CHAPTER 1
Mosquitos and other biting Diptera

Vectors of malaria, leishmaniasis, filariasis, onchocerciasis, dengue, yellow fever and other diseases
The biting Diptera are two-winged flying insects that suck blood from humans and animals. In many parts of the world their biting is a considerable nuisance. More importantly, they are carriers of a number of diseases, mostly in the tropics, causing illness and death on a large scale.

The most important group of biting Diptera is the mosquitoes, which have a long, slender body and long, needle-shaped, piercing mouthparts. Others include the blackflies, phlebotomine sandflies, tsetse flies, biting midges, horseflies (tabanids) and stable flies, which generally have shorter biting mouthparts and more robust bodies. The last three groups are of limited importance as vectors of human disease.

Table 1.1 shows the diseases transmitted by each group.

**Distinguishing features of biting Diptera**

**Mosquitoes**

Mosquitoes differ from the other biting Diptera in having a long slender body, long legs and long needle-shaped mouthparts (Fig. 1.1a). The wings sometimes have discernible patterns of scales. The adult insects measure between 2 mm and 12.5 mm in length.

Some species bite in the morning or evening and at night; others feed during the day. Species may bite indoors or out of doors.

**Table 1.1**

<table>
<thead>
<tr>
<th>Vectors</th>
<th>Diseases</th>
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<tbody>
<tr>
<td><strong>Mosquitoes (Culicidae)</strong></td>
<td></td>
</tr>
<tr>
<td>Anopheles</td>
<td>Malaria, lymphatic filariasis</td>
</tr>
<tr>
<td>Culex</td>
<td>Lymphatic filariasis, Japanese encephalitis, other viral diseases</td>
</tr>
<tr>
<td>Aedes</td>
<td>Yellow fever, dengue, dengue haemorrhagic fever, other viral diseases, lymphatic filariasis</td>
</tr>
<tr>
<td>Mansonia</td>
<td>Lymphatic filariasis</td>
</tr>
<tr>
<td><strong>Other biting Diptera</strong></td>
<td></td>
</tr>
<tr>
<td>Tsetse flies (Glossina)</td>
<td>African sleeping sickness</td>
</tr>
<tr>
<td>Blackflies (Simulium)</td>
<td>River blindness (onchocerciasis), mansonellosis (usually symptomless)</td>
</tr>
<tr>
<td>Sandflies (Phlebotomus, Lutzomyia)</td>
<td>Leishmaniasis, sandfly fever</td>
</tr>
<tr>
<td>Horseflies (Tabanidae)</td>
<td>Loiasis, tularaemia</td>
</tr>
<tr>
<td>Biting midges (Ceratopogonidae)</td>
<td>Mansonellosis (usually symptomless)</td>
</tr>
</tbody>
</table>
Blackflies are stout-bodied, about 1–5 mm long, and are usually black, although orange and yellow species exist. They have relatively large eyes. The legs are short, and the wings are short, broad and colourless (Fig. 1.1b).

**Fig. 1.1**
The biting Diptera: (a) mosquitos (by courtesy of Professor M. Wéry, Institute of Tropical Medicine, Antwerp, Belgium; mosquito at rest, © L. Robertson); (b) blackflies; (c) biting midges; (d) phlebotomine sandflies; (e) deerflies (f) and horseflies; (f) tsetse flies; (g) stable flies (all figures by courtesy of the Natural History Museum, London, except where otherwise indicated).
Blackflies bite in daytime, out of doors; some species prefer to feed only on certain parts of the body, for example the legs or the upper part of the body.

**Biting midges**

Biting midges are about 1.5 mm long. They bite at any time of day or night, but most commonly in the late afternoon and the early part of the night. Because of their short mouthparts (Fig. 1.1c) they are not very successful in biting through clothing; they are often observed in swarms around the head, biting the face. Other exposed parts of the body may also be attacked. Most species only feed out of doors. They can be a severe nuisance and because of their small size they can easily pass through standard mesh mosquito nets.

**Phlebotomine sandflies**

Sandflies are about 1.5–4 mm long. They have a hairy appearance, conspicuous black eyes and long, stilt-like legs (Fig. 1.1d). They have a characteristic hopping flight with many short flights and landings. In contrast to all other biting Diptera, the wings are held erect over the body when at rest. Sandflies usually bite after dark, but may bite in daytime during cloudy weather in forests. Most species feed outdoors but a few feed indoors. Because of their short mouthparts they cannot bite through clothing.

**Horseflies and deerflies**

The tabanids are medium- to large-sized flies (6–25 mm long) and are avid bloodsuckers and powerful fliers. Some species are the largest biting Diptera, having a wing span of 6.5 cm. They vary in colour from very dark to light and are often iridescent. They have a large head with large conspicuous eyes. The mouthparts do not point forward (as in the tsetse flies) but downward (Fig. 1.1e). The tabanids are especially active in daytime, in bright sunshine. They usually feed outdoors, mostly in woods and forests. Their bites are deep and painful and the wounds often continue to bleed after the flies have left. They can easily bite through clothing.

**Tsetse flies**

Tsetse flies occur only in tropical Africa. They are yellowish or dark brown, medium-sized flies, 6–15 mm in length. They can be distinguished from other large biting Diptera by their forward-pointing mouthparts (Fig. 1.1f; see also stable flies). They bite only in daytime.

**Stable flies**

Stable flies are dark, medium-sized flies, 5–6 mm in length, resembling houseflies in shape and size. They can be distinguished from houseflies and other similar-looking flies by their forward-pointing mouthparts (Fig. 1.1g). In Africa, they can be distinguished from tsetse flies, which also have forward-pointing mouthparts, by their smaller size and the position of the wings, which do not overlap when at rest. Stable flies bite in daytime and mostly outdoors. Biting is most common near
farms and other places where large domestic animals are kept. The flies feed mostly on the legs.

Mosquitos

Mosquitos are important vectors of several tropical diseases, including malaria, filariases, and numerous viral diseases, such as dengue, Japanese encephalitis and yellow fever. In countries with a temperate climate they are more important as nuisance pests than as vectors.

There are about 3000 species of mosquito, of which about 100 are vectors of human diseases. Control measures are generally directed against only one or a few of the most important species and can be aimed at the adults or the larvae.

Life cycle

Mosquitos have four distinct stages in their life cycle: egg, larva, pupa and adult (Fig. 1.2). The females usually mate only once but produce eggs at intervals throughout their life. In order to be able to do so most female mosquitos require a blood-meal (Fig. 1.3). Males do not suck blood but feed on plant juices. The digestion of a blood-meal and the simultaneous development of eggs takes

![Fig. 1.2](image1.png)
The life cycle of the mosquito (© WHO).

![Fig. 1.3](image2.png)
Freshly blood-fed mosquitos have a dilated abdomen.
2–3 days in the tropics but longer in temperate zones. The gravid females search for suitable places to deposit their eggs, after which another blood-meal is taken and another batch of eggs is laid. This process is repeated until the mosquito dies.

Depending on the species, a female lays between 30 and 300 eggs at a time. Many species lay their eggs directly on the surface of water, either singly (Anopheles) or stuck together in floating rafts (e.g. Culex). In the tropics, the eggs usually hatch within 2–3 days. Some species (e.g. Aedes) lay their eggs just above the water line or on wet mud; these eggs hatch only when flooded with water. If left dry they can remain viable for many weeks.

Once hatched, the larvae do not grow continuously but in four different stages (instars). The first instar measures about 1.5 mm in length, the fourth about 8–10 mm. Although they have no legs, they have a well developed head and body covered with hairs, and swim with sweeping movements of the body. They feed on yeasts, bacteria and small aquatic organisms. Most mosquito larvae have a siphon located at the tip of the abdomen through which air is taken in and come to the water surface to breathe; they dive to the bottom for short periods in order to feed or escape danger. Anopheles larvae, which feed and breathe horizontally at the surface, have a rudimentary siphon. Larvae of Mansonia do not need to come to the surface to breathe, since they can obtain air by inserting the siphon into a water plant, to which they remain attached for most of the time.

In warm climates, the larval period lasts about 4–7 days, or longer if there is a shortage of food. The fully grown larva then changes into a comma-shaped pupa, which does not feed and spends most of its time at the water surface. If disturbed it dives swiftly to the bottom. When mature, the pupal skin splits at one end and a fully developed adult mosquito emerges. In the tropics the pupal period lasts 1–3 days. The entire period from egg to adult takes about 7–13 days under good conditions.

**Biting behaviour**

Female mosquitoes feed on animals and humans. Most species show a preference for certain animals or for humans. They are attracted by the body odours, carbon dioxide and heat emitted from the animal or person. Some species prefer biting at certain hours, for example at dusk and dawn or in the middle of the night. Feeding usually takes place during the night but daytime biting also occurs. Some species prefer to feed in forests, some outside of houses, others indoors.

Because digestion of the blood-meal and development of the eggs takes several days, a blood-fed mosquito looks for a safe resting place that is shaded and offers protection from desiccation. Some species prefer to rest in houses or cattle sheds, while others prefer to rest outdoors, on vegetation or at other natural sites. Mosquitoes do not usually bite while eggs are developing.

The behaviour of mosquitoes determines whether they are important as nuisance insects or vectors of disease, and governs the selection of control methods. Species that prefer to feed on animals are usually not very effective in transmitting diseases from person to person. Those that bite in the early evening may be more difficult to avoid than species that feed at night. Mosquitoes that rest indoors are the easiest to control.
Distinguishing features of vector mosquitos

Among the mosquitos there are two groups that suck human blood and may transmit disease.

- The anophelines; the genus *Anopheles* is best known for its role in transmitting malaria, but in some areas it can also transmit filariasis.

<table>
<thead>
<tr>
<th>Anopheles</th>
<th>Aedes</th>
<th>Culex</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eggs</strong></td>
<td>Laid singly</td>
<td>Laid singly</td>
</tr>
<tr>
<td></td>
<td>Has floats</td>
<td>No floats</td>
</tr>
<tr>
<td><strong>Larvae</strong></td>
<td>Rest at an angle to the water surface</td>
<td>Rest at an angle to the water surface</td>
</tr>
<tr>
<td></td>
<td>Rudimentary breathing tube</td>
<td>Air tube</td>
</tr>
<tr>
<td></td>
<td>Short, stout breathing tube with one pair of hair tufts</td>
<td>Long, slender breathing tube with several pairs of hair tufts</td>
</tr>
<tr>
<td><strong>Pupae (differ only slightly)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Adult</strong></td>
<td>Proboscis and body at an angle to one another</td>
<td>Proboscis and body at an angle to one another</td>
</tr>
<tr>
<td></td>
<td>Maxillary palps as long as proboscis</td>
<td>Maxillary palps shorter than proboscis</td>
</tr>
<tr>
<td></td>
<td>Wings spotted</td>
<td>Wings generally uniform</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tip of female abdomen usually blunt</td>
</tr>
</tbody>
</table>

*Fig. 1.4*
Some of the main characteristics for differentiating *Anopheles*, *Aedes* and *Culex* mosquitos (© WHO).
• The culicines, which include the following genera:
  — *Culex*: vectors of filariasis and some viral diseases;
  — *Aedes*: vectors of dengue, yellow fever and other viral diseases, and sometimes of filariasis;
  — *Mansonia*: vectors of brugian filariasis;
  — *Haemagogus* and *Sabethes*: vectors of yellow fever in the forests of South and Central America.

*Anopheles*, *Culex* and *Aedes* mosquitoes can be distinguished from each other as shown in Fig. 1.4. The most useful characteristics for distinguishing anophelines from other mosquitoes are:

— the length of the palps is equal to that of the proboscis;
— while at rest they usually keep their mouthparts and abdomen in a straight line at an angle to the resting surface; the angle varies with the species and in some cases is almost perpendicular to the surface. *Anopheles culicifacies*, a malaria vector in south Asia, is an exception, keeping its body almost parallel to the surface. As its name suggests, it looks superficially like a *Culex* mosquito.

**Anopheles mosquitoes**

About 380 species of *Anopheles* (Fig. 1.5) occur around the world. Some 60 species are sufficiently attracted to humans to act as vectors of malaria. A number of *Anopheles* species are also vectors of filariasis and viral diseases.

**Life cycle**

Larval habitats vary from species to species, but are frequently exposed to sunlight and commonly found in association with emergent vegetation, such as grass or mats of floating vegetation or algae. The most preferred breeding sites are pools, seepages, quiet places in slow-running streams, rice fields, leaf axils of certain epiphytic plants and puddles of rainwater. Artificial containers, such as pots, tubs, cisterns and overhead tanks are not usually suitable, except in the case of *Anopheles stephensi* in south-west Asia.

The eggs, laid singly on the water surface where they float until hatching, are elongated, have a pair of lateral floats, and are about 1 mm in length. Hatching occurs in 2–3 days. The larvae float in a horizontal position at the surface, where they feed on small organic particles. In the tropics the duration of development from egg to adult is 11–13 days.

**Behaviour**

*Anopheles* mosquitoes are active between sunset and sunrise. Each species has specific peak biting hours, and there are also variations in their preference for biting indoors or outdoors.

The anophelines that enter houses to feed often rest indoors for a few hours after feeding. They may then leave for outdoor sheltered resting sites, among them vegetation, rodent burrows, cracks and crevices in trees or in the ground, caves and the undersides of bridges. Alternatively, they may stay indoors for the whole period needed to digest the blood-meal and produce eggs. Indoor resting is most common in dry or windy areas where safe outdoor resting sites are scarce. Once the eggs are
fully developed the gravid mosquitos leave their resting sites and try to find a suitable breeding habitat.

Many *Anopheles* species feed on both humans and animals. They differ, however, in the degree to which they prefer one over the other. Some species feed mostly on animals while others feed almost entirely on humans. The latter species are the more dangerous as vectors of malaria.

**Culex mosquitos**

About 550 species of *Culex* (Fig. 1.6) have been described, most of them from tropical and subtropical regions. Some species are important as vectors of
bancroftian filariasis and arboviral diseases, such as Japanese encephalitis. In some areas they are a considerable nuisance.

Life cycle
Rafts of 100 or more eggs are laid on the water surface. The rafts remain afloat until hatching occurs 2–3 days later. *Culex* species breed in a large variety of still waters, ranging from artificial containers and catchment basins of drainage systems to large bodies of permanent water. The most common species, *Culex quinquefasciatus*, a major nuisance and vector of bancroftian filariasis, breeds especially in water polluted with organic material, such as refuse and excreta or rotting plants. Examples of such breeding sites are soakaway pits, septic tanks, pit latrines, blocked drains, canals and abandoned wells. In many developing countries *Culex quinquefasciatus* is common in rapidly expanding urban areas where drainage and sanitation are inadequate.

*Culex tritaeniorhynchus*, the vector of Japanese encephalitis in Asia, prefers cleaner water. It is most commonly found in irrigated rice fields and in ditches.

Behaviour
*Culex quinquefasciatus* is a markedly domestic species. The adult females bite people and animals throughout the night, indoors and outdoors. During the day they are inactive and are often found resting in dark corners of rooms, shelters and culverts. They also rest outdoors on vegetation and in holes in trees in forested areas.

*Aedes* mosquitos
*Aedes* mosquitos occur around the world and there are over 950 species. They can cause a serious biting nuisance to people and animals, both in the tropics and in cooler climates. In tropical countries *Aedes aegypti* (Fig. 1.7) is an important vector of dengue, dengue haemorrhagic fever, yellow fever and other viral diseases. A closely related species, *Aedes albopictus*, can also transmit dengue. In some areas *Aedes* species transmit filariasis.
Life cycle

The eggs are laid singly on damp surfaces just above or near the water line in temporary pools and other habitats where the water level rises and falls. They can withstand desiccation for many months and hatch only when flooded with water. All species of Aedes which occur in regions with cold winters survive these periods in the egg stage. Some species breed in coastal salt marshes and swamps that are flooded at intervals by unusually high tides or heavy rains, while others have adapted to agricultural irrigation practices.

Aedes aegypti mainly breeds in the domestic environment: its preferred habitats are water storage tanks and jars inside and outside houses, and roof gutters, leaf axils, bamboo stumps and temporary containers such as jars, drums, used car tyres, tin cans, bottles and plant pots. All these habitats typically contain relatively clean water.

Aedes albopictus originally occurred only in Asia and Madagascar but recently invaded North and South America, as well as West Africa, where it may become important in the transmission of dengue and other viral diseases. Like Aedes
Aedes aegypti, it breeds in temporary containers but prefers natural ones in forests, such as tree holes, leaf axils, ground pools and coconut shells, and breeds more often outdoors in gardens and less frequently indoors in artificial containers.

**Behaviour**

*Aedes* mosquitos bite mainly in the morning or evening. Most species bite and rest outdoors but in tropical towns *Aedes aegypti* breeds, feeds and rests in and around houses.

**Mansonia mosquitos**

*Mansonia* mosquitos are mostly found in marshy areas in tropical countries. Some species are important as vectors of brugian filariasis in south India, Indonesia and Malaysia.

The body, including the legs and wings, is covered with dark-brown and pale scales, giving it a rather dusty appearance, as if sprinkled with salt and pepper.

**Life cycle**

The species that transmit filariasis normally lay their eggs in masses that are glued to the lower sides of plants hanging or floating near the water surface. Because the larvae and pupae attach themselves to aquatic plants for the purpose of breathing they occur only in water bodies containing permanent vegetation, such as swamps, ponds, grassy ditches and irrigation canals, and may be difficult to find. They can also occur in deeper water where there is floating vegetation, and are very often attached to the underwater parts of floating aquatic weeds (*Eichhornia, Pistia, Salvinia*) and grasses (Fig. 1.8).

**Behaviour**

*Mansonia* species usually bite at night, mostly out of doors, but some species enter houses. Resting after a blood-meal normally takes place out of doors.

**Blackflies**

Blackflies (Fig. 1.9) occur around the world and there are about 1300 species. Usually black in colour, they are 1.5–4 mm in length. The blackflies are vectors of onchocerciasis or river blindness in Africa and in Central and South America. In Africa the most important species are *Simulium neavei* and members of the *Simulium damnosum* complex. In addition, blackflies are a serious nuisance in many parts of the world because of their painful bites and the sometimes enormous numbers involved in attacks. Blackfly bites may cause localized swelling and inflammation and intense irritation of the skin lasting days or weeks. Normally blackflies do not enter houses.

**Life cycle**

The eggs are laid in fast-flowing, oxygen-rich water in streams, rivers and spillways of dams (Fig. 1.10). In the tropics, the eggs hatch after 1–4 days. The larvae do not
swim, remaining attached to submerged vegetation, stones and other substrates. They feed on small suspended particles. Depending on the climate, the larval stage lasts from one week to several months. The pupae are also attached to submerged objects and the adults emerge after 2–6 days.

**Behaviour**

Blackflies bite in the daytime and outdoors, especially along riverbanks. Certain species show a strong preference for biting specific parts of the body. For example,
Fig. 1.9
Blackfly: (a) in flight (© WHO); (b) at rest (by courtesy of the Natural History Museum, London).

Fig. 1.10
(a) Typical *Simulium* breeding site (© L. Robertson). Adult blackflies often occur in large numbers near such places. (b) Larvae attached to a leaf-blade of submerged grass (by courtesy of the Natural History Museum, London).
Simulium damnosum in West Africa mainly attacks the legs. Most species feed predominantly on birds or mammals; several feed on humans. In the tropics, blackflies digest blood-meals over a period of 2–3 days in outdoor resting places on trees and other natural sites.

Sandflies

Sandflies (Fig. 1.11) are small bloodsucking flies that are important as vectors of leishmaniasis and that can cause a serious but localized biting nuisance. Species that occur in the Mediterranean region can transmit sandfly fever, a viral disease also known as Pappataci fever or three-day fever.

Life cycle

Sandflies are found in various habitats, ranging from semi-desert to rainforest. They deposit their eggs in humid places on damp soil rich in humus. The larvae feed on decaying organic matter. Examples of suitable breeding sites are small cracks and holes in the ground, the ventilation shafts of termite hills, animal burrows, cracks in mud walls and masonry, and among tree roots. Large populations of sandflies can build up in family compounds where cattle are kept at night. The cattle provide an abundant source of blood, while the stables and houses provide suitable resting places (Fig. 1.12). The life cycle may last from 1 to 4 months, depending on species and temperature, although it usually lasts less than 45 days.

Fig. 1.11
Phlebotomine sandfly. About 1.3–3.5mm in length; hairy appearance; conspicuous black eyes; long, stilt-like legs (by courtesy of the Natural History Museum, London).
Behaviour

The adult sandflies are weak fliers and usually stay within a few hundred metres of their breeding places. They fly in a characteristic hopping way, with many short flights and landings. As a result, biting is restricted to areas where suitable breeding sites occur. Most biting occurs outdoors but a few species also feed indoors. Most species are active at dawn and dusk and during the night, but in forests and dark rooms they may also attack in the daytime, especially if disturbed by human activities. They usually rest in the daytime in sheltered, dark and humid sites, such as those used for breeding, but also in tree holes, caves, houses and stables; other resting places near houses are crevices in walls, stacks of firewood, bricks and rubbish.

Sandflies feed on plant juices but for the most part the females need a blood-meal in order to develop eggs. Autogeny occurs in a few species. Blood is taken from humans and animals such as dogs, farm livestock, wild rodents, snakes, lizards and birds. Each sandfly species has specific preferences for its source of blood, but the availability of hosts is an important factor. The saliva of sandflies can enhance the virulence of inoculated *Leishmania* parasites. Sandfly species are only important as vectors of leishmaniasis if they feed regularly on humans.

Biting midges

Biting midges (Fig. 1.13) are bloodsucking flies, about 1.5 mm in length. The most important genus, *Culicoides*, is distributed worldwide and can cause a serious biting problem, as can the genus *Leptoconops* in the Americas. In parts of South America and Africa these insects are vectors of the human filarial parasites.
Mansonella ozzardi and M. perstans, which are generally considered to be harmless to humans.

These insects are called sandflies in some parts of the world, but they can be distinguished from the phlebotomine sandflies by the fact that the wings are folded flat over the body when the midges are at rest; furthermore, they often fly in swarms around the head or other exposed parts of the body and they do not fly in a hopping way with many short flights and landings, as do the phlebotomine sandflies.

Life cycle

Several species breed in swampy and marshy areas, including saltwater marshes and mangrove swamps, where they lay their eggs on the elevated surface of mud or wet soil. Some important pest species breed on sandy beaches near the sea. Other species lay their eggs on decaying leaf litter, humus, manure and semi-rotting vegetation, in tree holes and the cut stumps of banana plants, and on plants or objects near, or partially in, water. The larvae feed on decaying organic matter. The time taken for development from egg to adult may be 2–4 weeks in warm climates but up to several months in temperate regions.

Behaviour

Midges obtain blood from mammals, birds, reptiles and humans. They bite during the day and night but, for most species, biting activity peaks in the early evening. All exposed body parts are attacked. Individual midges can cause a painful bite, but they are considered to be an especially severe pest because of their habit of attacking in swarms of hundreds or thousands. Most species only bite outdoors, but indoor biting may also occur.

Some of the most important pest species breed in salt marshes and other places along coasts. In such areas they can hamper the development of tourism.

Biting midges frequently enter the tents of campers in marshy areas. People sitting on verandas and those living in open-walled houses are also frequently bitten.

Horseflies and deerflies (tabanids)

The tabanid flies (Fig. 1.14) are medium-sized to large and occur around the world. They can cause very painful bites, sometimes making outdoor activities
difficult in forested and swampy areas. They are of minor importance as vectors of
diseases, such as tularemia and certain arboviral diseases. In West and Central
Africa some species of the genus *Chrysops* transmit the filarial parasite *Loa loa*. The
most important groups are the genera *Tabanus* (horseflies, greenheads), *Chrysops*
deerflies, mangrove flies) and *Haematopora* (clegs or stouts).

The tabanids measure 5–25 mm in length. They are robust and strong fliers. 
They have a large head with conspicuous eyes which show iridescent colours. The 
mouthparts are large and point downward. The wings are completely clear or have 
a brownish colour or speckles. At rest the wings are folded flat along the body.

**Life cycle**

The female tabanids feed on large domestic and wild animals, such as horses, 
cattle and deer, and also on small mammals, reptiles and birds. In addition they 
feed on humans. The eggs are deposited on the underside of objects such as leaves, 
plant stems and small branches hanging above water. After emerging the larvae 
drop down on to the underlying mud or water. The larvae of most species live in 
mud, rotting vegetation, humus, damp soil and shallow, muddy water at the edges 
of pools, swamps and streams. They generally feed on decaying material of animal 
or vegetable origin. Depending on the species the larvae are between 1 and 6 cm 
long. Development from egg to adult may take 1–3 years.

**Behaviour**

Most species feed in the daytime, especially during the sunniest hours. They hunt 
by sight and can fly over long distances. They are most common in forests and 
swampy areas with woody vegetation. They do not usually enter houses to feed. 
Their bites are deep and painful and the wounds often continue to bleed after the 
flies have left. They need a large quantity of blood and are frequently disturbed 
while feeding; for this reason they take several small blood-meals from the same or 
different sources.
Stable flies

Stable flies (*Stomoxys*) occur around the world. They look similar to houseflies and are also known as biting houseflies. They can be distinguished from similar-looking non-biting flies by their forward-pointing mouthparts (Fig. 1.15). They cause painful bites and are a serious nuisance to humans and animals. They are not important as vectors of disease. However, in South America they sometimes play a role in the transmission of myiasis by carrying the eggs of the myiasis-producing fly *Dermatobia hominis*. In Africa they can be confused with tsetse flies, which also have forward-directed mouthparts. However, they are smaller than tsetse flies and the wings of stable flies do not overlap at the back when at rest.

**Life cycle**

Both male and female stable flies feed on animals, including horses, cattle and dogs, and on humans. The eggs are laid in wet and decaying organic material, such as horse manure, compost and piles of rotting plant debris. The larvae are creamy white in colour and resemble those of the housefly. The pupae develop in dry areas in the soil. Development from egg to adult takes from 12 days to 2 months, depending on the temperature.

**Behaviour**

Stable flies bite in the daytime and mostly out of doors, although indoor biting may also occur. The insects are most common near farms and places where horses are kept. In the absence of animals they may increase their attacks on humans. They mostly feed on the legs.

**Public health importance**

**Nuisance**

Some species of biting Diptera attack in large numbers and may cause considerable annoyance. In some areas, particularly in the northern areas of temperate regions, outdoor activities can be made impossible by swarms of biting mosquitoes. Certain species, especially the larger biting Diptera such as the tabanids and stable flies, and also blackflies and some *Aedes* mosquitoes, cause painful bites sometimes followed by localized swelling and inflammation. Irritation may last for weeks.

People are likely to be motivated to use personal protection and other control methods when biting densities are high. Where the biting Diptera are involved in disease transmission, increased self-protection against biting may automatically
result in a reduced risk of contracting infection. However, some diseases can be transmitted while biting densities are low and people may even be unaware that they have been bitten. This is particularly true for malaria transmission in some rainforest areas. In the absence of the nuisance factor it may be difficult to motivate people to protect themselves against infection.

Malaria

Malaria is caused by single-celled protozoan parasites of the genus *Plasmodium*. The parasites are transmitted from person to person by anopheline mosquitoes. Four species of malaria parasite infect humans:

- *Plasmodium falciparum* occurs throughout tropical Africa and in parts of Asia, the Western Pacific, South and Central America, Haiti and the Dominican Republic;
- *Plasmodium vivax* is almost absent from Africa but is the predominant malaria parasite in Asia and South and Central America;
- *Plasmodium malariae* is found worldwide but has a very patchy distribution;
- *Plasmodium ovale* occurs mainly in tropical West Africa and rarely in the Western Pacific.

Malaria is widespread in the tropics and also occurs in subtropical and temperate regions (Fig. 1.16). In 1993, it was estimated that about 2020 million people in some 90 countries or territories are at risk of infection, and that some 300–500 million people are ill with malaria each year, 1.5–2.7 million of whom die. Malaria is among the most important causes of death and illness in Africa, especially among children and pregnant women. Travellers, tourists and immigrants may be at high risk.

Fig. 1.16
Approximate distribution of malarious regions, 1996 (© WHO).
Treatment is complicated by the spread of strains of *Plasmodium falciparum* resistant to the commonly used antimalarial drugs and the high cost and toxicity of alternative drugs. In addition, mosquito control by indoor house spraying is increasingly difficult because of the development of insecticide resistance in many species of *Anopheles*. Many malaria control programmes are hampered by financial and operational problems.

**Transmission**

Malaria parasites enter the human body via the bite of a malaria-carrying mosquito of the genus *Anopheles*. The parasites invade the liver via the bloodstream and...
multiply. During this period, the victim does not feel ill. After about nine days or longer, depending on the species, the parasites (called merozoites) enter the bloodstream, invade the red blood cells, and again multiply. A few days after the appearance of the first symptoms some merozoites develop into gametocytes, the sexual stage in the life cycle.

*Anopheles* mosquitoes that feed on a person with gametocytes in the blood become infected and the parasites undergo another phase of reproduction in the insects. At the end of this process a new generation of malaria parasites, called sporozoites, migrates to the salivary glands of the mosquito where they remain until the insect bites a person and injects the sporozoites together with its saliva into a new human host. The sporozoites then invade the liver and the cycle is repeated (Fig. 1.17). The cycle in the mosquito usually lasts between 9 and 12 days.

Malaria can also be transmitted accidentally by the transfusion of blood containing malaria parasites, or through contaminated needles or syringes. During pregnancy, fetuses can become infected with parasites from the blood of the mother (transplacental transmission).

**Clinical symptoms**

Malaria begins as an influenza-like illness with attacks of fever eight days or more after the bite of an infected mosquito. Cycles of fever, shaking chills, drenching sweats and headaches may develop. The frequency and severity of the fever depends on the malaria species involved but it usually lasts 2–3 days. The attacks of fever coincide with waves of parasite multiplication and the destruction of red blood cells. Long-lasting infections often result in enlargement of the liver and spleen.

Malaria caused by *P. falciparum* does not always show this cyclic pattern. It is the most severe type of malaria and, if untreated, may progress to shock, kidney and liver failure, coma or death. Death is often due to parasitized red blood cells blocking the narrow blood vessels in an organ of the body. If blood vessels of the brain are affected, the condition is called cerebral malaria. Prompt treatment is essential to prevent damage to the brain or any other organ. *P. vivax*, *P. malariae* and *P. ovale* are generally not life-threatening but death may occur in very young children and old and sick people.

With *P. vivax* and *P. ovale* malaria the interval between attacks of fever is typically two days and for *P. malariae* it is three days. For *P. falciparum* malaria the intervals are irregular, usually about 36–40 hours but shorter intervals are also common. The duration of an untreated first attack may last from a week to a month or longer.

Attacks of illness after an interval of weeks or more, called relapses, do not occur with *P. falciparum* but are common in *P. vivax* and *P. ovale* infections. Relapses may occur at irregular intervals for up to two years with *P. vivax* and for up to five years with *P. ovale*. Infections with *P. malariae* may persist for up to 50 years with periods of fever returning at intervals.

**Immunity**

Where malaria has long been highly endemic, as in many parts of Africa, people are infected so frequently that they develop a degree of immunity. In many cases
they may carry malaria parasites without showing any symptoms. Epidemics of malaria which cause serious illness are often related to the movement of non-immune groups of people into highly endemic areas (for example, people in search of work, refugees and soldiers).

**Prevention and treatment**

Malaria can be prevented if measures are taken to avoid being bitten by anopheline mosquitoes. Protective measures include the wearing of protective clothing, the use of repellents on exposed skin, mosquito coils and other insecticide vaporizers, sleeping under mosquito nets, and improving dwellings.

Because it is not possible always to be sure about the effectiveness of such measures, visitors to malarious areas should use prophylactic drugs to prevent the development of the disease in the event of receiving an infective bite. Information on the most appropriate malaria prophylaxis should be obtained from the health authorities familiar with the local situation.

Persons showing signs of malaria should be treated promptly. If possible a blood sample should first be examined microscopically in a laboratory (Fig. 1.18). Prompt treatment of non-immune patients and of children is important because an infection can become life-threatening within hours.

The drugs used for the treatment of infections should be effective against the locally occurring strains of the malaria parasites.

**Malaria control**

In areas with intense transmission of malaria, control activities aim to stop preventable deaths and minimize suffering from the disease. Essential to this strategy are basic health services that provide prompt diagnosis and adequate treatment. An efficient system needs to be in place for referring patients with severe malaria and those who have not responded to standard treatment regimens. Vector control measures may be included in certain areas as part of a properly designed control programme.

Where the health infrastructure is sufficiently well developed, services should aim to prevent mortality and illness among vulnerable groups with low immunity, such as infants, pregnant women and groups of workers. Such groups can be given additional protection through the use of mosquito control measures. Chemoprophylaxis is recommended for travellers, children under five and pregnant women in areas of high endemicity.

*Fig. 1.18*

Malaria may be confirmed by taking a sample of blood and examining it under a microscope.