In areas with low or moderate transmission of malaria, in those with advanced health services with well trained and experienced personnel, and in priority areas such as those with development projects, attempts may be made to reduce the prevalence of malaria by community-wide mosquito control measures.

In areas subject to epidemic risk, quick-acting and timely vector control measures, such as insecticide spraying, play an important role in the control or prevention of epidemics.

Apart from the input of health services in the planning and management of activities, it is also important for communities to participate in control efforts. Sufficient resources have to be ensured for the long-term maintenance of improvements obtained. In developed countries with advanced professional capabilities and sufficient resources, it is possible to aim at a countrywide eradication of malaria. Eradication has been achieved in southern Europe, most Caribbean islands, the Maldives, large parts of the former USSR and the USA.

As most anopheline mosquitos enter houses to bite and rest, malaria control programmes have focused primarily on the indoor application of residual insecticides to the walls and ceilings of houses. House spraying is still important in some tropical countries but in others its significance is diminishing because of a number of problems (see Chapter 9), which, in certain areas, have led to the interruption or termination of malaria control programmes. There has been increased interest in other control methods that would avoid some of the problems related to house spraying. Methods that are less costly and easier to organize, such as community-wide use of impregnated bednets, and methods that bring about long-lasting or permanent improvements by eliminating breeding places are now being increasingly considered.

Lymphatic filariasis

Lymphatic filariasis is caused by three species of parasitic worm which occur in the lymph vessels and may cause huge swellings of the limbs and other parts of the body. Although the disease causes much suffering and disability it is rarely life-threatening.

- Bancroftian filariasis, caused by *Wuchereria bancrofti*, is mainly transmitted by *Culex quinquefasciatus* and by some *Anopheles* and *Aedes* species. In 1996, it was estimated that some 107 million people were infected in parts of China, India, other parts of south-east Asia, the Pacific Islands, tropical Africa, and South and Central America (Fig. 1.19).
- Brugian filariasis, caused by *Brugia malayi* and *B. timori*, was estimated to infect some 13 million people in 1996, mainly in south-east Asia. Its main vectors are the *Mansonia* species. *B. timori* occurs on the islands of Flores, Timor and Alor, to the east of Java, and is transmitted by *Anopheles barbirostris* (Fig. 1.19).

Transmission

The adult worms live in the lymphatic vessels in the human body and produce embryos called microfilariae, which circulate in the bloodstream and are picked up by biting mosquitos. After developing for several days in the mosquito, infective larvae enter the skin when the mosquito feeds, migrate to the lymph nodes and develop into adult worms in the lymph vessels (Fig. 1.20). The chance of an

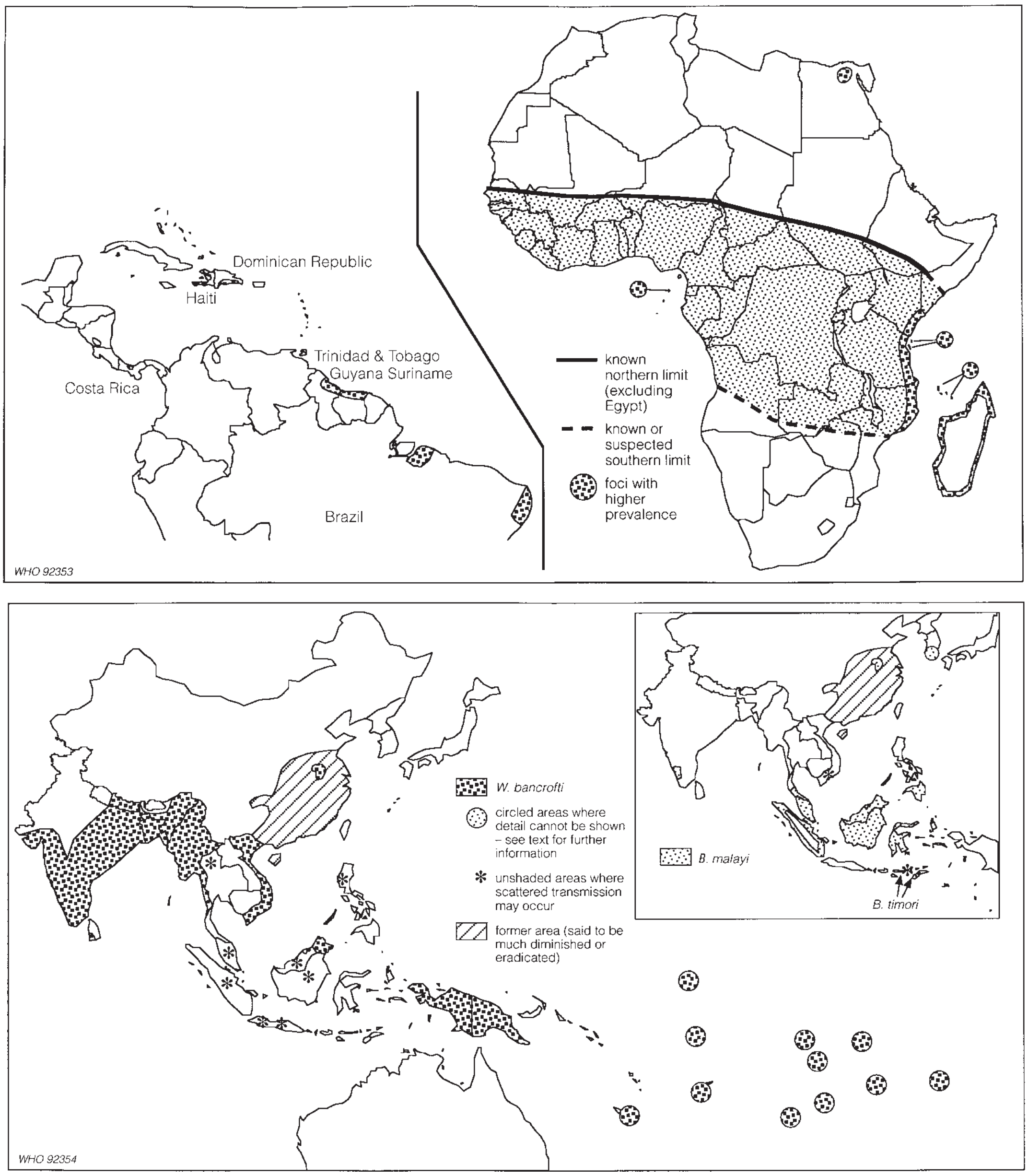


Fig. 1.19
Geographical distribution of lymphatic filariasis, 1992 (© WHO).

infection being established from a single bite by an infected mosquito is very low. The adult worms can live for many years, giving rise to large numbers of microfilariae in the blood.

Bancroftian filariasis occurs in two forms: in the most common form the microfilariae circulate in the blood at night, whereas in the second form they occur continuously in the blood but increase in number during the day. The vectors of the first form are *Culex quinquefasciatus* and certain *Anopheles* species (which bite at night). The second form is found in the South Pacific and in some rural areas in

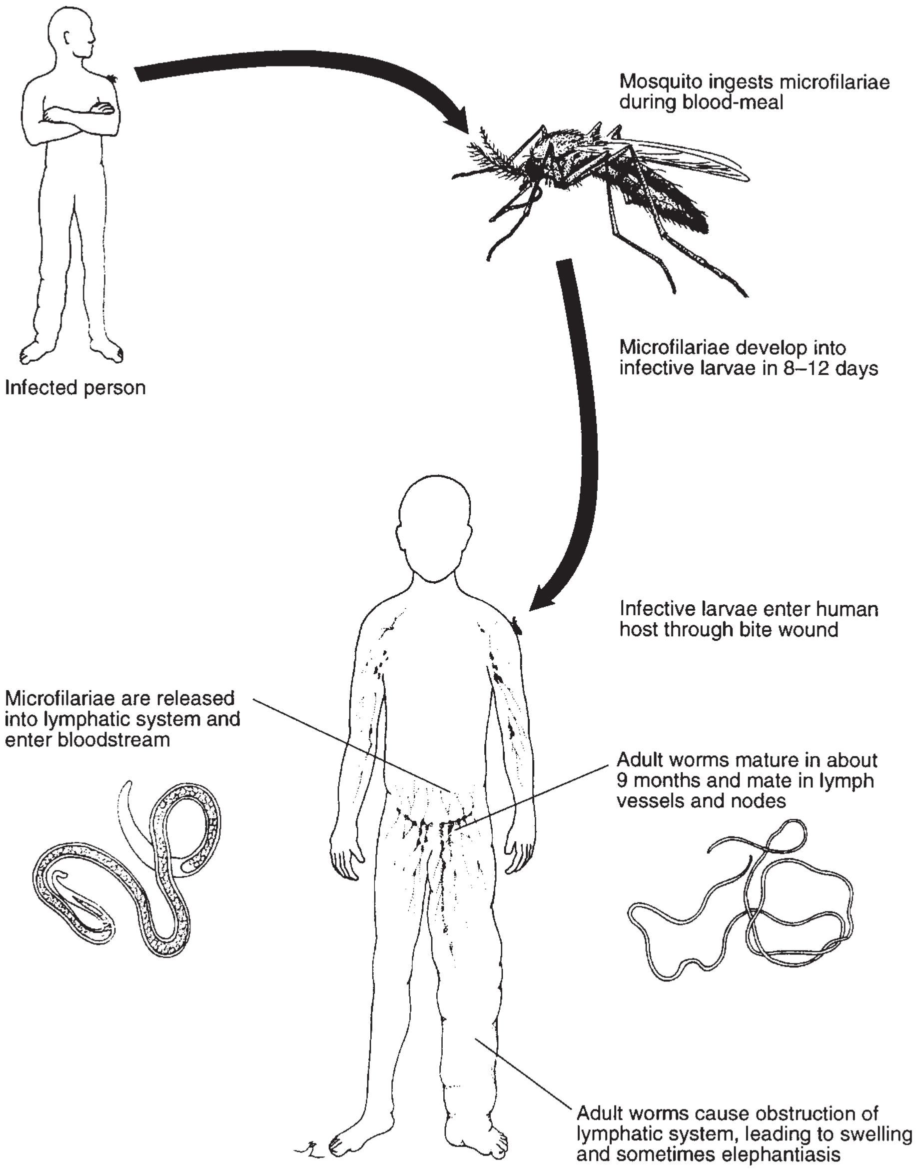


Fig. 1.20
Life cycle of filarial parasites (by Taina Litwak for the United States Agency for International Development's VBC Project).

south-east Asia where the main vectors are daytime-biting mosquitos such as certain *Aedes* species.

In rural areas, bancroftian filariasis is mainly transmitted by some *Anopheles* species that are also malaria vectors, and by *Aedes*. Urban bancroftian filariasis typically occurs in slums in developing countries. It is transmitted by *Culex quinquefasciatus*, which breeds in polluted water in drains, cesspits and ditches.

Brugian filariasis, caused by *B. malayi*, also occurs in two forms, of which the most common is transmitted at night and the other during both day and night. The first form occurs in rural populations in rice-growing areas in Asia. It is transmitted by night-biting *Anopheles* species and by *Mansonia* species which breed in swamps

Fig. 1.21
Elephantiasis (permanent swelling) of the leg due to lymphatic filariasis.

and ponds with aquatic vegetation. The second form is mainly a parasite of monkeys living in swamps. *Mansonia* species breeding in swampy forests in Indonesia and Malaysia may infect people living nearby.

Brugian filariasis caused by *Brugia timori* is transmitted only by *Anopheles barbirostris.*

Clinical symptoms

The clinical symptoms and signs are mainly determined by the duration of the infection. The adult worms, which live in the lymphatic vessels, can cause severe inflammation of the lymphatic system and acute recurrent fever. Secondary bacterial infections are a major factor in the progression towards lymphoedema and elephantiasis, the characteristic swelling of the limbs, genitalia and breasts (Fig. 1.21).

Prevention and treatment

The transmission of filariasis is much less efficient than that of malaria, and prophylactic treatment for travellers is not, therefore, recommended. The risk of infection can be reduced by taking measures to prevent mosquito bites or reduce mosquito numbers.

Suspected cases can often be confirmed by detection of microfilariae in samples of blood examined microscopically. A new diagnostic method uses an immunological procedure to detect circulating filarial antigen in the blood. The test is as sensitive and specific as examination of blood by microscopy, and offers the

advantage that samples can be collected during the day, even when the microfilariae are nocturnally periodic. People who are infected can be treated with diethylcarbamazine (DEC). This has been used in some areas for the mass treatment of infected people to reduce morbidity and transmission. DEC is much more lethal to the microfilariae than to the adult worms, which may only be killed after prolonged treatment. The death of microfilariae due to the action of DEC may cause nausea and other unpleasant, but not dangerous, side-effects, which sometimes discourage people from completing courses of treatment.

Control

Filariasis should be easier to control than malaria because of the inefficiency of transmission from mosquitos to humans and because of the long period before symptoms of infection become serious, during which time drug treatment can be effective. However, in practice, control is difficult because it takes a long time to eliminate the worm reservoir in the human host and because of a lack of compliance by communities.

The new approach to control of filariasis is based on annual treatment of populations in endemic areas with a single dose of DEC and ivermectin, given alone or (preferably) in combination (*3*). The combination of these two drugs also reduces or eliminates other parasitic worm infections and scabies. However, ivermectin alone is preferred in areas endemic for onchocerciasis or loiasis. Treatment should preferably be continued for at least five years.

Vector control measures, when practicable, are carried out in addition to drug treatment. The control of *Culex* is normally based on measures aimed at the prevention of breeding. The control or elimination of breeding sites in polluted water is possible by improving sanitation systems and hygiene in general. Where such improvements are impossible or economically unfeasible, larvicides or polystyrene beads can be applied to breeding sites. Because of the pollution of breeding sites, not all larvicides are effective and relatively high dosages are needed.

Indoor residual spraying is generally not very effective against *Culex quinquefasciatus*, at least partly because of this species' habit of resting on unsprayed objects, such as clothes, curtains and other hanging fabrics, rather than on walls and ceilings. A practical problem in urban areas is the large number of rooms that would have to be sprayed.

The most commonly used method of controlling the *Mansonia* vectors of brugian filariasis is to remove or destroy the aquatic vegetation to which the larval and pupal stages are attached. Sometimes, as for instance in swamp forests in parts of Indonesia and Malaysia, larval control measures are impracticable because of the large extent of the breeding areas. In such situations the main emphasis should be on the prevention of mosquito bites by means of self-protection.

Mosquito-borne viral diseases

The viruses that are transmitted by mosquitos and other arthropods are called arboviruses (arthropod-borne viruses). Approximately 400 different arboviruses are known; they usually occur in animals and are sometimes transmitted from animals to humans by mosquitos. The most important arbovirus infections

transmitted by mosquitos are yellow fever, dengue and several forms of encephalitis. The vectors are *Aedes, Culex* or, in a few cases, *Anopheles* species.

Yellow fever

Yellow fever is an acute disease of short duration which often causes death. The disease starts with a high fever, headache, body aches, vomiting and sometimes jaundice (which gives the patient a yellow colour). This is followed by internal haemorrhages (bleeding) and vomiting. Death may occur within three days after the onset of the disease.

Transmission and distribution

The yellow fever virus mainly occurs in populations of monkeys in dense forests and gallery forests in Africa and South and Central America (Fig. 1.22). It is transmitted from monkey to monkey by forest-dwelling mosquitos (*Aedes* species in Africa, *Haemagogus* and *Sabethes* in South and Central America; Figs. 1.23 and 1.24). These mosquitos occasionally bite humans when they enter forests and may thus transmit the virus from the monkey reservoir to the human population. There is evidence in some areas of endemicity that the virus is maintained in mosquito populations through transovarial transmission in the absence of a vertebrate reservoir.

In Africa, monkeys sometimes leave the forest in search of bananas in plantations and may then infect the local mosquito species, which in turn infect humans living or working on the plantations. People infected in or near forests can carry the virus to rural or urban areas where *Aedes aegypti* or related mosquitos can pick it up and transmit it among the human population. Such situations can result in serious epidemics and many deaths.

In the Americas, urban outbreaks used to be extremely severe but have not occurred since 1954. However, the risk remains and cases are reported each year among people working in forests. In Africa, urban or rural outbreaks are occasionally reported from areas near forests and may cause thousands of deaths. People working in forests also become infected regularly. Yellow fever has never been reported in Asia.

Prevention and control

Yellow fever is best prevented by immunization, which is recommended for all persons working in or visiting forests where yellow fever occurs. Immunization is also indicated for people in urban or rural areas at risk.

Vaccination normally provides protection for at least 10 years and revaccination every 10 years is required by the port or frontier health authorities in a number of tropical countries (*4*).

Epidemics can be controlled by vaccinating all persons living in affected areas; by space-spraying with insecticides against adult mosquitos; and by appropriate larval control measures. Non-immunized people can reduce the risk of infection by protecting themselves from mosquito bites with protective clothing, repellents and screens to prevent daytime biting.

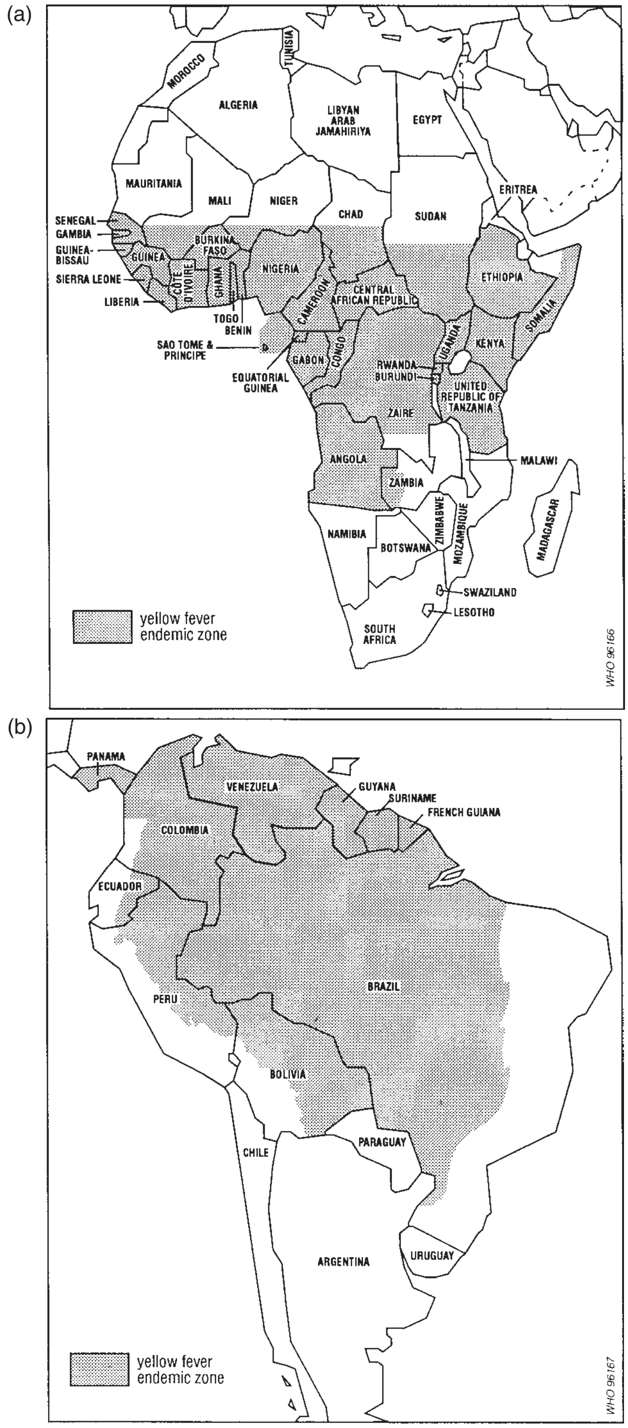


Fig. 1.22
Areas of Africa (a) and Central and South America (b) where yellow fever is endemic, 1995 (© WHO).

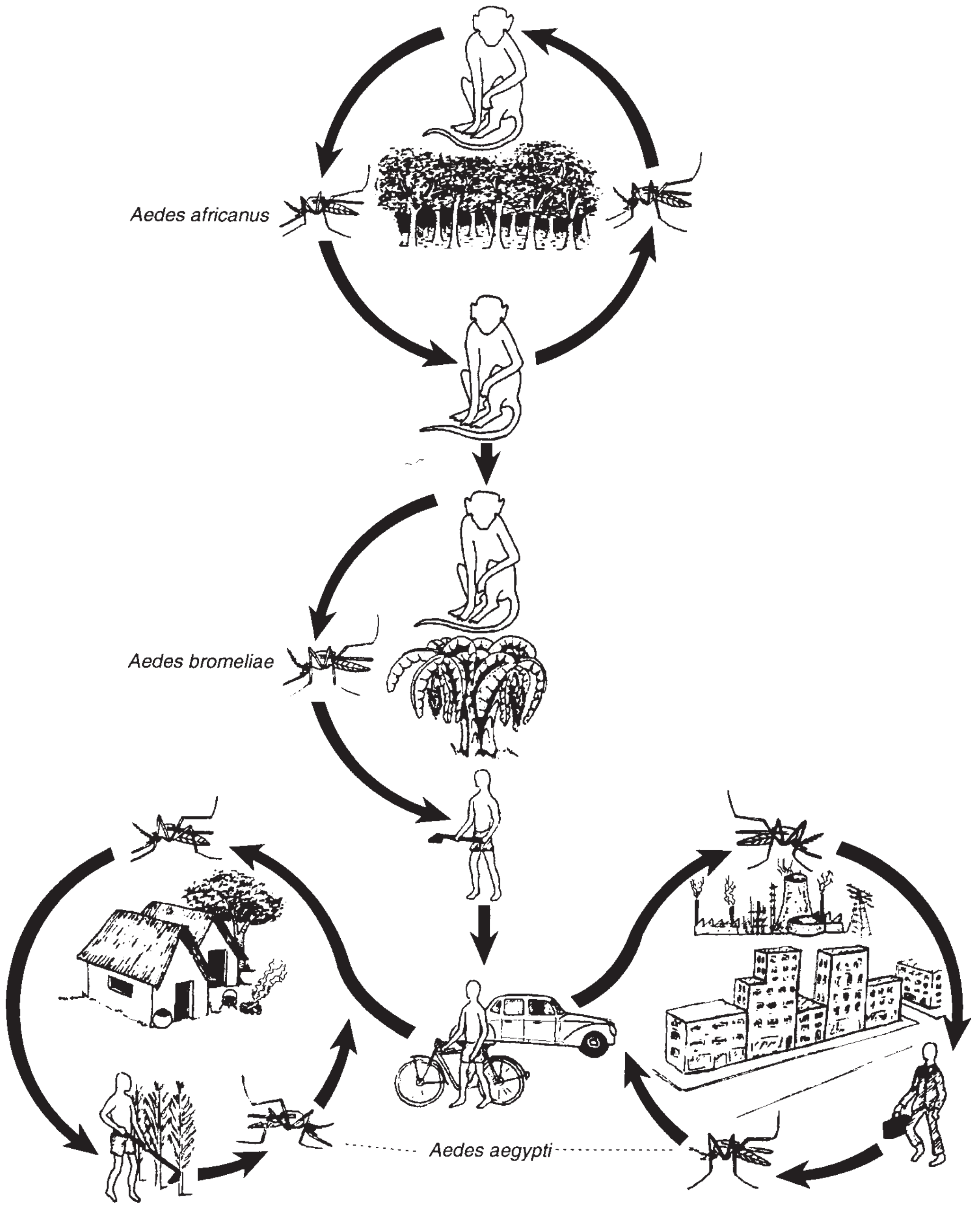


Fig. 1.23
Sylvatic, rural and urban transmission cycles of yellow fever in Africa (*2*).

Dengue and dengue haemorrhagic fever

Dengue is caused by several closely related viruses, called dengue types 1, 2, 3 and 4. The disease is transmitted from person to person mainly by *Aedes aegypti*, but *Aedes albopictus* can also act as a vector.

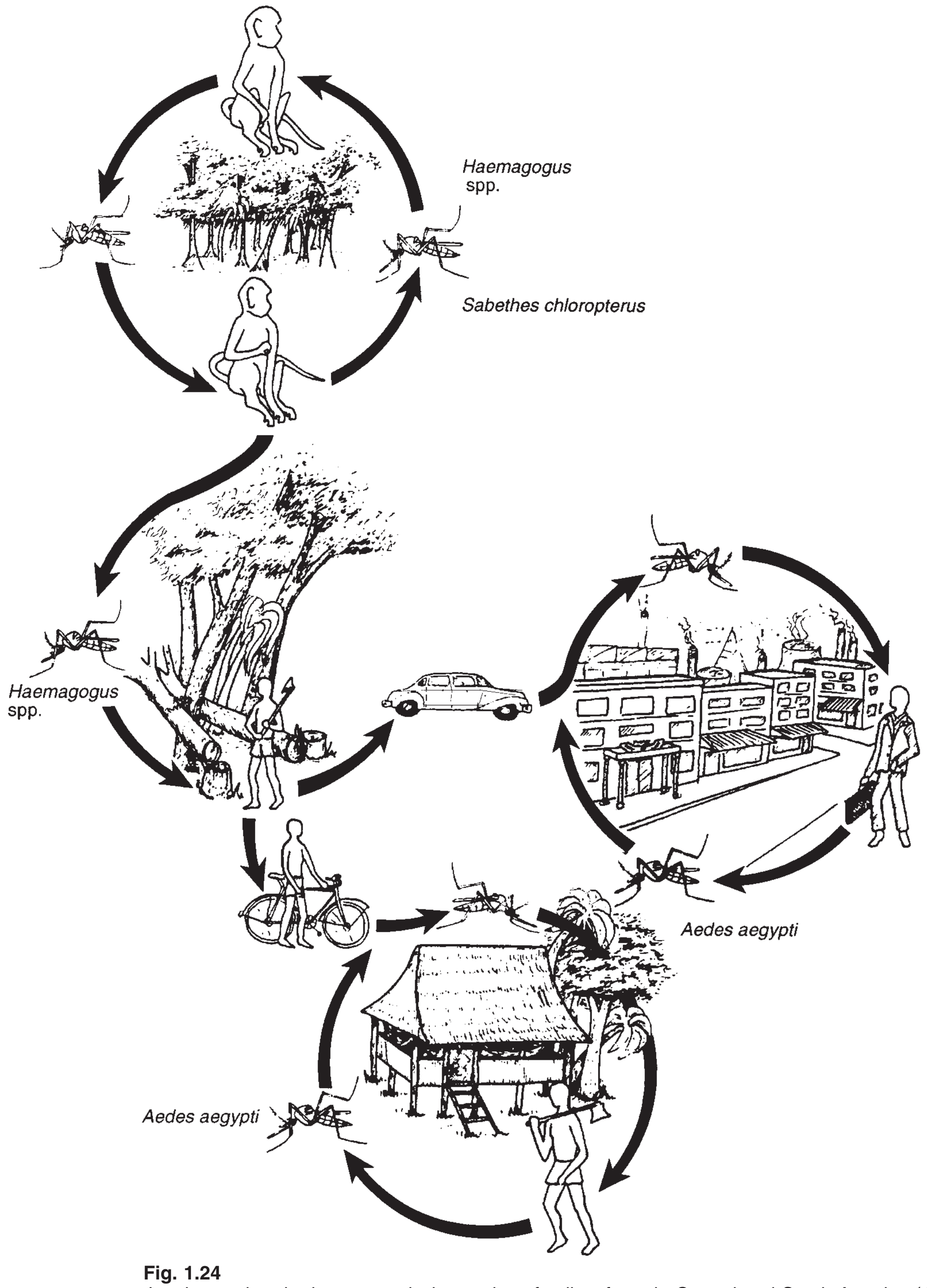


Fig. 1.24
Jungle, rural and urban transmission cycles of yellow fever in Central and South America (*2*).

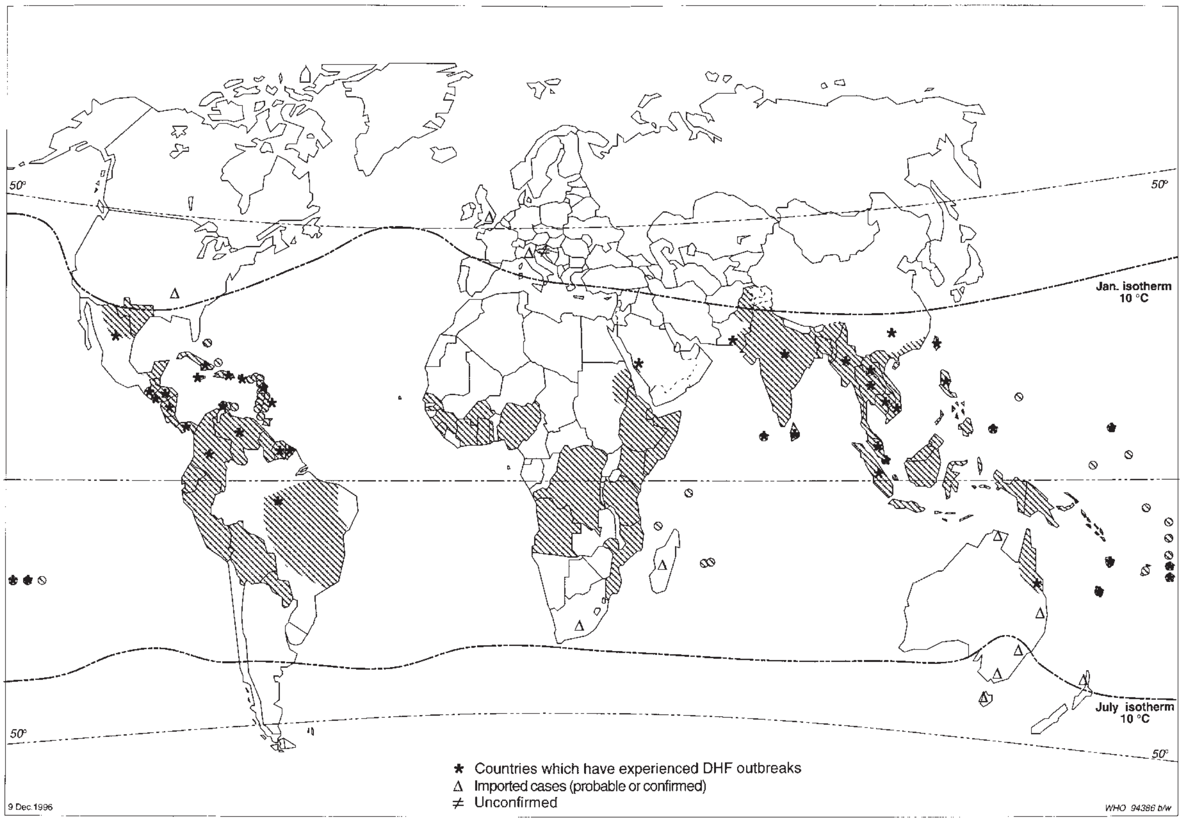


Fig. 1.25
Distribution of dengue and dengue haemorrhagic fever (DHF) outbreaks, 1975–1996 (© WHO).

Two forms of the disease occur: dengue fever and dengue haemorrhagic fever.

Dengue fever occurs in explosive epidemics that mainly affect adults, sometimes with tens of thousands of cases, especially in urban areas. It is an acute febrile disease that starts suddenly and lasts for a week or more, causing intense headache, pain in joints and muscles, and rash. Infection rarely results in death. It occurs in most tropical countries and in some subtropical areas (Fig. 1.25). It can occur in rural and urban areas, if suitable vector mosquitos are present.

Dengue haemorrhagic fever is a severe illness that occurs in south-east Asia and has appeared relatively recently in the Americas and the South Pacific (Fig. 1.25), mainly affecting children. Infection starts with high fever, vomiting, headache, difficulty in breathing and pain in the abdomen. Signs of internal bleeding are common (Fig. 1.26). Dengue shock syndrome may develop as a result of loss of blood and lowered blood pressure. If treatment is not available, as many as 50% of patients with shock may die, but overall mortality from dengue haemorrhagic fever is usually in the range of 5–10%.

Prevention, treatment and control

No vaccines are available against dengue infections although work is in progress to

Fig. 1.26
Internal bleeding in dengue haemorrhagic fever may cause darkening of the skin of the face and hands. Children are most commonly affected.

develop one. There is no specific treatment for the disease, but patients with dengue shock syndrome can be treated by rapid administration of fluid and plasma and the monitoring of vital signs.

The most effective preventive measures aim at reducing the population density of the vector, *Aedes aegypti*. Sustained control is achieved most economically by large-scale prevention of breeding, through removal or filling of breeding habitats in man-made and natural containers, the burning of organic waste, screening or fitting mosquito-proof lids to drinking-water storage containers, installing piped drinking-water supply, and, if other methods are not feasible or practical, applying safe and effective larvicides to breeding sites. Strategies for such source reduction by communities require extensive, long-term health education.

Also recommended is personal protection against daytime-biting mosquitos, including the use of protective clothing, repellents and house screening. In addition to the chemical methods commonly employed against biting mosquitos, such as the use of indoor space-spraying, daytime protection is obtainable from mosquito coils and mats, bednets, and air-conditioning.

In epidemic situations the same measures should be taken, but attempts should also be made to reduce populations of adult mosquitos rapidly by outdoor space-spraying with insecticides. Insecticidal sprays are usually applied to the parts of towns where abundant breeding sites are available, supporting large populations of *Aedes*. Space sprays can be applied with knapsack or hand-carried fogging machines and by truck- or aircraft-mounted machines. Residual wall spraying against *Aedes aegypti* is generally ineffective as this species normally rests indoors on surfaces that are not suitable for spraying, such as curtains and other fabrics. Stocks of insecticides should be kept for emergencies.

Viral encephalitis

Viral encephalitis is an acute inflammatory condition of the brain and spinal cord. A number of viruses cause the same signs and symptoms but with differing severities and rates of progress. Many infected people may have no symptoms. In mild cases there is fever and headache; severe cases are marked by high fever, headache, tremors, coma and spastic paralysis. Death is most frequent in infections with Japanese encephalitis and is also common in Murray Valley encephalitis and eastern equine encephalitis. Survivors are often left mentally retarded and with neurological disturbances.

Distribution and transmission

Some of these viruses are maintained in birds, especially herons, egrets, ibises and other species that live in or near marshes. The viruses are transmitted by mosquitos from the bird reservoir to other animals, such as horses and pigs, and humans. Infected horses may become very sick and die, as with Venezuelan equine encephalitis.

Japanese encephalitis occurs in China and south-east Asian countries (see Fig. 1.27); it formerly occurred in Japan. It is most common in rice-growing areas where *Culex tritaeniorhynchus* and related species transmit the virus from birds to

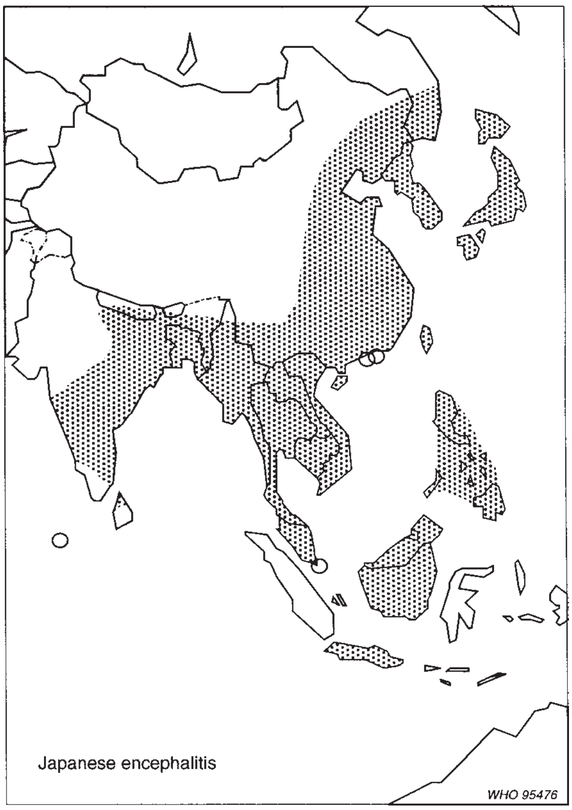


Fig. 1.27
Distribution of cases of Japanese encephalitis in southern and eastern Asia, 1995 (© WHO).

pigs and humans. Mosquitos also transmit it from pigs to humans. Venezuelan equine encephalitis is found in South and Central America and southern USA. The western equine and St Louis encephalitis viruses occur in the USA and northern parts of South America. Eastern equine encephalitis occurs in eastern USA, South America, and in parts of Asia, Australasia and Europe.

Prevention, treatment and control

A vaccine against Japanese encephalitis is used to immunize children in some of the Asian countries in which the disease is endemic. A vaccine is also available against eastern equine and western equine encephalitis. No specific treatment exists for infected individuals.

Infections can be prevented by using protective clothing, repellents, house screening, mosquito nets, coils and mats, and by the avoidance of outdoor activities in the evening. The spraying of houses and animal shelters in rural areas to control the *Culex* vectors of Japanese encephalitis is generally ineffective because of the outdoor biting and resting habits of the vector species (*5*). In some areas control is possible by measures that prevent breeding in rice fields and irrigation systems. Outdoor space spraying with insecticides can be carried out where epidemics occur. In endemic areas it is recommended that domestic animals be housed away from human habitations. This applies especially to pigs in areas where Japanese encephalitis is endemic.

Other viral diseases

Many other viral diseases are transmitted to humans by mosquitos, among them chikungunya virus disease and Rift Valley fever in irrigated areas of East Africa and India, where large-scale epidemics occur. Ross River disease occurs in parts of Australia and in some Pacific islands. It often causes arthritis of the joints of the hands and feet for a limited period.

No vaccines or specific treatments exist for these diseases. Prevention and control are possible by taking appropriate measures against the mosquito vectors.

Onchocerciasis (river blindness)

Onchocerciasis is caused by a parasitic filarial worm, *Onchocerca volvulus*. It is transmitted from person to person by *Simulium* blackflies. Infection can cause severe itching of the skin, eye lesions and blindness. The disease has a focal distribution and occurs throughout West and Central Africa and parts of East Africa. The most heavily infected areas are savanna regions in West Africa. Transmission also occurs in localized areas in Yemen and in Central and South America. In 1995 it was estimated that almost 18 million people were infected, of whom 268 000 were blind; in addition, a further 500 000 were severely visually disabled (Fig. 1.28).

Transmission

Blackflies are the only vectors. Embryos of *Onchocerca* (microfilariae) are ingested during feeding. The microfilariae develop into infective larvae in the body of the fly after 6–10 days and are then transmitted to humans during feeding and develop into adult worms (Fig. 1.29). The female worms can live in the human body for

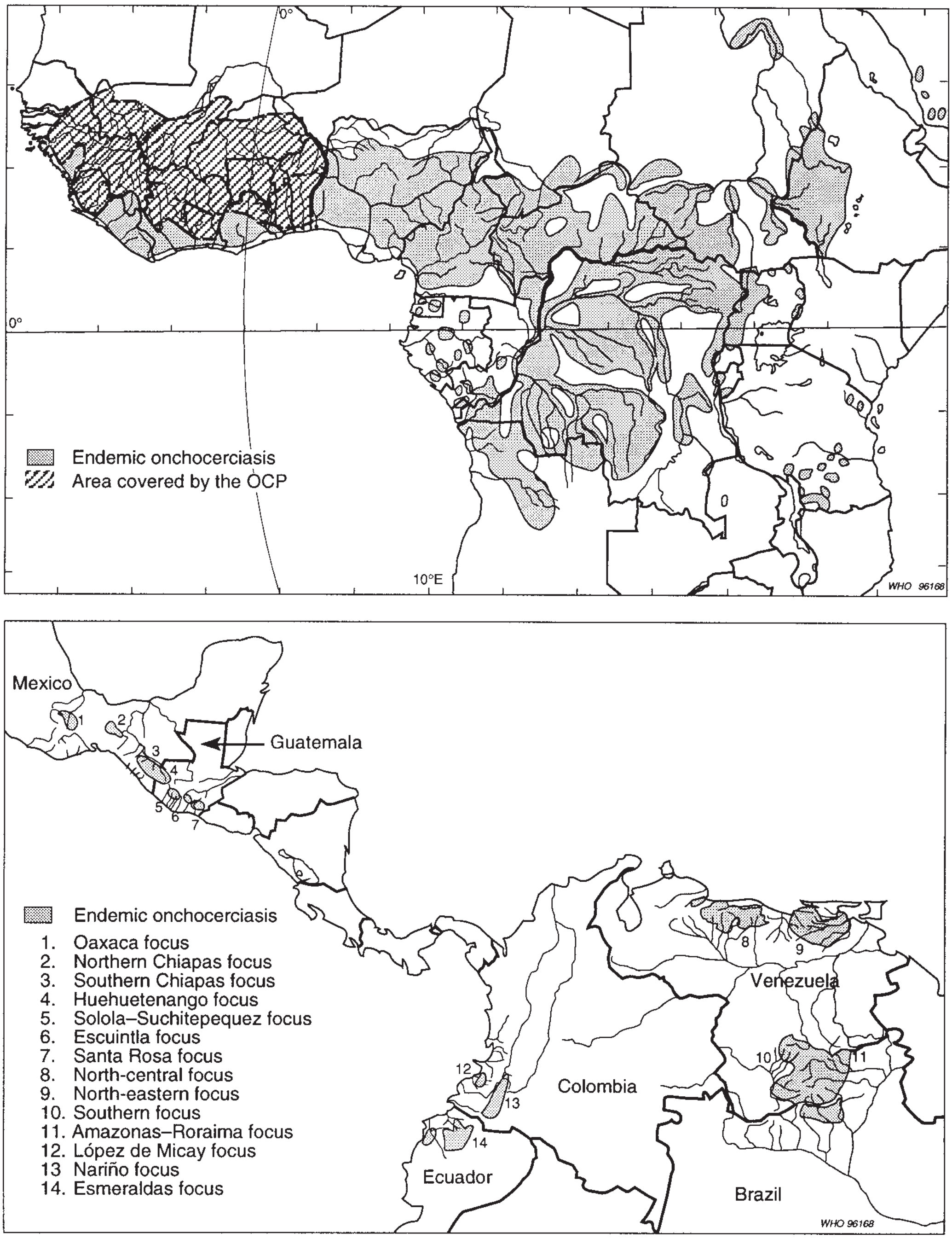


Fig. 1.28
Geographical distribution of onchocerciasis, 1995 (© WHO).

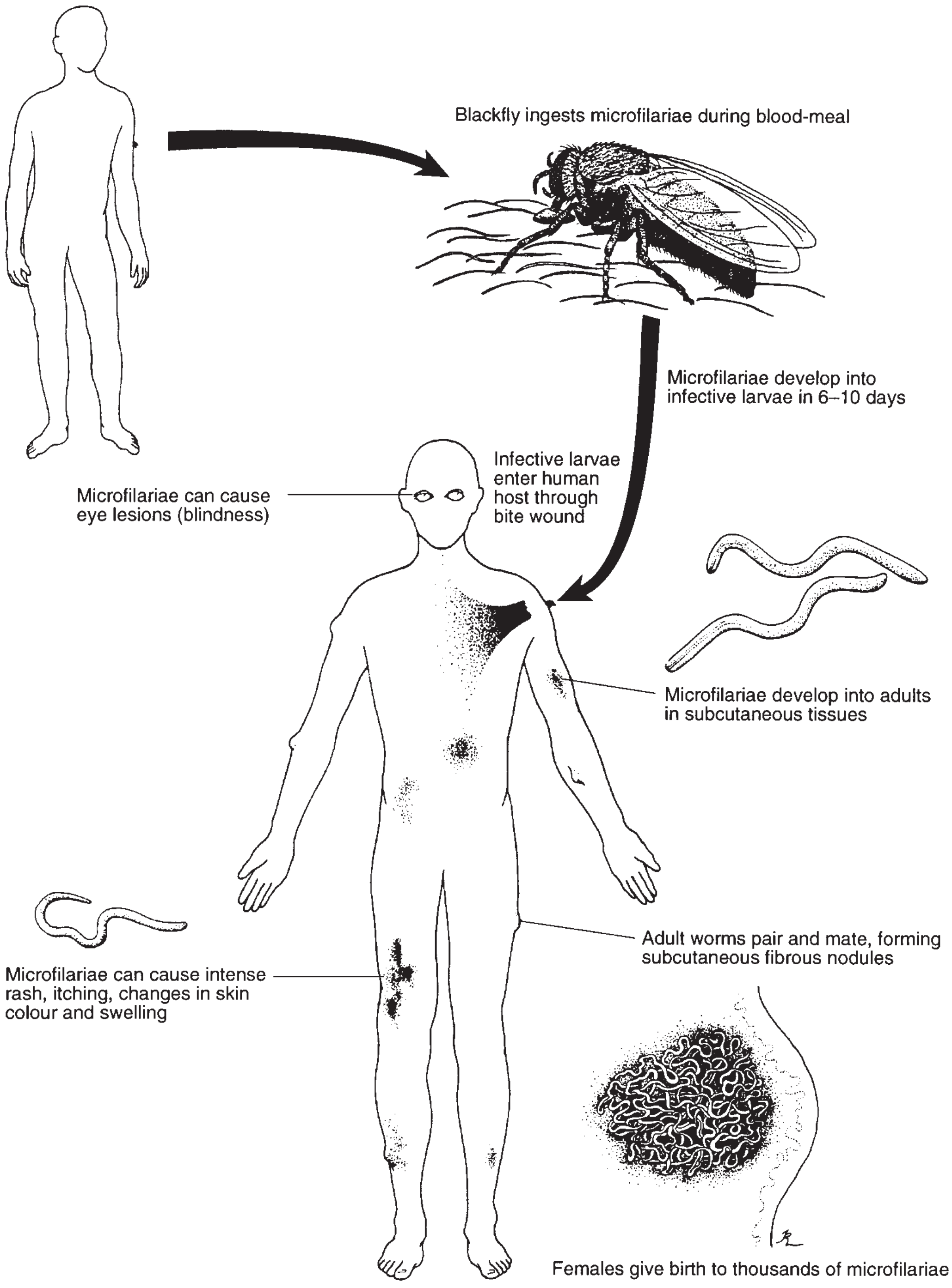


Fig. 1.29
Life cycle of *Onchocerca volvulus* (by Taina Litwak for the United States Agency for International Development's VBC Project).

up to 12 years and produce millions of microfilariae, which migrate to the skin where they can be ingested by biting blackflies. Transmission is most common near the fast-flowing rivers or streams where the blackflies breed and where they may attack humans in large numbers. Transmission does not take place below 18 °C and the disease occurs only in the tropics.

Clinical symptoms

The adult worms develop in nodules below the skin which range in diameter from a few millimetres to several centimetres. They are clustered in places where the skin closely overlies the bones. Most of the symptoms are caused by the microfilariae, which are released from the nodules and migrate to the skin and eyes. The most common complaint is itching.

In long-lasting infections the affected skin becomes atrophic and thin. Permanent damage to the eyes, including blindness—the most serious effect of the disease in terms of both individual well-being and rural economics—develops after prolonged heavy infection over several years. Travellers to affected areas are unlikely to develop serious symptoms should they become infected.

Fig. 1.30
Aerial application of insecticide to *Simulium* breeding sites in a river.

Treatment, prevention and control

The prevention of infection is only possible through blackfly control. Ivermectin, a newly developed drug, kills the microfilariae but not the adult worms. However, annual re-treatment with one tablet is sufficient to prevent blindness. It is now being used on a large scale to treat infected people and to stop further development of the disease.

In the eleven West African countries covered by the Onchocerciasis Control Programme (see box) the control of the disease is based on a combination of vector control and the distribution of ivermectin. In all other endemic countries in Africa and Latin America, and in Yemen, control is limited to the periodic distribution of ivermectin.

The Onchocerciasis Control Programme

In West Africa the Onchocerciasis Control Programme, a joint programme of WHO, UNDP, the World Bank, donor countries and the countries of West Africa, was initiated in 1974. It aims to reduce blackfly populations to low levels over a sufficiently long period (up to 20 years) to interrupt transmission of the parasite and to allow the adult worms, which can live in humans for up to 12 years, to die out completely. The programme is based on large-scale aerial applications of insecticides and, in recent years, the distribution of the drug ivermectin (*6*, *7*). The application of insecticides to streams and rivers in order to destroy the larvae is the only practical method of controlling the blackfly vectors (Fig. 1.30). The application of an insecticide to a selected breeding site usually also results in the killing of larvae in breeding sites located up to 10 km downstream. To avoid damaging the environment and wasting material, the insecticides employed are largely specific for blackfly larvae and are applied and monitored under careful supervision. Among the commonly used larvicides are temephos, phoxim and *Bacillus thuringiensis* H-14. The products are rotated to reduce the problem of the development of insecticide resistance in the blackfly populations (*8*, *9*).

One of the reasons for the large-scale applications to extensive networks of watercourses is the ability of the blackflies to fly with the wind over distances of up to several hundreds of kilometres. Localized control of breeding sites would not be sufficient because of the likelihood of reinvasion from outside areas.

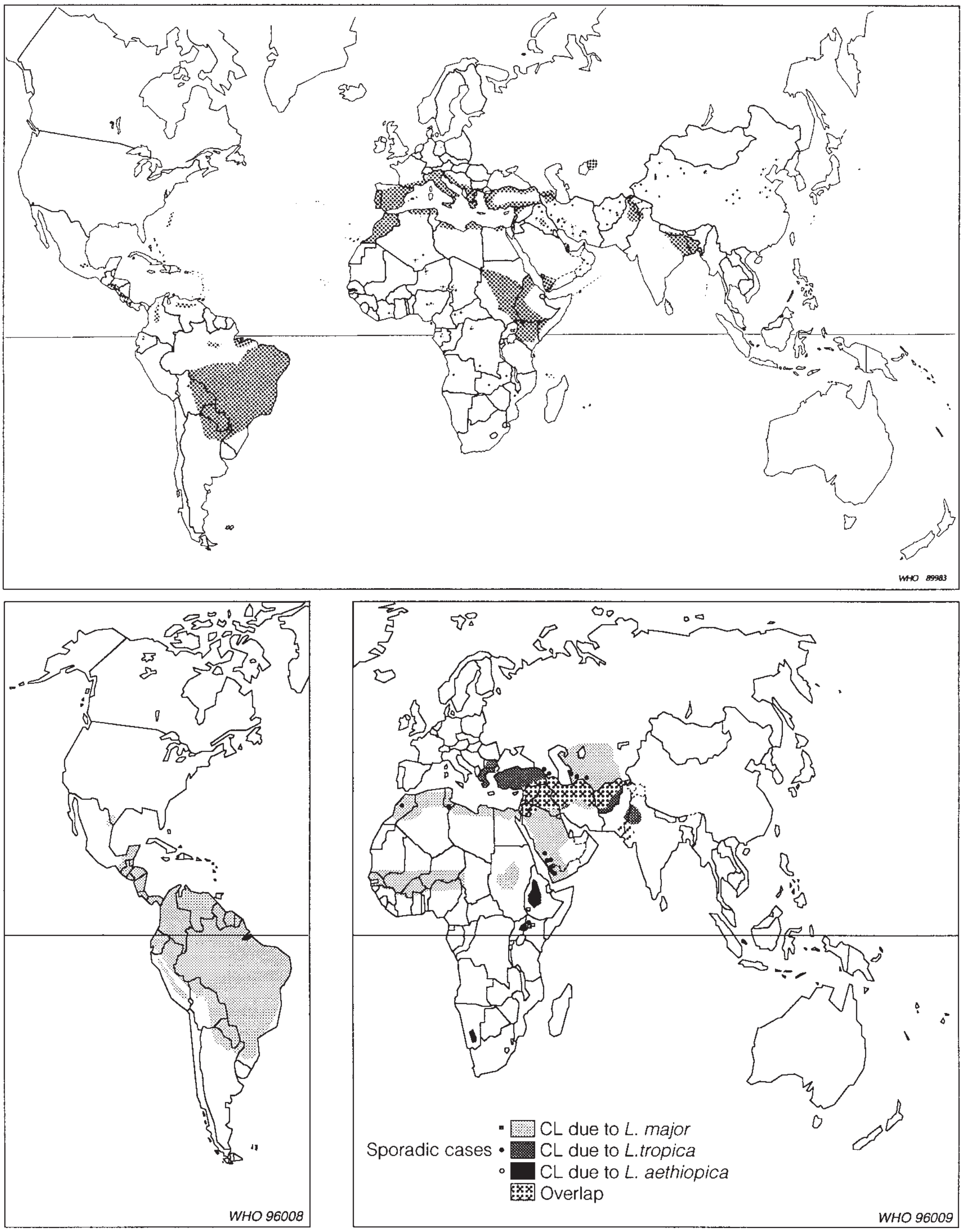
Leishmaniasis

Leishmaniasis is caused by protozoan parasites of the genus *Leishmania*, and occurs in both humans and animals. In 1996, it was estimated that some 12 million people were infected and 350 million were at risk of acquiring infection.

Visceral leishmaniasis, also known in the Indian subcontinent by its Hindi name, kala-azar, is caused by *Leishmania donovani, L. infantum* or *L. chagasi*; it is a disease of the internal organs and is often fatal if left untreated. It is endemic in East Africa, the Indian subcontinent and South America, and occurs sporadically in China, the Mediterranean region, south-west Asia and the countries of the southern part of the former USSR (Fig. 1.31a).

Mucocutaneous leishmaniasis, also known in South America as espundia, is caused mainly by *Leishmania braziliensis*; it is a disease of the skin and mucosal tissues in the nose and mouth, and can lead to gross deformities. It occurs in

(a)



(b) (c)

Fig. 1.31
Distribution of leishmaniasis: (a) visceral leishmaniasis in the Old and New World, 1989; (b) cutaneous and mucocutaneous leishmaniasis in the New World, 1996; (c) cutaneous leishmaniasis in the Old World, 1996 (© WHO).

Central and South America; oronasal leishmaniasis due to other *Leishmania* species has been recorded in Ethiopia and Sudan (Fig. 1.31b).

Cutaneous leishmaniasis is known under a variety of common names such as oriental sore, clou de Biskra, Aleppo boil, Bahia ulcer and chiclero's ulcer. It is caused by, among other species, *Leishmania major, L. tropica* and *L. aethiopica*, and species of the *braziliensis* and *mexicana* complexes, and results in ulcers of the skin. It is the most common form of leishmaniasis and occurs in Africa, South America, the Indian subcontinent, south-west Asia, the Mediterranean region and the countries of the southern part of the former USSR (Figs 1.31b and1.31c).

Transmission

Most forms of leishmaniasis are primarily infections of small mammals. Humans are often infected by sandflies which previously fed on infected animals (Fig. 1.32). The importance of animals as reservoirs of parasites varies from place to place and transmission from human to human also occurs. The sandfly species involved in transmission also vary from one place to another and often differ in their ecology and behaviour.

In South America the persons at highest risk of infection with cutaneous or mucocutaneous leishmaniasis are those entering forests, such as woodcutters, collectors of rubber and other forest products, hunters, construction workers and farmers. An elevated risk occurs in settlements close to dense forests (*10*).

In the Indian subcontinent, indoor and peridomestic transmission is more common since visceral leishmaniasis is anthroponotic and the vector is strictly peridomestic. In Africa, there is a great variety of epidemiological situations. For example, in East Africa the risk of visceral leishmaniasis infection is increased among men who often sit in communal groups around termite hills, and there is a heightened risk of cutaneous leishmaniasis infection among boys who drive cattle into caves to find shelter and salt licks (R. Killick-Kendrick, personal communication).

The risk of being infected is higher for people who sleep outdoors or have outdoor activities at night. An increased risk also occurs in places where there are infected rodents or other host animals.

Clinical symptoms

Where visceral leishmaniasis (kala-azar) is endemic, children are most affected except in southern Europe and China, and twice as many males are affected as females. The disease starts slowly with fever, malaise, loss of weight and, in many cases, cough and diarrhoea. A major clinical sign is enlargement of the spleen and liver (Fig. 1.33); lymphadenopathy may be present. Kala-azar may cause darkening of the skin of the face, hands, feet and abdomen in India. Other signs are similar to those of malnutrition, such as oedema and changes in skin and hair. The disease may follow a more severe and acute course in people from areas without kala-azar who have no immunity.

In cutaneous leishmaniasis the symptoms differ between and within regions, depending on the species of parasite and the immune response of the patient. A typical ulcer starts as a nodule at the site of the sandfly bite; a crust develops in the middle which, if it falls away, exposes the ulcer (Fig. 1.34). The ulcer heals

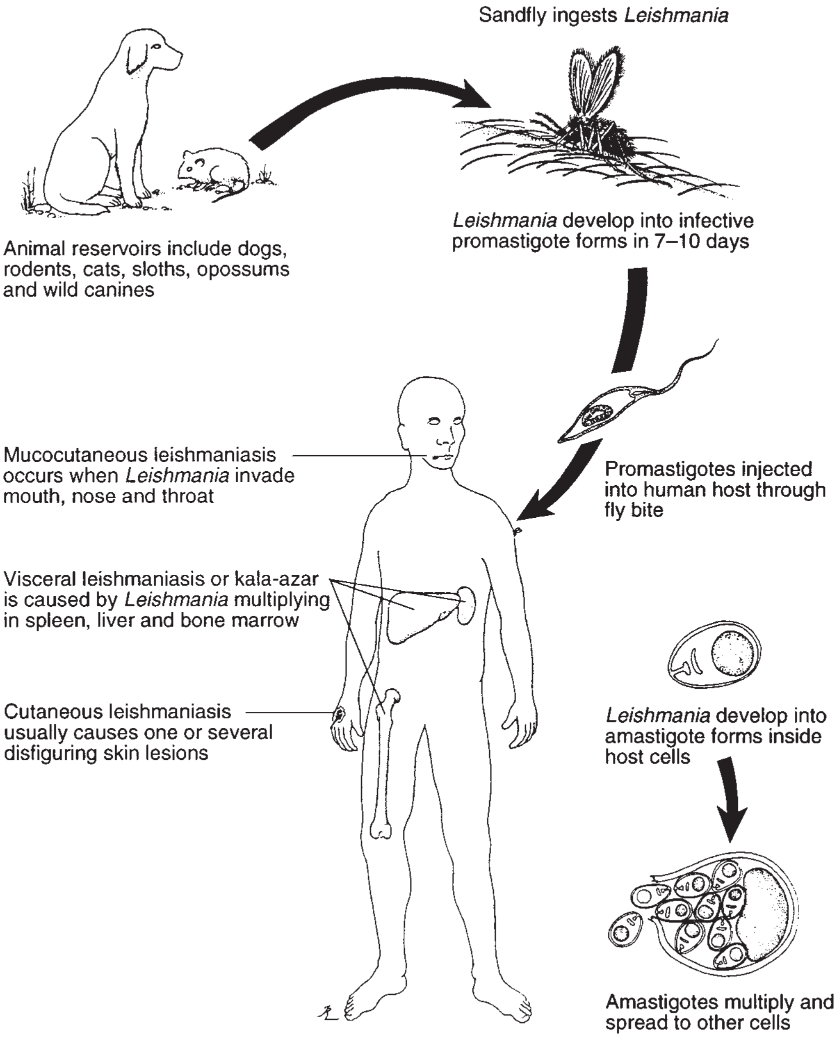


Fig. 1.32
Life cycle of *Leishmania* (by Taina Litwak for the United States Agency for International Development's VBC Project).

gradually and leaves a permanent depressed scar different in colour from the surrounding skin. Depending on the parasite species, healing takes place spontaneously in periods ranging from two months to several years. Some types do not heal without treatment and may develop into mucocutaneous leishmaniasis. Sometimes the disease spreads via the lymphatic system and causes ulcers all over the body.

The first symptoms of mucocutaneous leishmaniasis are similar to those of cutaneous leishmaniasis but the parasites may spread to the mucosa in the oronasal and pharyngeal cavity. The soft tissues and cartilage in these areas are then progressively destroyed by ulcers and erosion (Fig. 1.35). Swelling of the lips and nose may produce a so-called "tapir nose". Mutilations are severe and occasionally result in death due to malnutrition and bronchopneumonia.

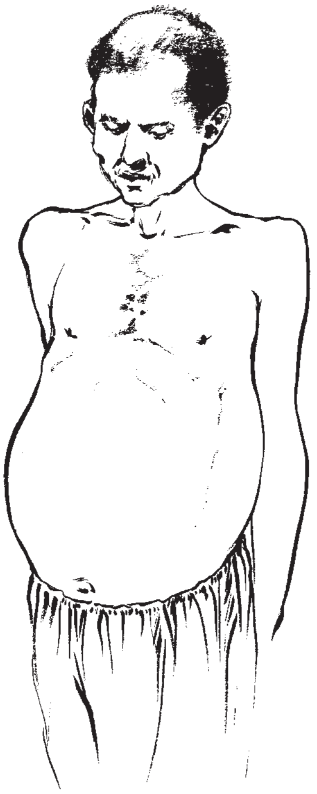


Fig. 1.33
A typical clinical sign of visceral leishmaniasis is enlargement of the spleen and liver.

Fig. 1.34
Cutaneous leishmaniasis may typically cause ulcers which, after healing, leave permanent depressed scars.

Treatment

Simple cutaneous leishmaniasis usually heals without treatment and renders the person immune to other infections with the same parasite species. For this reason, infants have sometimes deliberately been infected on their back or buttocks to protect them from other infections which might have caused ugly scars on the face.

Fig. 1.35
Mucocutaneous leishmaniasis may cause severe mutilations of the face through progressive destruction of soft tissues in the cavities of the mouth and nose.

The other forms of leishmaniasis are difficult to treat and usually require a long course of pentavalent antimony—meglumine antimoniate or sodium stibogluconate. The injections are frequent and painful and although treatment is usually well tolerated, mild side-effects can arise, including anorexia, vomiting, nausea, malaise, myalgia and headache. More rarely, hepatotoxicity and cardiotoxicity produce more serious side-effects. The second-line drugs are amphotericin B and pentamidine.

Prevention and control

Individuals can prevent infection by avoiding being bitten by sandflies. It is recommended that personal protection measures be taken, that fine-mesh or insecticide-treated bednets be used and that house improvements be carried out. Self-protection is sometimes possible by avoiding places where sandflies are known to rest or breed. In dense forests it is recommended not to stand between buttress roots of large trees (Fig. 1.36). New settlements in forests should preferably be surrounded by a forest-free belt about 300–400 metres in width (*11*, *12*).

To reduce the transmission of leishmaniasis, approaches adapted to the epidemiological circumstances have to be put into effect, such as the detection and treatment of patients and the control of vectors or reservoir hosts. Control measures also depend on the habits of local vector species and, if applicable, the habits of the reservoir animals. Where the parasite reservoir is exclusively in humans, outbreaks can be controlled by case detection and rapid treatment.

Indoor-resting sandflies can be effectively controlled by spraying the inside surfaces of walls and the interiors and exteriors of doorways, windows and other openings with a residual insecticide. Only in a few areas have insecticides been sprayed against leishmaniasis vectors alone. In most cases, the control of malaria mosquitos has been the main priority, that of sandflies being coincidental. In the

case of epidemic outbreaks, ultra-low-volume insecticide space-spraying in and around houses is worthy of consideration.

With regard to the control of animal reservoirs, it should be noted that certain development activities can cause a reduction in the occurrence of *Leishmania* when alteration of the environment makes it unsuitable to the wild host animals that live in forests. In Ethiopia, control measures were carried out against the rock hyrax, a wild animal reservoir of leishmaniasis. The most important domestic reservoir animal is the dog, but horses, donkeys and mules have also been reported as domestic reservoirs for cutaneous leishmaniasis in the Americas. In some areas, for instance Brazil, China, the Mediterranean region and the former USSR, measures have been taken to destroy infected dogs and other reservoir animals. In the former USSR the main control programme was against the great gerbil, *Rhombomys opimus* (*13*).

Mansonellosis

Mansonellosis is caused by infection with one of the human filarial parasites belonging to the genus *Mansonella. Mansonella ozzardi* occurs in Mexico, Panama, the Caribbean and South America. It is most prevalent among American Indians and is transmitted by biting midges of the genus *Culicoides* and by blackflies. It is generally considered harmless but some complaints, such as pain in the joints,

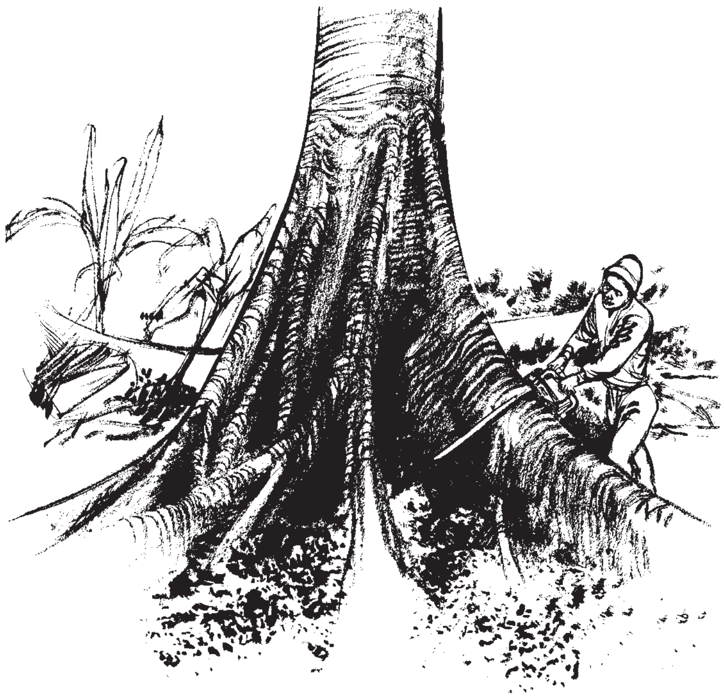


Fig. 1.36
In dense tropical forests of South America, sandflies often rest and breed in humid soil between the buttress roots of large trees.

have been reported. *Mansonella perstans* occurs in parts of South America and Africa, *M. streptocerca* in some West and Central African countries. Both parasites are transmitted by *Culicoides* biting midges.

The adult worms live in body cavities and in the mesentery where they seem to cause little or no harm to the human host. The larvae occur in the blood and skin.

Infections with these parasites can be treated with diethylcarbamazine. Most cases remain untreated because infected persons rarely complain of symptoms.

Loiasis

This disease is caused by the filarial parasite *Loa loa*. It is transmitted by deerflies of the genus *Chrysops* and occurs only in woods and forests in West and Central Africa, from Benin to Uganda and southern Sudan.

Its life cycle resembles that of *Onchocerca volvulus* (see Fig. 1.29). The adult worm lives in tissues under the skin. Migrations of the worms under the skin may cause a pricking, itching sensation. Infection sometimes causes swelling of various parts of the body. The larvae occur in the bloodstream and are picked up by biting tabanids.

Treatment is possible with diethylcarbamazine and ivermectin.

Tularaemia

This is a bacterial disease transmitted by the bites of deerflies (*Chrysops*) and hard ticks. For more information see Chapter 4.

Control measures

Selecting the most appropriate control measures

Table 1.2 shows where and when the different groups of biting Diptera are active. Personal protection measures, such as repellents and protective clothing, are effective against all of them. Bednets are effective against Diptera that bite at night. Measures to make houses and shelters insect-proof work against species that enter houses to feed and rest. Mosquitos can usually be prevented from breeding in and around houses by simple, long-lasting measures. However, some biting may continue because of mosquitos flying in from adjacent plots of land where they still breed. Cooperation between neighbours is therefore important in order to achieve good control.

The self-protection methods can be selected without knowing exactly which species one wishes to control. They are mainly used to protect individuals, families or small groups of people living together. Methods such as the use of insecticide-treated bednets, house improvement and the prevention of breeding may also be used to reduce diseases in a community if the majority of the people participate.

The methods for disease control in the community are usually implemented on a large scale and require at least some support and participation by a local health care organization. Health workers with experience in the control of vector-borne disease should be consulted for the selection and implementation of the most appropriate control strategy for the local situation.

Table 1.2
Selection of control measures for biting Diptera[a]

Pest/ vector	Indoor/ outdoor biting (I/O)	Day/night biting (D/N)	Self-protection					Disease control in the community			
			Personal protection		Insect-proofing of houses	Prevention of breeding in and around houses	Other control methods (adults)	Residual wall-spraying	Space-spraying[b]	Prevention of breeding in field	Other control methods (adults)
			Repellents, clothing	Bednets							
Anopheles	I/O	N	+ +	+ +	+ +	+/–[c]	+/–[d]	+	+/–	+	+/–[d]
Culex	I/O	N	+ +	+ +	+ +	+ +[e]	+/–[f]	+/–	+/–	+/–[g]	+/–[f]
Aedes	I/O	D	+ +	+/–	+ +	+ +	–	+/–	+	+/–[h]	–
Mansonia	I/O	N	+ +	+ +	+ +	–	–	–	–	+/–[i]	–
Blackflies	O	D	+ +	–	–	–	–	–	–	+[j]	–
Sandflies	I/O	D/N	+ +	+ +	+ +	–	+/–[k]	+/–	+/–	+/–	+/–[k]
Midges	I/O[l]	D/N	+ +	+ +	+ +	–	–	–	–	+/–[m]	–
Horseflies	O	D	+[n]	–	–	–	–	–	–	–	–
Stable flies	O	D	+ +	–	–	+/–	+[o]	–	–	–	+[o]
Tsetse flies[p]	O	D	+	–	–	–	+[q]	–	+/–	–	+[q]

[a] + + = effective; + = usually effective; +/– = sometimes effective; – = not effective.
[b] In the case of epidemic outbreaks, ultra-low-volume insecticide space-spraying can be considered.
[c] *Anopheles* does not usually breed near houses in urban areas, with the exception of *A. stephensi* in southern Asia. In Africa, malaria transmission occurs in the semiurban fringes of cities with prevailing rural conditions.
[d] It may be possible to obtain some additional protection by diverting mosquitos to domestic animals (see p. 105).
[e] Against *Culex quinquefasciatus*.
[f] Siting animal shelters far away from rice fields was effective in Japan (*14*).
[g] Control of the larvae of *Culex tritaeniorhynchus* in rice fields in Asia is difficult but may sometimes be achieved by intermittent irrigation, the use of larvivorous fish, and the application of bacterial larvicides.
[h] To control pest mosquitos breeding in rural areas, such as tidal salt marshes, granular insecticides are sometimes used which only release the active agent after flooding with water, which coincides with the hatching of the eggs. Other methods include the control of water levels and the improvement of irrigation and drainage systems.
[i] Sometimes by removing or destroying the aquatic vegetation to which the larval and pupal stages are attached (see p. 18).
[j] By application of larvicides to streams and rivers (see p. 45).
[k] By avoiding places where sandflies are known to rest and breed.
[l] Sometimes biting midges enter houses or tents.
[m] Where feasible the draining or filling of marshy areas is highly effective but is often too costly. In some cases, aerial spraying of such places with insecticides provides effective but temporary control by killing the larvae.
[n] Protection from bites is possible with thick clothing. Commonly available repellents are moderately effective against tabanids.
[o] Methods that reduce or stop feeding on domestic animals not only benefit them but also the people living near their quarters. Commercially available insecticide-impregnated eartags for animals are highly effective against *Stomoxys calcitrans* for between one and two months.
[p] See Chapter 2.
[q] Includes the use of traps and screens and spraying of daytime resting places of the flies with residual insecticides.

Personal protection

Personal protection methods, used by individuals or small groups of people to protect themselves from biting insects and the diseases they may carry, act by preventing contact between the human body and the insects. The equipment is small, portable and simple to use. The methods may offer significant protection against infection to individuals and sometimes have an impact on disease transmission in communities when a large proportion of people use them.

Repellents

Repellents are among the most commonly used methods to prevent mosquitos and other blood-sucking pests from biting. They are applied directly to the skin or to clothing and other fabrics such as bednets and anti-mosquito screens. Repellents evaporate much more quickly than most insecticides. Insecticides last longer and act by killing or knocking down insects after contact, whereas most repellents act by preventing human–insect contact and do not knock down or kill. The duration of protection by a repellent applied to skin may range from 15 minutes to 10 hours; on clothing and other fabrics the effect lasts much longer. The effectiveness and duration depend on the type of repellent (active ingredients and formulation; see Fig. 1.37), the mode of application, local conditions (temperature, humidity, wind), the attractiveness of individual people to insects, loss due to removal by perspiration and abrasion (*15–17*) and the sensitivity of the insects to repellents, each species having its own specific sensitivity (*18–20*). The biting density also plays an important role: the more mosquitos there are, the more one is likely to be bitten.

Under certain conditions the user may be completely protected while in other situations the protection is limited. People working or travelling in humid tropical forests are likely to need repeated application of repellents to the skin because of quick removal by perspiration (*21*). Because of the short period of action,

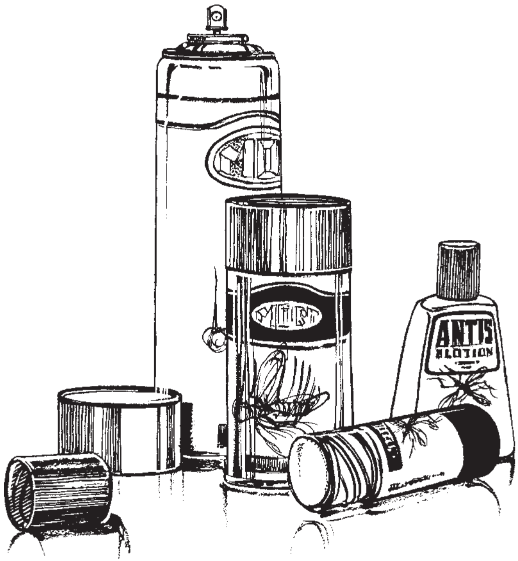


Fig. 1.37
Repellents are available as sprays, lotions, creams, sticks and wipe-on applicators or tissues.

repellents are mostly applied when insects start biting. For mosquitos this is very often around sunset.

When and where to use

Repellents are valuable for people in situations where other protective measures do not work, are impractical or are prohibited: people who must be outdoors at night; plantation workers at risk during daytime; people crossing or approaching areas such as tundras, swamps, grasslands or forests infested with mosquitos or other biting insects; and so on. Repellents may be preferred for use indoors if the screening of a house is impossible or considered unpleasant because it reduces ventilation too much in hot climates. Travellers often favour repellents as they are easily transportable and they can be applied anywhere at any time. Repellents can play an important role in combination with other methods for the control of mosquitos or biting flies; for example their use in the early evening can be followed by the use of bednets against indoor night-biting mosquitos.

Repellents are widely available but their retail price may be too high for daily use by many people. The various types differ in effectiveness according to their composition.

Instructions for use

Whatever repellent is used, it should be applied sparingly to all exposed skin, especially the neck, wrists and ankles. The surroundings of the eyes or mucous membranes (nose, mouth) should not be treated. Repellents should not be sprayed on the face; instead they can be applied by spraying on to the hands (Fig. 1.38) and then rubbing on to the less sensitive parts of the face as necessary. If an allergic skin reaction is observed the treated skin should be washed with water and a physician consulted and shown the can or other packing material (Fig. 1.39). A repellent can be checked for adverse skin reactions by applying a small quantity to the back of the hand.

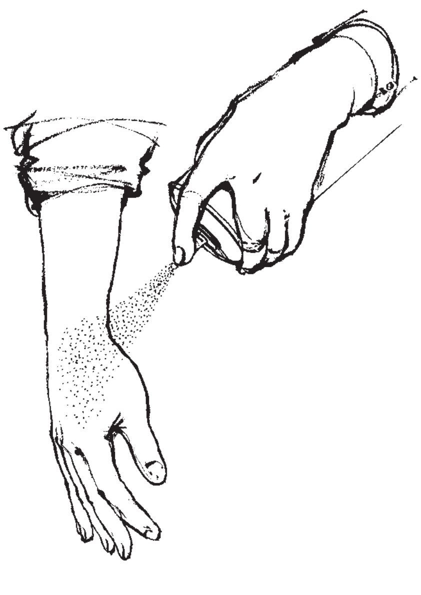


Fig. 1.38
Spray cans are used to apply repellent to exposed body parts.

Types of repellent

Traditional or natural repellents

Various substances and methods of application have been used since ancient times to repel blood-sucking insects (*22*). Smoke from an open fire repels insects, especially in still air or a poorly ventilated dwelling. The repellent effect of smoke may be increased by burning certain materials such as aromatic wood containing resins or various types of plant. In southern India, leaves of *Vitex negundo* ("nochi") are burned to repel mosquitos from houses.

The oils of some plants, such as citronella, are repellent when applied directly to the skin or clothing but their protective effect is very brief. It has sometimes been prolonged by mixing the volatile repellent with animal fat or oil to reduce the rate of evaporation. Many traditional repellents have the disadvantages that:

— they last a very short time;
— they are unpleasant to use (strong odours, irritating);
— they may have unhealthy side-effects (e.g. smoke).

However, their advantages are that:

— they are easily available;
— they are locally known and acceptable;
— they are inexpensive.

In this manual it is impossible to mention all the locally used traditional repellent substances and their application methods. Many of these substances have never been tested by scientists and their effectiveness remains to be confirmed.

Some plant products used as repellents which are safe for humans

Citronella

Oil from the citronella plant is widely used as a repellent. Industrially produced citronella is an active ingredient in some commercial repellents. When freshly applied to human skin, citronella is about as effective in repelling some biting insects as the chemical repellents, but for only about an hour.

Neem tree

In Africa, Asia and Latin America, leaves of the neem tree (*Azidarachta indica*) are sometimes burnt, producing an unpleasant odour, or hung dried inside houses. Some people believe that neem trees near a house keep mosquitos away but there is no scientific evidence of this. Extracts of neem seeds are used as agricultural insecticides.

Aromatic trees

The wood or the extracted resin of certain aromatic trees is sometimes burnt as a mosquito repellent. In some African countries such wood is sold in local markets (*23*).

Modern repellents for application to the skin

During the latter half of the twentieth century, several synthetic repellents have been produced which are long-lasting, nontoxic, cosmetically acceptable on the

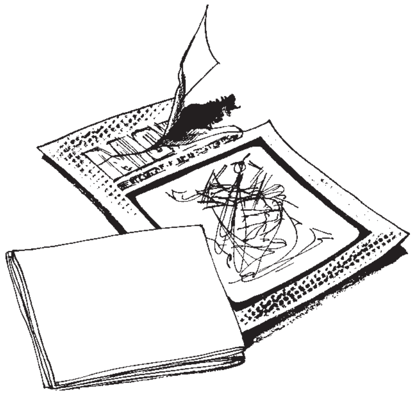


Fig. 1.39
A repellent-impregnated tissue taken out of its air-tight package. The tissue is saturated in a mixture of deet and alcohol. It is used for wipe-on application.

skin, and effective against a wide variety of insects. The most successful substances for skin application, developed in the first half of this century, were dimethyl phthalate, indalone and ethyl hexanediol. These substances are still among the active ingredients of some commercial repellents.

A breakthrough came in 1954 with the discovery of *N,N*-diethyl-3-toluamide or deet, a colourless, oily liquid with a slight odour. It is still the best available product, repelling a wide variety of insects, ticks and mites and generally lasting longer than the other repellents (*18–20*, *24–27*). Deet is also effective against blood-sucking terrestrial leeches (*28*, *29*).

Deet is available as a pure liquid and in 5–90% solutions. To make deet and other repellents more convenient to apply and cosmetically attractive, they are often prepared as lotions, creams, foams, solid waxes (sticks) or spray-on preparations in pressurized containers. The repellents are often mixed with an oily or alcoholic base and a pleasant smelling perfume. The mixtures are spread, wiped or sprayed onto the exposed skin.

In some mixtures the base material (oils, silicones, polymers) reduces the evaporation rate of the repellent, thus extending the duration of efficacy (*15–17*). In some formulations of deet the repellent effect may last up to 12 hours, although 4–6 hours is more common. A disadvantage of some extended-duration formulations is that they may feel sticky when applied to the skin; this does not happen with an ethanol solution of deet.

Allergic or other serious reactions to deet, such as the development of rash, have rarely been reported (*30–32*). The compound is considered safe for adults, except following prolonged exposure to high concentrations. Since children appear more sensitive, it is recommended that their skin exposure be kept to a minimum whenever possible and that deet should be applied to their clothing, rather than to their skin (*33*). Some plastic materials (e.g., pens, watch faces, spectacle frames, car seat covers) and painted surfaces may be dissolved or damaged by deet.

Data from India suggest that *N,N*-diethylphenylacetamide (DEPA) is as effective as deet but less expensive (*34*). Citronella is often used because it is inexpensive and some people think that it has a more pleasant smell. Less commonly available are dimethyl phthalate and some carboxylic compounds. They are mixed with deet in some commercial formulations. Mixtures of different repellent substances may be effective against a wider variety of insects than single repellents.

Repellent bar

This is a recently developed inexpensive personal repellent that provides relatively long-lasting protection. It is made of materials used in soap production, such as coconut oil, and contains 20% deet and 0.5% permethrin. The bar is used by wetting it (or the skin) and producing a lather that is rubbed on exposed parts of the body (Fig. 1.40). The face can be protected by application to the neck, forehead and ears. After application a white lotion-like film remains on the skin for a short time. The residual film feels sticky and some users find it unpleasant. It is not easily removed by contact with clothes but can be removed by rinsing or rubbing. The method is considered safe but care should be taken to avoid sensitive skin areas when it is used on small children. However, it is not yet recommended by WHO for long periods of repeated daily usage, pending a full safety evaluation.

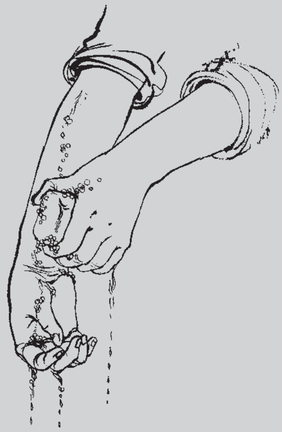


Fig. 1.40
The repellent bar.

The repellent bar should be applied at sunset to provide protection during the evening. Depending on the local mosquito species and other factors, the repellent soap protects for 4–8 hours. Under optimal conditions, protection lasting up to 12 hours may be achieved. The amount and duration of protection have been reported to vary for different species of insects and different conditions of use (*35–39*).

A 40-gram bar, used daily and sparingly on arms, legs and other exposed areas, lasts approximately 20 days. Although the bar is patented, the patent holder permits local production for non-commercial purposes. The procedure and ingredients are similar to those for the production of soap.

Ingredients	*% by weight*
Crude raw coconut oil	49.86
Antioxidant, such as butylated hydroxyanisole (BHA)	0.14
Deet	20.00
Pharmaceutical-grade permethrin (25/75 *cis/trans* permethrin)	0.50
Perfume base (e.g., rose, oil of lavender)	1.00
Caustic soda solution	27.50
Natural clay	1.00

The ingredients should be obtainable from most pharmacies. Deet can be obtained from most chemical suppliers. Technical-grade permethrin is a suitable alternative to the pharmaceutical-grade compound.

Mix the permethrin with deet at room temperature and add to the coconut oil in which the antioxidant has been dissolved. Heat the resultant blend to 40 °C and add the perfume base. 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.