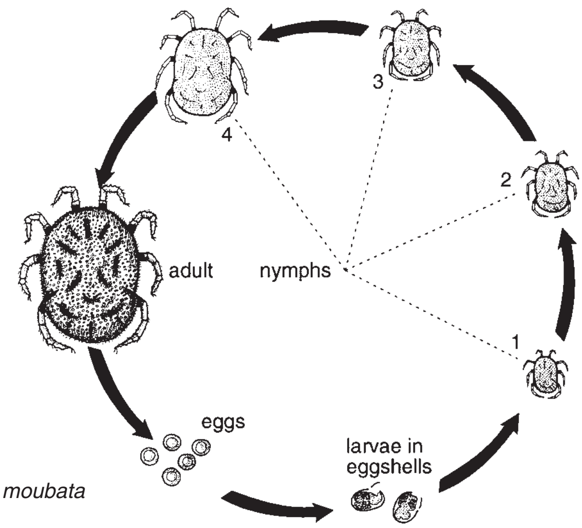

Fig. 4.24
Life cycle of the soft tick, *Ornithodoros moubata* (*30*).

Soft ticks

The adults are flat and oval in outline and have tough, leathery, wrinkled bodies. The mouthparts are situated underneath the body and are not visible from above. The eggs are laid in the places where the adults rest, such as cracks and crevices in the walls and floors of houses and in furniture. The larva, the five nymphal stages and the adults all actively search for hosts from which to take blood-meals. After feeding, which lasts about 30 minutes, they drop to the ground. Most species can survive for more than a year between blood-meals, and some for more than 10 years.

The soft ticks live apart from their hosts and are most common in the nests and resting places of the animals on which they feed. Some species, such as the chicken tick and the pigeon tick (*Argas* species) may feed on humans when the preferred hosts are not available.

Species that commonly feed on humans are found around villages and inside houses (Fig. 4.25). Their habits are comparable to those of bedbugs: ticks often emerge from hiding places at night to suck the blood of humans and animals. Some species are common on travel routes, in rest houses and camping sites, and in caves and crevices.

Hard ticks

The adult hard ticks are flat and oval in shape and between 3 and 23 mm long, depending on the species (Fig. 4.26). The mouthparts are visible at the front of the body, differentiating them from the soft ticks. In contrast to the soft ticks they have a shield-like plate or scutum behind the head on the back of the body, and there is only one nymphal stage (Fig. 4.27).

The eggs are deposited on the ground in large numbers. The larvae are very small, between 0.5 and 1.5 mm in length; they climb up vegetation, wait until a suitable host passes by, then climb on to it and attach themselves at a preferred feeding site, such as in the ears or on the eyelids.

After several days, when fully engorged, they drop to the ground, seek shelter and moult to the nymphal stage, which in turn seeks a blood-meal (Fig. 4.28), engorges, detaches itself and moults into an adult. The adult females climb up vegetation to wait for a suitable host, remaining on it for one to four weeks, then

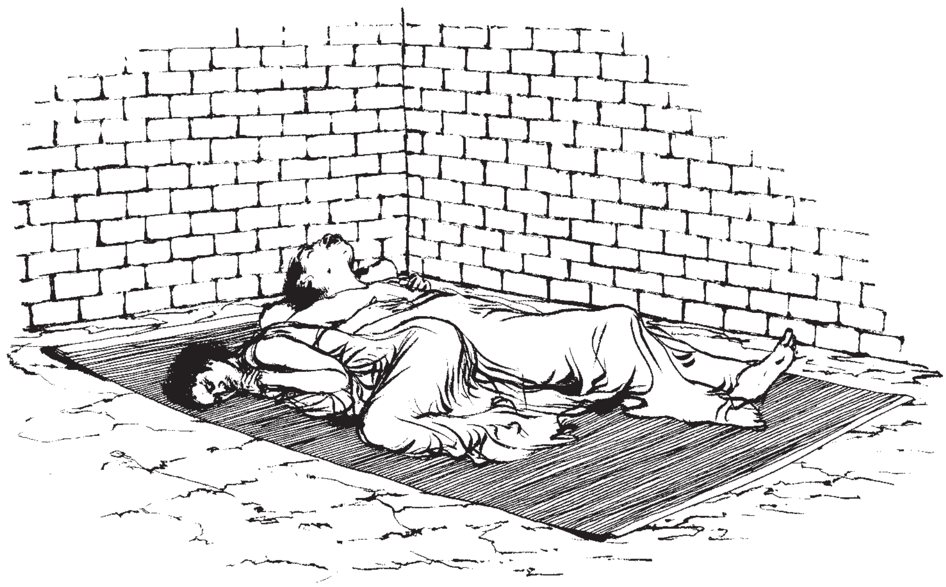

Fig. 4.25
Ornithodoros soft ticks are common in traditional-style mud-built houses with mud floors in some parts of Africa.

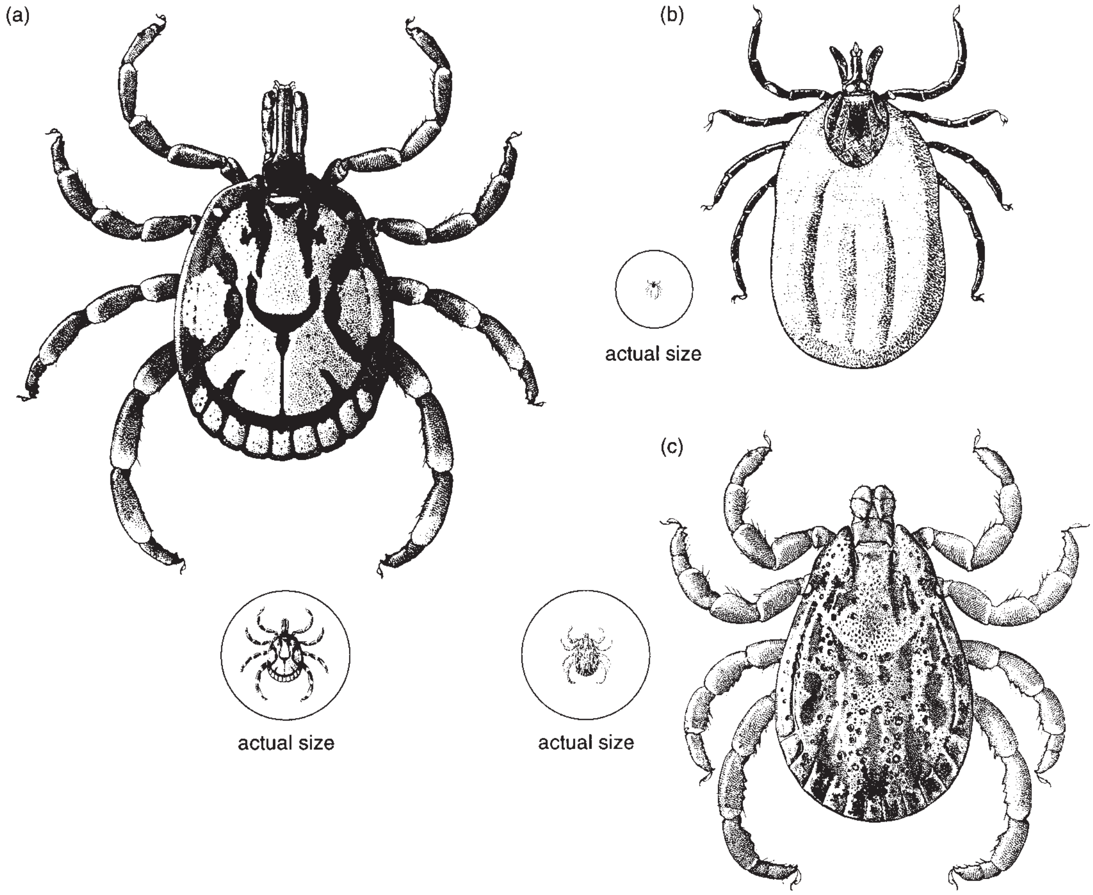

Fig. 4.26
Hard ticks. (a) The bont tick, *Amblyomma hebraeum*, vector of spotted fever due to *Rickettsia conori* in southern Africa. (b) The sheep tick, *Ixodes ricinus*, vector of tick-borne (Central European) encephalitis. (c) The Rocky Mountain wood tick, *Dermacentor andersoni*, vector of spotted fever due to *Rickettsia rickettsii* in North, Central and South America (by courtesy of the Natural History Museum, London).

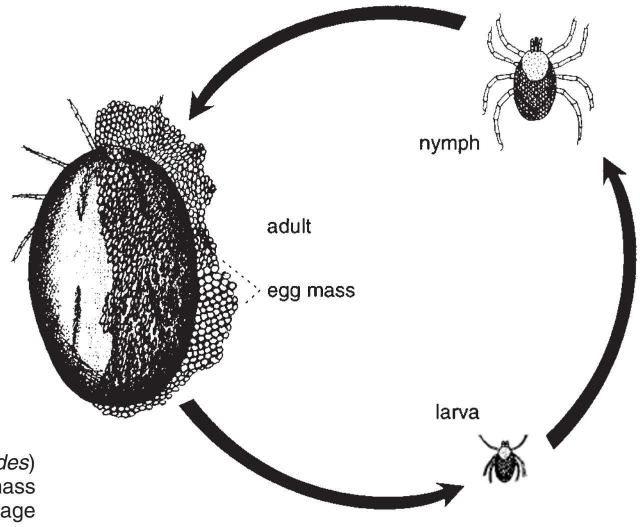

Fig 4.27
Life cycle of a hard tick (*Ixodes*) showing a female with a large mass of eggs, and a single nymphal stage (*30*).

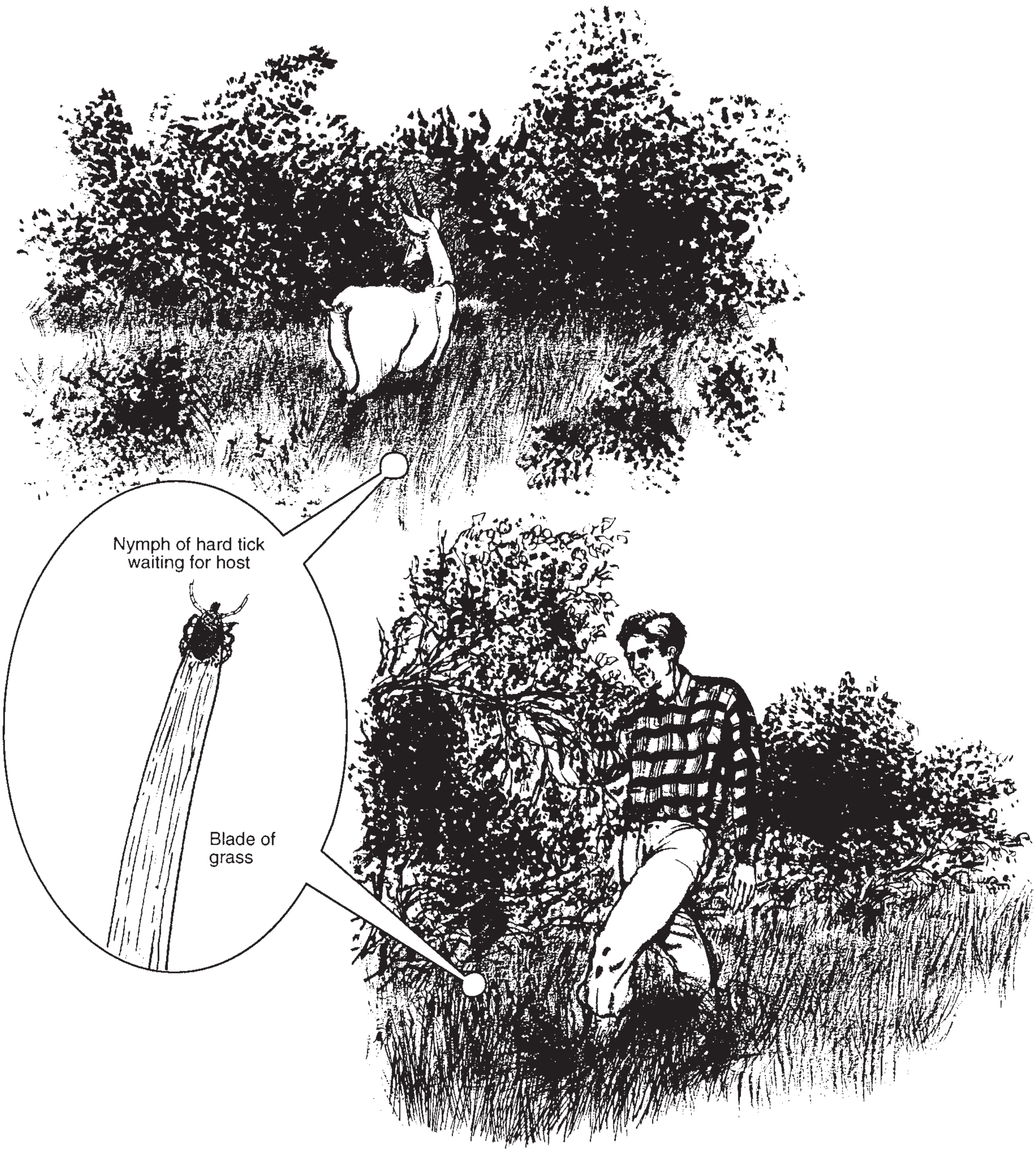

Fig. 4.28
A typical habitat of hard ticks, which normally feed on wild animals.

drop to the ground and seek shelter in cool places under stones and leaf litter, where they lay their eggs.

Most species of hard tick feed on three different hosts: one each for the larva, nymph and adult. However, some species feed on only one or two hosts. Because they remain attached to their hosts for several days, the hard ticks may be carried over large distances. The combination of feeding on different hosts and travelling considerable distances partly explains their importance as disease vectors.

Public health importance

Nuisance

Ticks can cause painful bites; heavy infestations, not uncommon in animals, can cause serious loss of blood.

Tick-borne relapsing fever

This disease is caused by a microorganism of the genus *Borrelia*. It is transmitted by biting soft ticks of the genus *Ornithodoros* in many countries in the tropics and subtropics and also in Europe and North America. The ticks usually feed quickly at night in or near houses, and then leave the host (*31*).

The disease causes bouts of fever alternating with periods without fever. Death occurs in about 2–10% of persons who are untreated.

Treatment

Treatment is possible with tetracycline or its derivatives.

Prevention

Prevention requires measures to control soft ticks and to avoid their bites.

Tick paralysis

Hard ticks inject into the body with their saliva certain toxins that can cause a condition in people and animals called tick paralysis. It appears 5–7 days after a tick begins feeding, paralysing the legs and affecting speaking ability, swallowing and breathing. It occurs worldwide and is most common and severe in children aged up to two years. Treatment involves removing the tick.

Tick-borne rickettsial fevers

This group of diseases is caused by closely related *Rickettsia* microorganisms transmitted by tick bites or contamination of the skin with crushed tissues or faeces of the tick.

- Spotted fever due to *Rickettsia rickettsii* occurs in Brazil, Canada, Colombia, Mexico, Panama and the USA.
- Spotted fever due to *R. sibirica* occurs in Japan, the Russian Federation and the Pacific.
- Spotted fever due to *R. conori* is found in the Mediterranean region, Africa and southern Asia.
- Spotted fever due to *R. australis* occurs in Queensland, Australia.
- Q fever, caused by *Coxiella burnetii*, has a worldwide distribution and is commonly present in abattoirs, meat-packing and meat-rendering plants, diagnostic laboratories, stockyards and poultry farms. It is transmitted to humans mainly by the consumption of milk and meat from contaminated

cattle or the inhalation of dried infected tick faeces by people working with cattle.

Symptoms in humans are sudden fever persisting for several weeks, malaise, muscle and joint pains, severe headache and chills. A rash sometimes spreads over the entire body. Death may result in about 15–20% of persons if the disease is misdiagnosed or left untreated.

Treatment

Antibiotics such as tetracycline or chloramphenicol can be used.

Prevention

Tick bites should be avoided and attached ticks should be removed rapidly and carefully. Several hours of attachment are needed before the *Rickettsia* organisms can infect humans.

Lyme disease

Lyme disease (erythema chronicum migrans) is a severe and often debilitating condition caused by a spirochaete, *Borrelia burgdorferi*. Acute Lyme disease is a flu-like illness, characterized by an expanding red rash in about 50% of patients, accompanied by fever, fatigue, and muscle and joint pain. Weeks or even months after the infecting tick bite, patients may experience swelling and pain in large joints (knee, elbow), encephalitis, facial palsy, ocular lesions and carditis, irrespective of whether a rash occurred in the acute phase. Later, perhaps years after the bite, there may be cartilage erosion (arthritis) and neuromuscular dysfunction (Fig. 4.29). Lyme disease occurs principally in northern temperate regions of the world, including China, Europe, the USA and the former USSR.

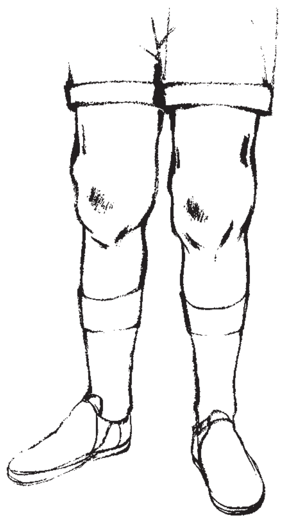

Fig. 4.29
A typical symptom of Lyme disease is swelling and pain in the large joints, such as the knees, and chronic arthritis.

Transmission

The disease is transmitted mostly by *Ixodes* ticks, commonly in the summer when the nymphs are abundant. Small rodents, especially mice, serve as reservoirs of infection while large mammals serve principally as hosts maintaining tick populations. The larvae acquire infection while feeding on mice, and nymphs or adults can transmit spirochaetes during subsequent blood-meals. In the northern temperate zone, where it occurs most intensely, Lyme disease has become more common as deer populations have increased and as this critical host has adapted to living in closer proximity to people. In many areas, Lyme disease is acquired in the suburban residential environment (*32*).

Treatment

Further development of the disease in adults may be reduced or prevented by treatment with tetracycline or its derivatives for 2–4 weeks, and in children by treatment with penicillin.

Prevention

Prevention requires avoidance of tick habitats and bites, and vector control. Personal protection may be possible by the use of repellents on the skin and clothing in tick-infested areas. The removal of attached ticks within 24 hours may prevent spirochaete transmission. Prophylactic antibiotic therapy may be desirable following the bite of an infected tick. New molecular assays are commercially available for detecting the spirochaetes in tick samples.

Tularaemia

Tularaemia, also known as rabbit fever, deerfly fever and Ohara disease, is caused by the infectious agent *Francisella tularensis*. The symptoms, which vary according to how the agent enters the body, include headache, chills, fever and the swelling of lymph nodes. The disease occurs in Europe, Japan, North America and the former USSR.

Transmission

Transmission takes place through the bites of ticks and deerflies (see Chapter 1) or as a result of handling infected animals such as rabbits and other game. Hunters and forest workers are at the highest risk of infection.

Treatment

Antibiotics such as streptomycin can be used to treat the disease.

Prevention

Tick bites and tick habitats should be avoided, impermeable gloves should be worn when skinning and dressing game animals, wild game meat should be thoroughly cooked, and untreated drinking-water should be avoided in areas where the disease occurs.

Tick-borne viral encephalitides

This is a group of viral diseases causing acute inflammation of the brain, spinal cord and meninges. The symptoms vary in severity with the type of disease. Many infections do not result in disease. Severe infections may cause violent headaches, high fever, nausea, coma and death.

- Far Eastern tick-borne encephalitis is found in the far east of the former USSR.
- Central European tick-borne encephalitis occurs in Europe from the Urals to France.
- Louping ill is a disease of sheep in the United Kingdom which sometimes affects people.

Transmission and prevention

These diseases are transmitted by biting ticks and by the consumption of milk from infected animals. No specific treatment is available but vaccines have been developed against some of the diseases. Prevention requires avoidance or rapid removal of ticks.

Principal hard tick vectors

Usually various tick species act as vectors for any one disease and their importance varies from region to region.

Disease	Vector
Lyme disease	Deer tick, *Ixodes dammini*
Spotted fever due to:	
Rickettsia rickettsii	American dog tick, *Dermacentor variabilis*
R. sibirica	Asiatic wood tick, *Dermacentor silvarum*
R. conori	Brown dog tick, *Rhipicephalus sanguineus*
R. australis	Wattle tick, *Ixodes holocyclus*
Q fever	Lone star tick, *Amblyomma americanum*
Tularaemia	American rabbit tick, *Haemaphysalis leporis-palustris*
Far Eastern tick-borne encephalitis	Taiga tick, *Ixodes persulcatus*
Central European tick-borne encephalitis	Castor bean tick, *Ixodes ricinus*
Kyasanur Forest disease	A tick of birds and monkeys, *Haemaphysalis spinigera*
Colorado tick fever	American wood tick, *Dermacentor andersoni*
Crimean–Congo haemorrhagic fever	A tick of birds and mammals, *Hyalomma marginatum*

Other viral diseases

Kyasanur Forest disease occurs in parts of India.

Omsk haemorrhagic fever is found in south-western Siberia; it causes severe disease and death in muskrat handlers; it is mainly waterborne, although it is found in hard ticks.

Colorado tick fever is a moderately severe disease that occurs in western North America.

Crimean–Congo haemorrhagic fever is an acute, often severe and fatal disease found in parts of Africa, Asia and Europe.

Control measures

Self-protection

Avoidance

Fields and forests infested with ticks should be avoided if possible. In Africa, bites by the soft tick *Ornithodoros moubata*, the vector of relapsing fever, can be prevented by avoiding old camp sites and by not sleeping on floors of mud houses. Beds, especially metal ones, may provide some protection because the ticks have difficulty in climbing the legs. However, they may still be able to reach hosts by climbing up the walls.

Repellents

Effective repellents that prevent ticks from attaching to the body include deet, dimethyl phthalate, benzyl benzoate, dimethyl carbamate and indalone (*33*). These substances can be applied to the skin or clothing. On the skin, repellents often do not last more than a few hours because of absorption and removal by abrasion. On clothing they last much longer, sometimes for several days (*34*). For more information on repellents, see Chapter 1.

Clothing

Clothing can provide some protection if, for example, trousers are tucked into boots or socks and if shirts are tucked into trousers. Clothing should be removed and examined for the presence of ticks after a tick-infested area has been visited.

Impregnated clothing

People who frequently enter tick-infested areas should consider impregnating their clothing by spraying (*35*, *36*) or soaking with a pyrethroid insecticide such as permethrin or cyfluthrin. Ticks crawling up trousers or shirts are quickly knocked down. Thus, not only is biting prevented but the ticks are also killed. Pyrethroid treatment of clothing is additionally effective against mosquitos for a month or longer (*34*). Information on how to treat clothing with a pyrethroid insecticide is given in Chapter 1.

Removal of attached ticks

During and after visits to tick-infested areas it is important to examine the body frequently for ticks. They should be removed as soon as possible because the risk of disease transmission increases with the duration of attachment.

A tick should be removed by pulling slowly but steadily, preferably with forceps to avoid contact between the fingers and the tick's infective body fluids. The tick should be grasped as close as possible to where the head enters the skin, so as not to crush it, and care should be taken not to break off the embedded mouthparts, as they may cause irritation and secondary infection. Some veterinarians may have a special tool for quick removal of ticks from dogs.

The following methods may induce soft ticks to withdraw their mouthparts: touching with a hot object such as a heated needle tip; dabbing with chloroform, ether or some other anaesthetic. With hard ticks these methods only work immediately after biting because they are attached with a saliva cement that prevents them from quickly withdrawing their mouthparts. In areas where ticks are only a nuisance they can be coated with oil, paraffin, vaseline or nail varnish to prevent them from obtaining oxygen. Hard ticks then dissolve the cement so that they can withdraw their mouthparts, but this may take several hours. However, these methods are not recommended in areas where ticks are vectors of disease, as they work too slowly and may cause ticks to regurgitate into wounds, injecting disease organisms. In such circumstances it is recommended to pull the ticks out immediately, even if the head is left in the wound.

Application of insecticides to animals

Domestic animals are often hosts to ticks that can feed on humans and transmit disease to people and animals. Insecticides applied directly to the bodies of these animals in the form of dusts, sprays, dips or washes can be very effective. Pour-on formulations are applied over the animals' backs. The insecticide (a pyrethroid) is distributed over the whole body by tail and other movements.

Insecticidal powders or dusts can be applied by means of a shaker, puff-duster or plunger-type duster. Insecticidal sprays are applied with hand-compression sprayers. The same insecticides and dosages can be used as for the control of fleas (see Table 4.2). It is particularly important to treat the back, neck, belly and the back of the head.

Plastic collars impregnated with an insecticide for the control of fleas in dogs and cats (see Table 4.2) are only partially effective against most species of tick.

Spraying insecticides in houses and resting places for animals

Ticks can be killed by insecticides sprayed on floors in houses, porches, verandas, dog kennels and other places where domestic animals sleep. Suitable residual sprays are indicated in Table 4.4 (see also p. 246).

Houses infested with soft ticks (*Ornithodoros*) can be sprayed with lindane ($0.2\,g/m^2$) or another insecticide formulation. Special care must be taken to treat the hiding and resting places of ticks in cracks and crevices in walls, floors and

Table 4.4
Insecticidal formulations used against ticks

Application method	Insecticide formulation
Dipping, washing or spray-on	malathion (5%), dichlorvos (0.1%), carbaryl (1%), dioxathion (0.1%), naled (0.2%), coumaphos (1%)
Insecticidal powder (dust)	carbaryl (5%), coumaphos (0.5%), malathion (3–5%), trichlorphon (1%)
Residual spray on floors, etc.	oil solutions or emulsions of DDT (5%), lindane (0.5%), propoxur (1%), bendiocarb (0.25–0.48%), pirimiphos methyl (1%), diazinon (0.5%), malathion (2%), carbaryl (5%), chlorpyrifos (0.5%)
Ultra-low-volume fogging (area spraying)	organophosphorus insecticides, carbamate compounds and pyrethroids
Flea and tick collars for dogs and cats	dichlorvos (20%), propoxur (10%), propetamphos (10%), permethrin (11%)

furniture. Residual house-spraying against malaria mosquitos has often resulted in a reduction in the numbers of ticks (see also p. 241).

Impregnated mosquito nets

Soft ticks that habitually feed indoors on sleeping persons can be controlled with impregnated bednets (*5*) (see also p. 240 and Chapter 1).

Community protection

Large-scale control activities are sometimes carried out in recreational areas or in areas where ticks transmit tick-borne diseases. It is often economical and effective to integrate several methods into a comprehensive control strategy (*37*). Possible components of an integrated strategy are as follows:

- *Surveillance*: sampling to identify tick habitats where control is needed.
- *Vegetation management*: physical or chemical measures to reduce and isolate tick habitats.
- *Host management*: removal or exclusion of host animals.
- *Targeted chemical control*: pesticide applications against ticks, targeted at the tick host or habitat.
- *Cultural practices*: lifestyle changes to limit exposure to ticks.
- *Personal protection*: protective clothing; repellents; checking for and removing of ticks.

Area spraying with insecticides

Spraying ticks directly in their natural habitats in forests and fields may control outbreaks of certain tick-borne diseases (e.g. Lyme disease (*38*) and tick-borne encephalitides). Large areas may be treated by ultra-low-volume spraying of liquid acaricide concentrates from fixed-wing aircraft or helicopters. Small areas may be sprayed by means of motorized knapsack sprayers or mist-blowers, applying either ultra-low-volume formulations or formulations of water-based emulsions or wettable powders. Control lasts for a month or longer, depending on conditions and the size of the treated area. Suitable biodegradable insecticides are shown in Table 4.4 (*39–44*).

Vegetation management

In, for example, parks and camp sites, ticks can be controlled by removal of the vegetation serving as their habitat (*37*, *45*). This can be done by cutting, mowing or applying herbicides.

Host management

Tick populations can be reduced by removing the animals on which they usually feed. Fences can be used to exclude larger animals such as deer (*37*).

Insecticide-treated nesting material

Nest-building rodents serve as natural reservoirs or critical hosts for many vector-borne infections, including Lyme disease, several of the tick-borne encephalitides, and others. One host-targeted vector control strategy uses insecticide-impregnated nesting material directed at the rodent reservoirs of Lyme disease spirochaetes. In the USA, white-footed mice serve as the principal reservoirs. Larval deer ticks become infected while feeding on these mice, and nymphs derived from mouse-fed larvae become infected vectors. Mice actively harvest soft material for their nests; when they incorporate cotton nesting material treated with 7–8% permethrin, their tick infestations are virtually eliminated.

This method has been used in residential areas bordering woodlands and parklands in the northern USA to reduce the abundance of infected nymphal ticks (*46*, *47*). The treated nesting material is protected in dispensing tubes (4 cm in diameter by 20 cm in length) and is placed about every 10 m in mouse habitats. The impregnated material is made using a patented method of soaking cotton in a permethrin emulsion and then drying it.

Clearly, mice must find and use the nesting material if this method is to work, and failures have been reported (*48*). However, when used properly, such a host-targeted treatment can significantly reduce the abundance of infected ticks, using up to 20 times less active ingredient and at less cost than insecticidal spray treatments. Community-wide programmes, where all properties in a neighbourhood receive treatment, have proved most effective.

MITES

Mites are very small, ranging from 0.5 to 2.0 mm in length; there are thousands of species, of which many live on animals. Like ticks, they have eight legs and a body with little or no segmentation. In most species there are egg, larval, nymphal and adult stages. The immature stages are similar to the adults but smaller.

Some mites are important vectors of rickettsial diseases, such as typhus fever due to *Rickettsia tsutsugamushi* (scrub typhus) and several viral diseases. Mites can present a serious biting nuisance to humans and animals. Many people show allergic reactions to mites or their bites. Certain mites cause a condition known as scabies. The major mite pests discussed here are:

— biting mites (vectors of scrub typhus);
— scabies mites;
— house dust mites.

Biting mites

Numerous species of mite are parasitic on mammals and birds and occasionally attack humans. Their bites can cause irritation and inflammation of the skin. One group, the trombiculid mites, transmits typhus fever due to *R. tsutsugamushi* in Asia and the Pacific. Only the trombiculid mites are described here, the biology and life cycle of other biting mites being similar.

Biology

Adult trombiculid mites are about 1–2 mm in length, bright red or reddish-brown in colour, and of velvety appearance. The nymph is similar but smaller. The larvae, also called chiggers, are very small, being only 0.15–0.3 mm in length (Fig. 4.30). Neither the adults nor the nymphs bite animals or humans; they live in the soil and feed on other mites, small insects and their eggs. The larvae, however, feed on skin tissue.

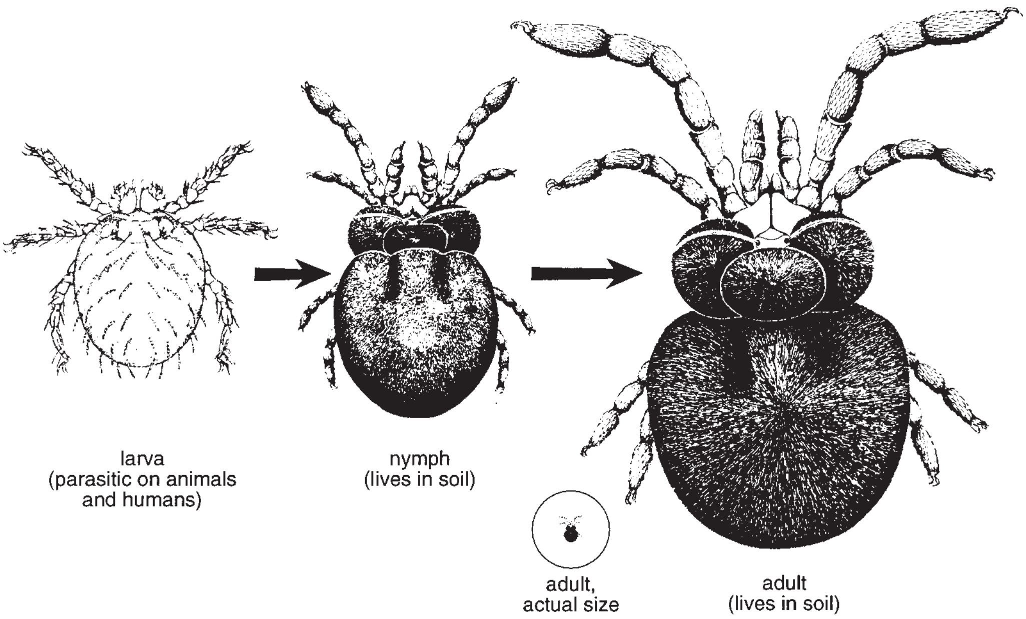

Fig. 4.30
The biting mite (*Trombicula* species). Reproduced from reference *49* with the permission of the publisher. Copyright Macmillan Publishing Company.

After emerging from the eggs the larvae crawl onto grasses or low-lying vegetation and leaf litter to wait for an animal or human host. They attach themselves to the skin of reptiles, birds, mammals and humans walking or resting in the habitat. On humans they seek out areas where clothing is tight against the skin, the waist and ankles being the parts most commonly attacked.

The larvae remain attached to the skin of the host for between two days and a month, depending on the species. They then drop to the ground and enter the soil to develop into the harmless nymphal and adult stages.

Distribution

Mites have a very patchy distribution over small areas because of their special requirements. The nymphs and adults need certain soil conditions for their survival and development while the larvae require host animals, such as wild rats, other small rodents and birds. Suitable habitats are found in grassy fields, shrubby areas, forests, abandoned rice fields and cleared forests. The mites are also found in parks, gardens, lawns and moist areas alongside lakes and streams.

The larvae wait on leaves or dry grass stems until an animal or human passes by. People usually become infested after walking or standing in mite-infested areas. Bamboo bushes are favoured by the mites in the tropics and subtropics.

Public health importance

Nuisance

The bites can cause severe itching, irritation and inflammation of the skin (scrub itch). They usually occur on the legs. At the site of a bite the skin swells slightly and turns red. In the centre a red point indicates the location of the chigger. Because chiggers are invisible to the naked eye, most people are not aware of their presence until bites appear.

Scrub typhus

Biting mites can transmit a number of rickettsial and viral diseases to humans but only the most important one, scrub typhus, is discussed here. It is caused by *Rickettsia tsutsugamushi* and causes an acute fever, severe headache and lymphadenopathy.

At the site of attachment of the infected mite a primary skin lesion consisting of a punched-out ulcer covered by an eschar commonly develops before the onset of the fever attack. Depending on a number of factors the mortality rate is in the range 1–60%.

Distribution and transmission

Scrub typhus occurs mostly in low-lying rural areas of Asia and Australia (Fig. 4.31). It was very common in troops during the Second World War. The disease occurs most frequently in people visiting or working in mite-infested areas in scrub, overgrown terrain, forest clearings, reforested areas, new settlements and newly irrigated desert regions.

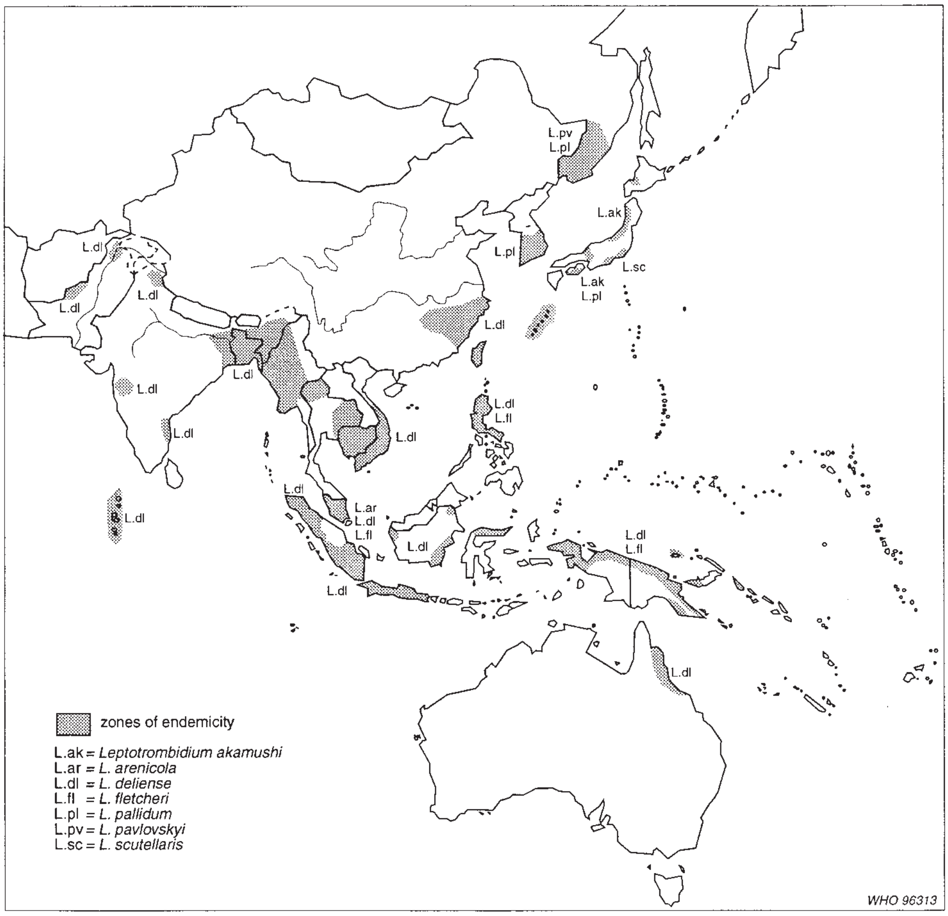

Fig. 4.31
Areas in south-east Asia and the western Pacific where scrub typhus occurs, 1996 (© WHO).

Treatment, prevention and control

Infected persons can be treated with tetracycline or its derivatives. Prevention is possible by avoiding contact with mites. The chiggers can be controlled by spraying of residual insecticides in woodland or bush areas, although this is expensive.

Control measures

Prevention of bites

Biting can be prevented by avoiding infested terrain and applying repellents to skin and clothing. Openings in clothing can be treated by hand or spray. A band of 1–3 cm is normally sufficient. Benzyl benzoate, dimethyl phthalate, deet, dimethyl carbamate and ethyl hexanediol are effective repellents. Under conditions of frequent exposure the best protection is given by impregnated clothing and by tucking trousers inside socks. Where vegetation is low it is sufficient to treat socks and the bottoms of trouser legs. The clothing can be treated with one or a combination of the above repellents or with a pyrethroid insecticide (see Chapter 2) providing more long-lasting protection, even after one or two washes. Deet and dimethyl phthalate have been shown to be the most effective repellent compounds against some mite species (*50*, *51*).

Removal of vegetation

The control of mites by killing them in their habitats is very difficult because of the patchy distribution of their populations. If it is possible to identify the patches of vegetation that harbour large numbers of larval mites (mite islands), it may be advantageous to remove them by burning or cutting and then to scrape or plough the top-soil. Mowing grass or weeds in these areas also helps. Such measures are recommended in the vicinity of camp sites and buildings.

Residual spraying of vegetation

Where the removal of vegetation is not possible, mite islands can be sprayed with residual insecticide. The spraying of vegetation up to a height of 20 cm around houses, hospitals and camp sites is effective against grass mites in Europe. The insecticides can be applied as fogs with ultra-low-volume spray equipment. Some suitable compounds are diazinon, fenthion, malathion, propoxur and permethrin (*52*).

Scabies mite

The scabies mite, *Sarcoptes scabiei*, causes an itching condition of the skin known as scabies. Infestations with scabies are common worldwide.

Biology

The mites are between 0.2 and 0.4 mm long and virtually invisible to the naked eye (Fig. 4.32). Practically the whole life cycle is spent on and in the skin of humans. In order to feed and lay eggs, fertilized females burrow winding tunnels in the surface of the skin. The tunnels are extended by 1–5 mm a day and can be seen on the skin as very thin twisting lines a few millimetres to several centimetres long.

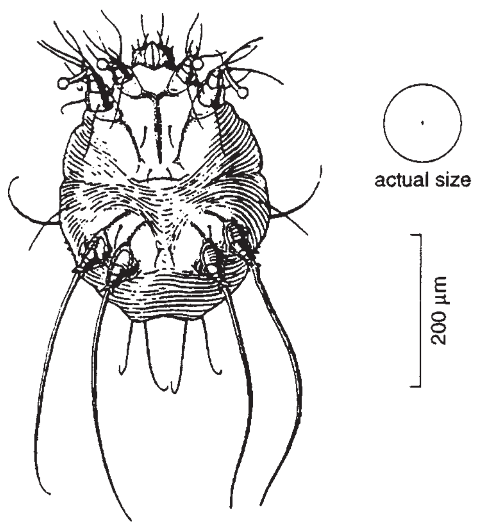

Fig. 4.32
The scabies mite. With a length of 0.2–0.4 mm it is hardly visible to the naked eye (by courtesy of the Natural History Museum, London).

Development from egg to adult may take as little as two weeks. The females may live on people for 1–2 months. Away from the host they survive for only a few days.

Scabies mites are commonly found where the skin is thin and wrinkled, for instance between the fingers, on the sides of the feet and hands (Fig. 4.33), the bends of the knee and elbow, the penis, the breasts and the shoulder blades. In young children they may also be found on the face and other areas.

Public health importance

Transmission

Scabies is usually transmitted by close personal contact, as between people sleeping together, and during sexual intercourse. Dispersal mostly takes place within families and if one family member becomes infested it is likely that all the others will follow suit. The mites are unlikely to be acquired by someone sleeping in a bed previously used by an infested person, but may be passed on in underclothes.

Distribution

Scabies occurs throughout the world in persons of all ages and social groups. In some developing countries up to a quarter of the population may be affected. It is

Fig. 4.33
A heavy infestation of scabies mites in the skin of the wrist (*53*).

most common in young children. Outbreaks of scabies are frequently reported from places where people live in overcrowded, unhygienic conditions (e.g. refugee camps) and where there is poor hygiene, such as in poorly maintained prisons and nurseries.

Symptoms

Initially a small, slightly elevated, reddish track appears, which itches intensely. This is followed by the formation and eventual rupture of papulae and tiny vesicles on the surfaces of the skin. Scratching causes bleeding and leads to the spread of the infestation. Vigorous and constant scratching often results in secondary infections, giving rise to boils, pustules and eczema.

A typical scabies rash can develop in areas of the body not infested with mites. This occurs mainly on the buttocks, around the waist and on the shoulders, and is an allergic reaction.

In newly infested persons the itching and rash do not appear until about 4–6 weeks after infestation but in previously infested individuals the rash develops in a few days.

A rare form of the disease is Norwegian scabies, which is associated with an immense number of mites and with marked scales and crusts, particularly on the palms and soles. It appears to occur more frequently among people with immunodeficiency disorders (especially HIV infection) than among immunocompetent patients (*54–56*).

Confirmation

Scabies infection can be confirmed by scraping the affected skin with a knife, transferring the material to a glass slide, and examining it for mites under a microscope. The application of mineral oil facilitates the collection and examination of scrapings. Another method involves applying ink to infested skin areas and then washing it off, thus revealing the burrows.

Treatment

It has recently been discovered that ivermectin, which is used in the treatment of onchocerciasis and lymphatic filariasis, is also suitable for the treatment of scabies infections. It is administered in a single oral dose of 100–200 μg per kg of body weight (*57–59*).

Conventional treatment methods aim to kill the mites with insecticide (see Table 4.5). Information on how to make and apply the formulations is provided on pp. 259–261. After successful treatment, itching continues for some time but eventually it disappears completely. Treatment of all family members is necessary to prevent reinfestation.

Most treatments provide a complete cure but sometimes a second application within 2–7 days is needed. Overtreatment should be avoided because of the toxicity of some of the compounds.

Commonly used insecticides are lindane (10% lotion), benzyl benzoate (10% lotion), crotamiton (10% cream) and permethrin (5% cream). The latter is now considered the treatment of choice because of its high efficacy and the low risk of associated side-effects (*55*, *60–62*).

Table 4.5
Formulations of insecticides which can be applied as creams, lotions or aqueous emulsions for use against scabies

Insecticide	Formulation
benzyl benzoate	20–25% emulsion
sulfur	in oily liquid
lindane	1% cream or lotion
malathion	1% aqueous emulsion
permethrin	1% soap bar or 5% cream

Application method

The formulation must be applied to all parts of the body below the neck, not only to the places where itching is felt. It should not be washed off until the next day. Treated persons can dress after the application has been allowed to dry for about 15 minutes.

House dust mite

House dust mites (*Dermatophagoides* complex) have a worldwide distribution (Fig. 4.34). They are very small (0.3 mm) and live in furniture, beds, pillows and carpets where they feed on organic debris, such as discarded skin scales and scurf. The inhalation of house dust laden with mites, mite faeces, and other debris and fungi associated with them produces allergic reactions in many people, such as asthma and inflammation of the nasal mucous membrane. Large numbers of allergens produced by house dust mites may be in the air after bed-making.

In temperate climates, mites occur throughout the year mainly in beds and carpets. Mites living on living room floors show a seasonal peak in density in late summer and early autumn.

Some other mites causing similar reactions in humans live among stored products, grains and animal feeds.

Prevention and control

The density of house dust mite allergens can be assessed by a test which measures the concentration of mite excreta (guanine) in dust (*63*).

Mites and associated fungi can be controlled by decreasing the humidity in rooms, improving ventilation and removing dust. Bedrooms and living rooms should be aired regularly, or other measures should be taken to reduce dampness. The shaking of bedclothes and frequent washing of sheets and blankets reduces the availability of food and therefore the number of mites. Vacuum cleaning of beds, carpets and furniture is also effective. General insecticides used for pest control are

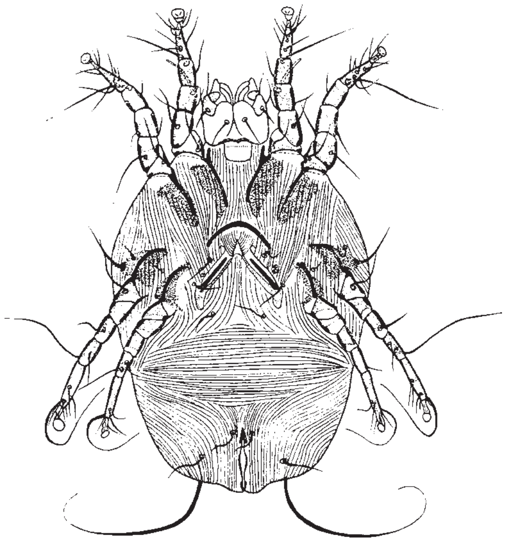

Fig. 4.34
The house dust mite (*Dermatophagoides pteronyssinus*) (by courtesy of the Natural History Museum, London).

not effective but a special product containing benzyl benzoate is available, which destroys mites when applied to mattresses, carpets and upholstery (*63*, *64*).

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