Arthropods

All insects and arachnids belong to a very large phylum of invertebrate animals termed the Arthropoda. This phylum contains over 85% of the known species of animals. Arthropods have a body composed of numerous segments (which may be fused so that the segmentation is not clearly visible). The entire body is covered with a tough skin called the cuticle. Arthropods possess jointed appendages.

The class Insecta (mosquitoes, flies, fleas, lice, bugs etc) is the largest within Arthropoda.

Other classes within the phylum are:

Arachnida - spiders, scorpions, ticks, mites etc
Crustacea - crabs, lobsters, shrimps, Cyclops etc.
Diplopoda - millipedes
Chilopoda - centipedes
Pentastomida- tongue worms

All these classes contain animals of greater or lesser medical importance. However, the following six are the principal orders of arthropod vectors;

1. Diptera- Flies and mosquitoes
2. Anoplura- sucking lice
3. Siphonaptera- Fleas
4. Hemiptera- True bugs
5. Orthoptera- Cockroaches
6. Acarina- Ticks and mites

The term 'vector' is defined as a living transporter or transmitter of the causative agent.

Methods of transmission of disease by arthropods.

1. Mechanical transmission

In mechanical transmission, the parasite neither changes nor multiplies significantly on or within the vector. The arthropod is only a vehicle which transports the parasite.

Examples of mechanical vectors and the pathogens transmitted by them include:
House flies - typhoid bacillus
Cockroaches - dysenteric bacillus
Tsetse flies - Trypanosome parasites
Stable flies - Anthrax bacillus

2. Biological Transmission

In biological transmission, the parasite multiplies and/or changes in form as it undergoes part of its life cycle in the arthropod vector, which serves as an "essential" host.

There are three types of biological transmission.

a. Propagative
Parasite multiplies within the vector, but does not change in its form.
- Encephalitis and yellow fever virus in mosquitoes.

b. Cyclo-developmental
Parasite undergoes changes in form, but does not multiply within the vector.
- Filarial worms in mosquitoes

c. Cyclo-propagative
Parasite undergoes changes in form and also multiplies within the vector.
-Malarial parasites in anopheline mosquitoes.
-Trypanosomes in triatomine (kissing) bug.

3. Transovarial transmission
This is a special form of transmission in which the parasite is transmitted to the next generation of the vector through its eggs.
-scrub typhus by mites.

Larvae having fed on an infected animal host become infected. Nymphs and adults do not feed on animals, but the pathogen is transmitted transovarially to the next generation of larvae.

Mechanisms by which arthropod vectors transmit parasites

1. Injection
Infected mosquitoes inject the parasites that cause yellow fever, dengue, malaria and encephalitis into a blood capillary with their saliva.

2. Regurgitation
Fleas, when their intestinal tracts are blocked with masses of plague bacteria, infect new hosts by the passive regurgitation of blood into the puncture wounds, as they attempt unsuccessfully to feed.

3. Contamination of skin or mucous membrane

a. Parasites in faeces of vectors
-Fleas and murine typhus
-Lice and epidemic typhus
-Kissing bugs and chagas disease

b. Parasites in body fluid of vectors
-Hard ticks when crushed – spotted fever, rickettsia

c. Parasites carried externally on body of vectors
-House fly

d. Contamination of food or eating and cooking utensils
-Flies carrying pathogenic organisms crawl on food or utensils and contaminate them.

e. Direct injection ("eating") of vectors
-*Hymenolepis diminuta* – fleas are accidentally swallowed by children.

Mosquitoes

Class: Insecta
Order: Diptera
Family: Culicidae
Sub families: Anophelinae (anophelines), Culicinae (culicines), Toxorhynchitinae

There are some 3,450 species of mosquitoes belonging to 38 genera. Mosquitoes have a world-wide distribution. Some species are found even at elevations of 5,500 m and down mines at depths of 1,250 m below sea level.

The most important vector species belong to four genera – ***Anopheles***, ***Culex***, ***Aedes*** and ***Mansonia***. Mosquitoes are vectors of malaria, filariasis and a number of viral diseases.

External morphology of adult mosquitoes

All mosquitoes are slender and relatively small insects, usually measuring about 3-6 mm in length. Some species, however, can be as small as 2 mm while others may be as long as 19 mm. The body is distinctively divided into a head, thorax and abdomen (Figure 1). Mosquitoes possess only one pair of functional wings, the fore-wings. The hind-wings are represented by a pair of small, knob-like halters. Mosquitoes are distinguished from other flies of a somewhat similar shape and size by: (i) the possession of a conspicuous forward-projecting proboscis; (ii) the presence of numerous appressed scales on the thorax, legs, abdomen and wing veins; and (iii) a fringe of scales along the posterior margins of the wing.

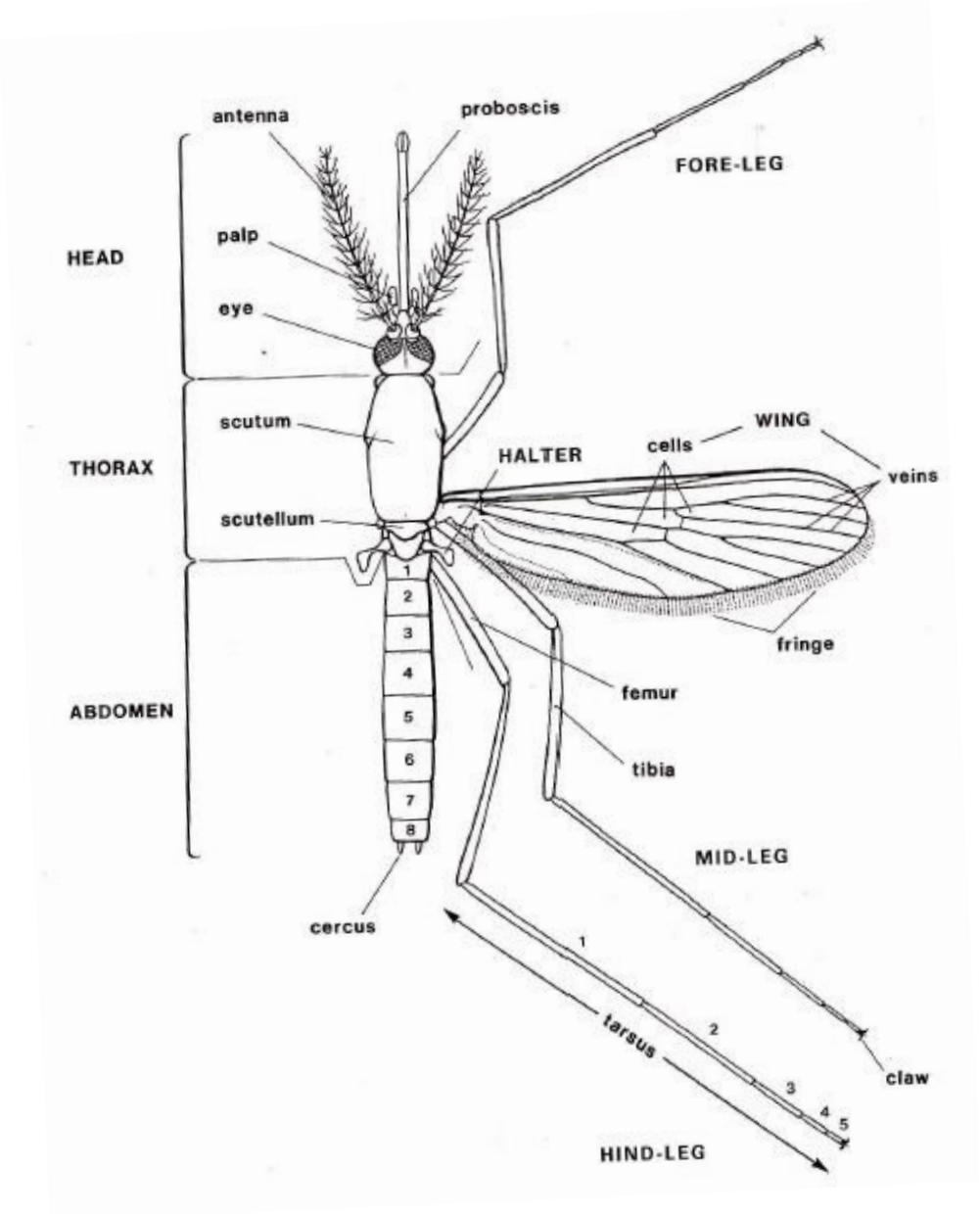


Figure 1. Diagrammatic representation of a female adult mosquito

Head:

The head is ovoid in shape, with two large, conspicuous, kidney-shaped compound eyes. It bears five appendages (Figure 2);

- Two long segmented filamentous antennae (differ in sexes).
- Two palps.
- Proboscis extends forward; the tip of the proboscis is called the labellum.

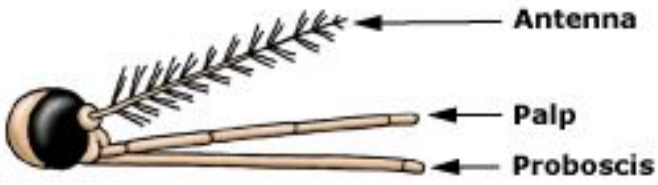


Figure 2. Head of a mosquito with appendages

The mosquitoes can be conveniently sexes by examining the antennae. In females the antennae have whorls of short hairs (pilose antennae), but in males, with a few exceptions genera of no medically importance, the antennae have long hairs giving them a feathery or plumose appearance (Figure 3).

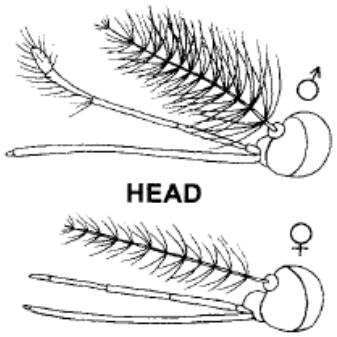


Figure 3. Appearance of antennae in male and female mosquitoes

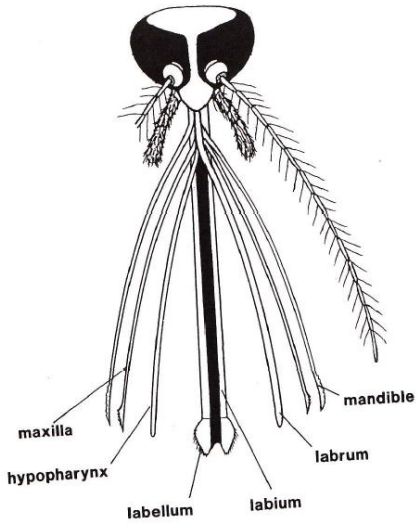


Figure 4. Components of the mouth parts of a mosquito.

The mouth parts are collectively known as the proboscis. It is projected forward in both sexes. The largest component of the mouth parts is the long and flexible gutter-shaped labium which terminates in a pair of small flap-like structures called labella. The proboscis of a mosquito showing the mouth parts is illustrated in figure 4. Although male mosquitoes have a proboscis, the maxillae and mandibles are usually reduced in size or absent. Therefore, males cannot bite to obtain a blood meal. Hence, only male mosquitoes are concerned in transmission of diseases.

Thorax:

The thorax of the mosquito is stoutly build and slightly humped, being oval in cross section. There are setae on the thorax, the nature and arrangement of which are of value in classifying the various species. The thorax is covered with scales, the shape colouration and arrangement of which are also made use of the identification of the species.

Figure 5. Dorsal and lateral view of the mosquito thorax

From the thorax arise a pair of wings have a characteristic wing venation (Figure 6). Along the anterior border is the costa, behind which are the subcosta and six longitudinal veins, the 2nd, 4th and 5th veins are forked. The third arises from a connection between the 2nd and 4th. Scales are arranged along the posterior border, when colored scales are present, they are often arranged in a definite pattern, which may be of assistance in identification of species.

Figure 6. Wing of a mosquito

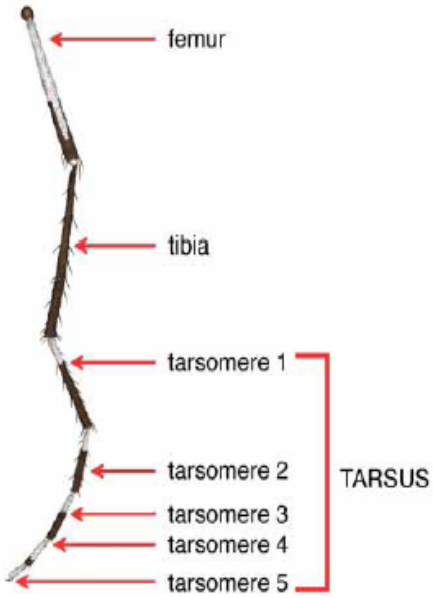
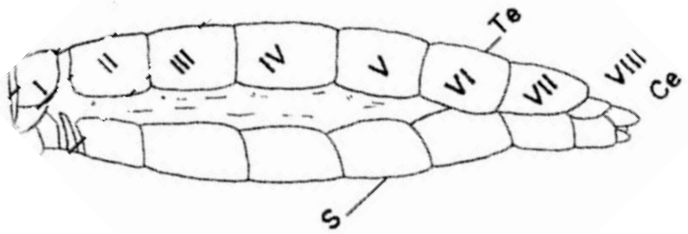


Figure 7. Anterior view of a hind-leg

From the thorax arises 3 pairs of legs, each of which is composed of coax, trochanter, femur, tibia and 5 tarsi terminating in claws which may or may not be toothed (Figure 7).

Abdomen:

The abdomen is composed of 10 segments but only first eight segments are visible. Last two segments are specialized for reproduction and excretion (Figure 8). The upper plates are called tergites and the lower plates are called stemites. In females, the abdomen ends in a pair of short, finger-like projections called cerci. In males, the abdomen ends in a pair of hook-like structures called claspers. These are used to grasp the female during mating.



İ-viii- Abdominal segments
Te- Tergites
S- Stemites
Ce- Cercus

Figure 8. Abdomen of an adult mosquito

In the unfed mosquito the abdomen is long and slender and segmented but when the female is fully fed, or when the ovaries are well developed, the abdomen becomes distended and ovate.

External morphology of immature stages of mosquitoes

Eggs:

Female mosquitoes lay about 30-300 (depending on species) at any one oviposition. Eggs are brown or blackish and 1mm or less in length. Many culicine eggs are elongated and approximately ovoid in shape. Anopheline eggs are laid singly and have lateral floats on both sides. *Culex* eggs are laid in several rows held together to form an egg raft. *Aedes* eggs are laid singly but do not have floats. *Mansonia* species lay their eggs in a sticky mass (cluster) that is attached to the undersides of floating plants. These eggs are drawn out into a terminal filament. *Aedes* eggs can withstand desiccation and can remain dry for months or years but still can remain viable. But eggs of the other genera (*Anopheles, Culex* and *Mansonia)* cannot withstand desiccation.

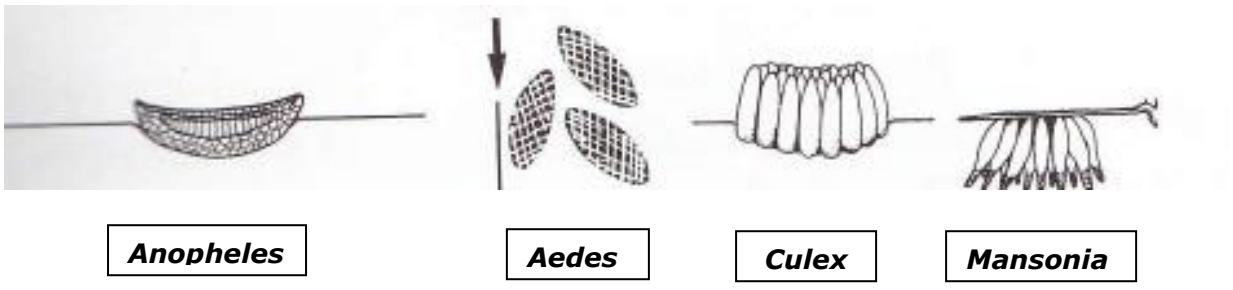


Figure 9. Morphology of mosquito eggs

Larvae:

Mosquito larvae are legless and have a bulbous thorax that is wider than both the head and abdomen. There are four active larval stages (L1, L2, L3 and L4). All mosquito larvae require water in which to develop. Mosquito larvae have a well developed head, bearing a pair of antennae, pair of compound eyes and a pair of prominent mouth brushes. Thorax is roundish in outline and has various simple branched hairs. The ten-segmented abdomen has 9 visible segments.

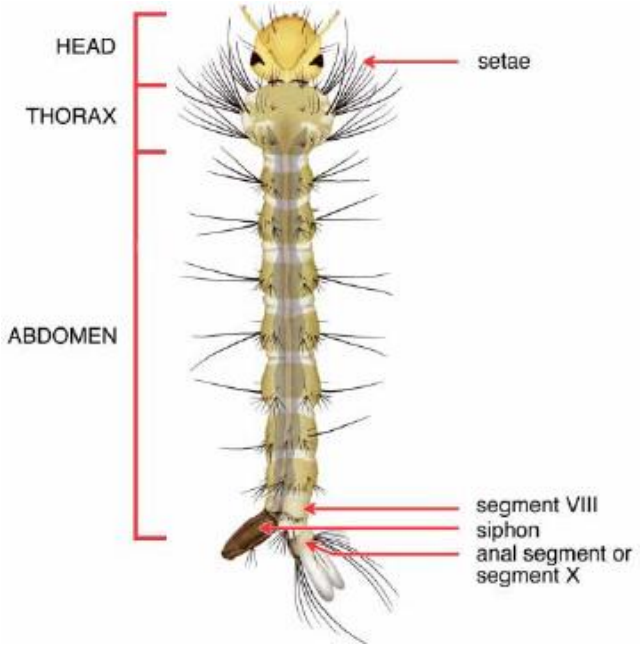


Figure 10. Dorsal view of mosquito larvae (*Aedes*)

Anopheline larvae do not possess a siphon tube. Terminal segments of *Culex l*arva have a long siphon tube with three subventral tufts. Terminal segments of *Aedes* larva have a short siphon tube with a single subventral tuft. *Mansonia* larvae possess a specialized siphon tube (chitinized and Saw-like) which can be inserted into the roots or stems of aquatic plants.

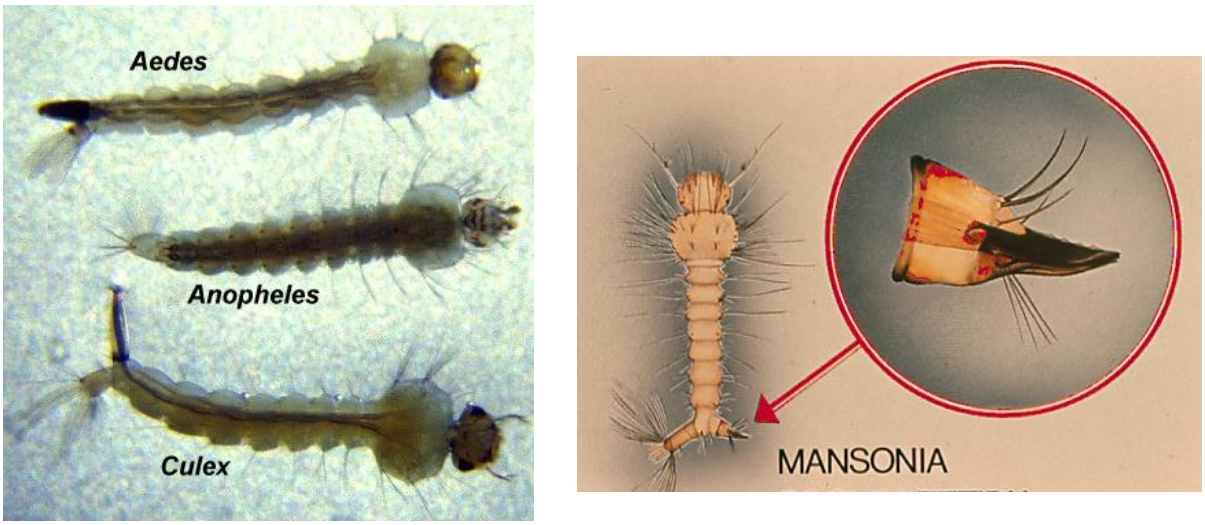


Figure 11. Larval stages of *Anopheles*, *Aedes*, *Culex* and *Mansonia*

Pupae:

All mosquito pupae are aquatic and comma shaped. Head and thorax are fused to form the cephalothorax which has a pair of respiratory trumpets. The abdomen is 10 segmented but only a segments are visible (Figure 12). *Anopheles* pupae have short and broad trumpets. *Culex* pupae have long trumpets. *Mansonia* pupae have trumpets which are modified to pierce water plants.

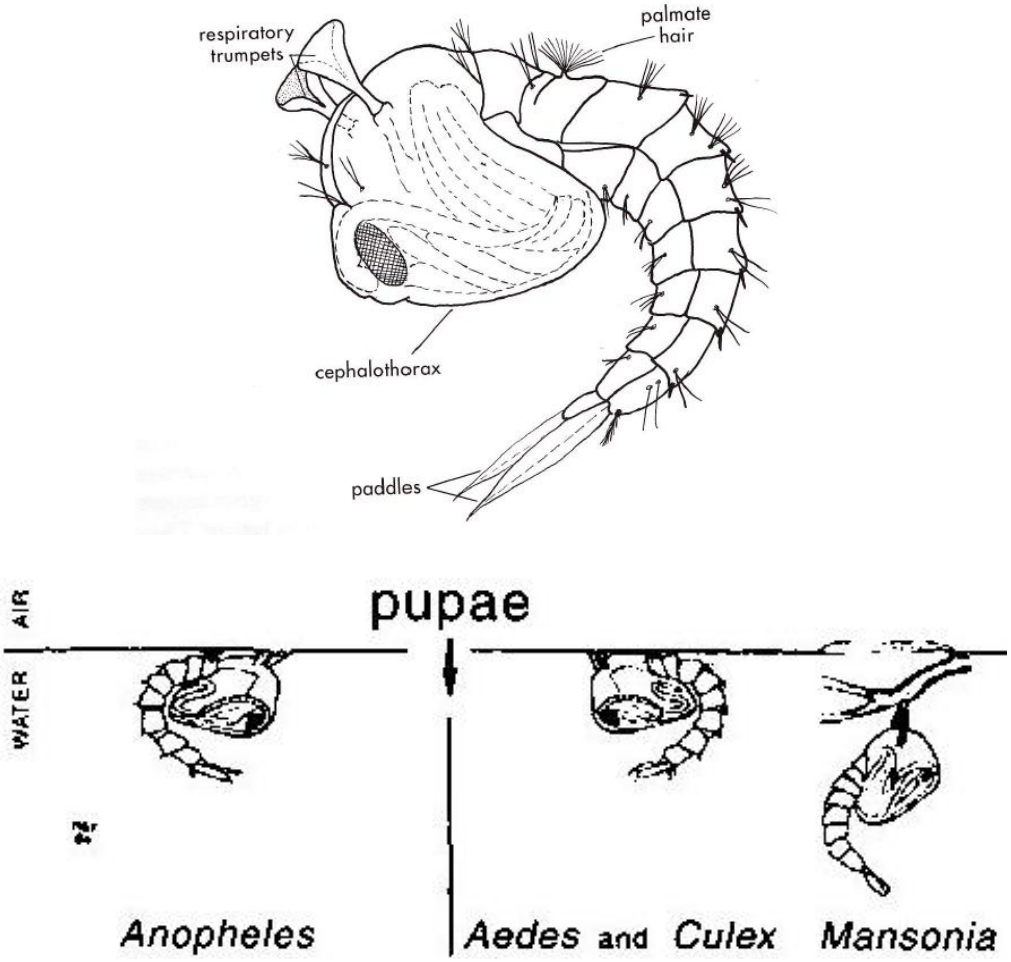


Figure 12. Pupal stages of mosquitoes

Anopheline mosquitoes

Distribution and medical importance:
Anopheles mosquitoes have a world-wide distribution. The most important disease carried by *Anopheles* mosquitoes is malaria. Only mosquitoes of the genus *Anopheles* transmit the parasites that cause human malaria. Because the sexual cycle of malaria parasites occurs in the vector, the mosquito can be called the definitive vector.

Some anopheline mosquitoes are also vectors of filariasis in other countries, especially that caused by *Wuchereria bancrofti* (rural strains). A few also transmit *Brugia malayi* and *Brugia timori.* Although there are over 400 species of *Anopheles* only about 70 are vectors. Of those only about 40 are important. An *Anopheles* sp. which is an important (primary) vector in some areas may be only a secondary vector in others. Some important malaria vectors are species complexes (consisting 2 or more sibling species)

There are 23 *Anopheles* species recorded from Sri Lanka. The best known vector of malaria in Sri Lanka is *Anopheles culcifacies. An. culicifacies* is a species complex. In has been reported that *An. culicifacies* complex in India consists of five sibling species (A,B,C,D,E). However, only sibling species B and E are so far reported in Sri Lanka.

More than 10 other *Anopheles* species have been reported to be potential vectors of malaria in Sri Lanka. Among these *An. subpictus* and *An. annularis*, *An. varuna* and *An. tessellatus* are considered as secondary vectors.

Behaviour:
Most *Anopheles* are nocturnal in their activities. Some species bite people mainly outdoors (exophagic). In contrast some other species bite indoors (endophagic). Both before and after feeding some species rest indoors (endophilic) whereas the others rest outdoors (exophilic). An infective anopheline mosquito may inject as many as 60,000-70,000 sporozoites into a person. The sporozoite rate (the percentage of female vectors with sporozoites in the salivary glands) varies from species to species as well as according to locality and season.

Breeding habitats:
Breeds in a great variety of clean and polluted habitats; edges of streams, small pools, borrow pits, rice fields, tank margins, rock pools, sand pools, filed canals, wells, quarry pits, gem pits, lagoon water, wastewater in drains, rain water collections etc.

With the onset of rains, the breeding increases enormously and may covers vast areas.

Identification to the genus *Anopheles*

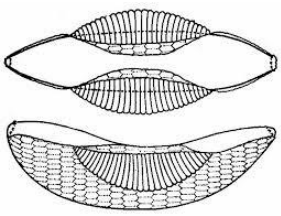
Eggs:
Eggs are laid singly on the water surface. In most species they are typically boat-shaped and laterally, have a pair of floats.

Larvae:
Lack a siphon tube and lies parallel to the water surface. They are surface feeders and spend most of their time at the water surface. Examination under a microscope shows that the abdomen has small, brown, sclerotized plates, called tergal plates, on the dorsal surface of abdominal tergits 1-8. In addition most or all of these segments have a pair of well-developed palmate hairs.

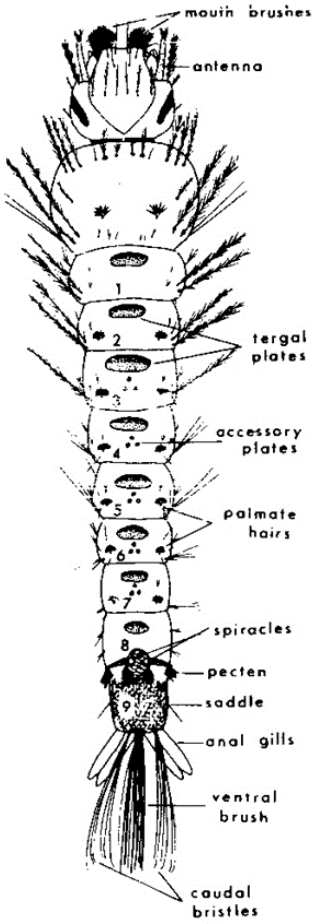
Pupae:
The respiratory trumpets are short and broad distally.

Adults

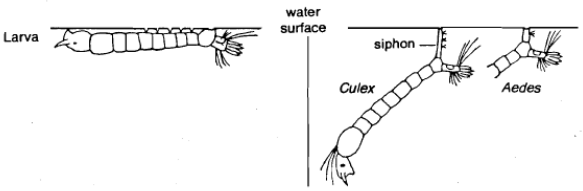
Adults usually keep their bodies at about 45 degree angle to the resting surface. The length of palps and proboscis of anophelines are approximately equal. Many of the anophelines have dark and pale scales on wing veins arranged in specific areas (wing spots).



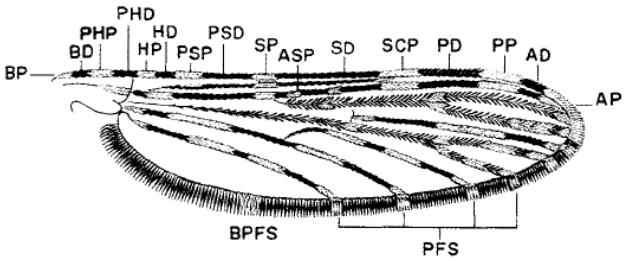
Anopheline egg



Anopheline pupa



Anopheline larvae (L4)



Basic identification features for adult anophelines

Culicine mosquitoes

Culex mosquitoes

Distribution and medical importance
Found more or less world-wide, but they are absent from the extreme northern parts of the temperate zones. In Sri Lanka, 35 *Culex* mosquito species have been recorded. The most important species *Culex quinquefasciatus,* which is the vector of lymphatic filariasis in Sri Lanka, breeds in waters polluted with organic debris. Larvae of this vector species are commonly found in partially blocked drains and ditches, soak-away pits, septic tanks etc. It is a mosquito that is associated with urbanization, and towns with poor and inadequate drainage and sanitation. Japanese encephalitis (JE) in Sri Lanka is transmitted by *Cx. tritaeniorhynchus* and *Cx. gellidus* which are common rice-field breeding mosquitoes. In addition, *Cx. vishnui*, *Cx. pseudovishnui* and *Cx. fuscocephala* are some other medically important mosquitoes.

Behaviour
Cx. quinquefasciatus, and many other *Culex* species, bite humans and other hosts at night. Some species such as *Cx. quinquefasciatus*, commonly rest indoors both before and after feeding, but they also shelter in outdoor resting places.

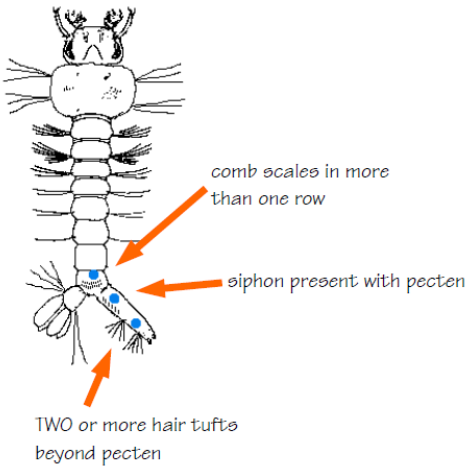
Identification features for *Culex* mosquitoes
Eggs:
Eggs are usually brown, long, cylindrical and placed together to form an egg raft. An egg raft may contain up to about 300 eggs. Eggs of a few other mosquitoes, including those of the genus *Coquillettidia*, also deposit their eggs in rafts.

Larvae:
Siphon long and narrow with 2 or more subvetral tufts.

Pupae:
The length of the respiratory trumpets are longer, more cylindrical and their openings narrower.

Adults:
Adults are recognized more by their lack of ornamentation. The tip of the abdomen of females is blunt.

Egg raft of *Culex*



Culex larvae

Culex pupae

Dorsal view of the abdomen of *Culex* mosquito showing the blunt end

antenna about the same size as the proboscis

no prespiracular or postspiracular setae

legs dark, no bands

Adult *Culex* mosquito

***Aedes* mosquitoes**

Distribution and medical importance
World-wide, the range of *Aedes* mosquitoes extends well into northern and arctic areas, where they can be vicious biters and serious pests to people and livestock. *Aedes* mosquitoes transmit dengue, yellow fever, chikungunya, zika and most of the important arboviral diseases. 48 mosquito species under the genus *Aedes* have been recorded from Sri Lanka. Of them *Ae. aegypti* and *Ae. albopictus* have been recognized as primary and secondary vectors for the transmission of dengue and chikungunya respectively, in Sri Lanka,. *Ae. aegypti* is considered as a more urban vector of dengue, whereas *Ae. albopictus* is regarded as a suburban vector. *Ae. aegypti* also transmits dirofilariasis in Sri Lanka.

Behavior
Adults of most *Aedes* species bite mainly during the day or early evening. Most biting occurs out of doors and adults usually rest outdoors before and after feeding.

Breeding habitats
Many *Aedes* breed in small container habitats, coconut shells, tins, trays, bottles, flower vases, ant traps, blocked gutters, brackish water bodies, tyres etc, with clean water and other natural/ man-made containers Some may also breed in tree-holes; plant axils etc.

Identification features for *Aedes* mosquitoes

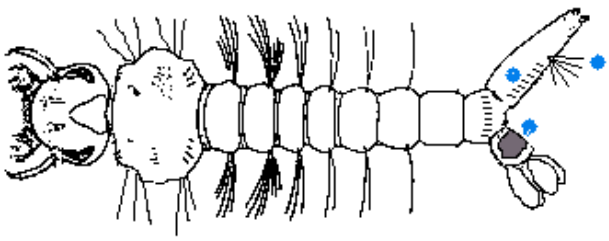
Eggs:
Laid singly. More or less ovoid. *Aedes* eggs can withstand desiccation.

Larvae:
Usually have short barrel-shaped siphon with one pair of subventral tufts.

Pupae:
The length of the respiratory trumpets are longer, more cylindrical and their openings narrower.

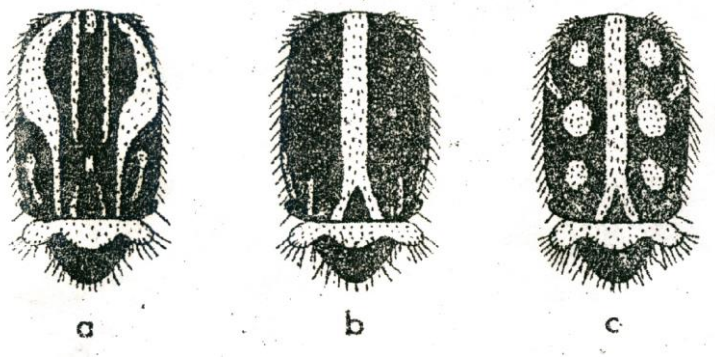
Adults:
Many *Aedes* adults have specific patterns on the thorax formed by black, white or silvery scales. The legs often have black and white banding. *Ae. aegypti*, is readily recognized by the lyre-shaped silver markings on the lateral edges of the scutum. *Ae. albopictus* has a silvery stripe. Apex of the abdomen is pointed.

Aedes eggs



Aedes larvae

Aedes pupae



Dorsal view of Thorax:

a. *Ae. aegypti*
b. *Ae. albopictus*
c. *Ae. vittatus*

has postspiracular setae, no prespiracular setae

basal bands on abdomen

Basic identification features for adult *Aedes*

***Mansonia* mosquitoes**

Distribution and medical importance

Mansonia is principally a genus of wet tropical areas, but a few species occur in temperate regions. In Sri Lanka only 3 species namely; *Mansonia annulifera*, *Ma. Indiana* and *Ma. uniformis* have been recorded. The main medical importance of *Mansonia* mosquitos is as vectors of filariasis especially *Brugia malayi*.

Behaviour

Adults usually bite during the night, but a few species are day-biters. After feeding, most of them rest outdoors.

Breeding habitats

All breeding habitats have aquatic vegetation, either rooted (grasses, rushes and reeds) or floating (*Pistia* sp, *Salvinia* or *Eichhornia*). Larvae consequently occur in permanent collections of waters, such as swamps, marshes, ponds, burrow pits, grassy ditches, irrigation canals and even the middle of rivers if they have floating plants.

Identification features for *Mansonia* mosquitoes

Eggs:

Dark brown-black. Cylindrical but have a tube-like extension apically. Eggs are arranged as a rosette. Eggs are glued to the undersurface of plants and hatch within few days.

Larvae:

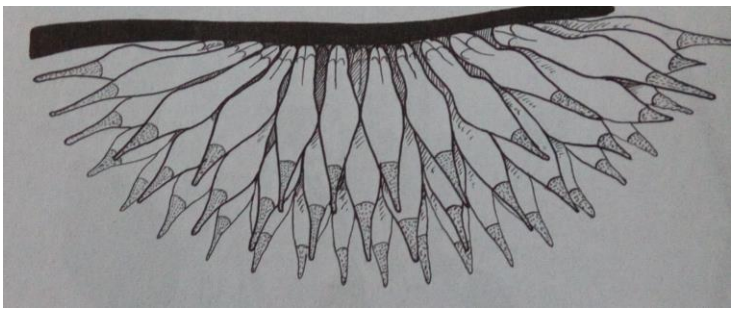
Can be easily recognized by the modified siphon tube (saw-tooth structure) adapted to piercing aquatic plants.

Pupae:

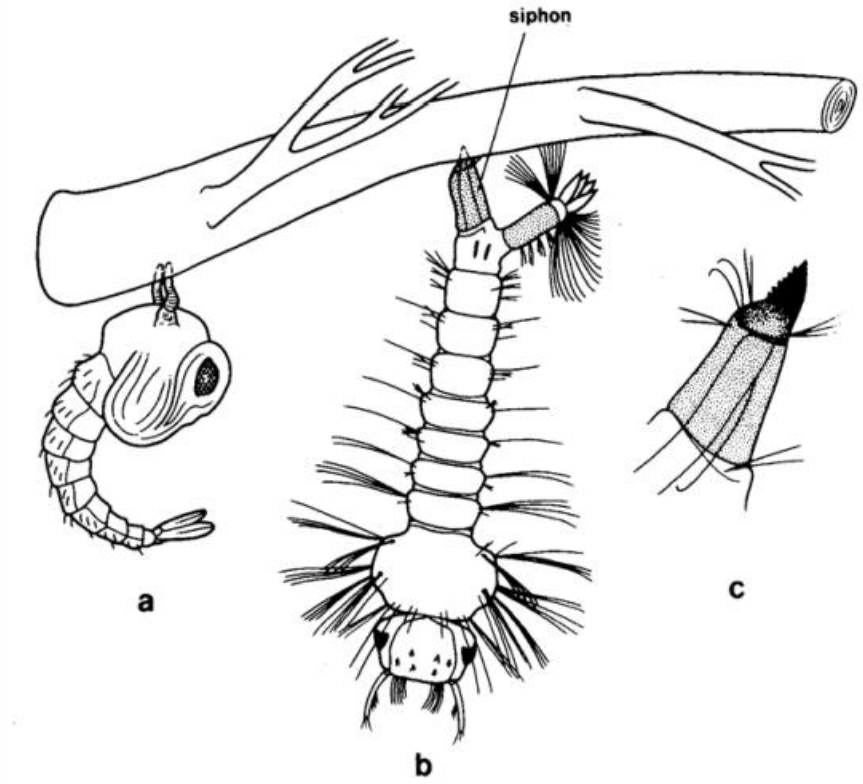
Breathing trumpet is long and pointed to pierce the aquatic vegetation in order to acquire oxygen.

Adults:

Adults have the legs, palps, wings and body covered with a mixture of dark and pale scales, giving the mosquito a rather dusty appearance. The speckled pattern of dark and pale scales on wing veins gives the wings the appearance of having been sprinkled with salt and pepper. Closer examination shows that the scales on the wings are very broad and often asymmetric. In other mosquitoes these scales are longer and narrower.

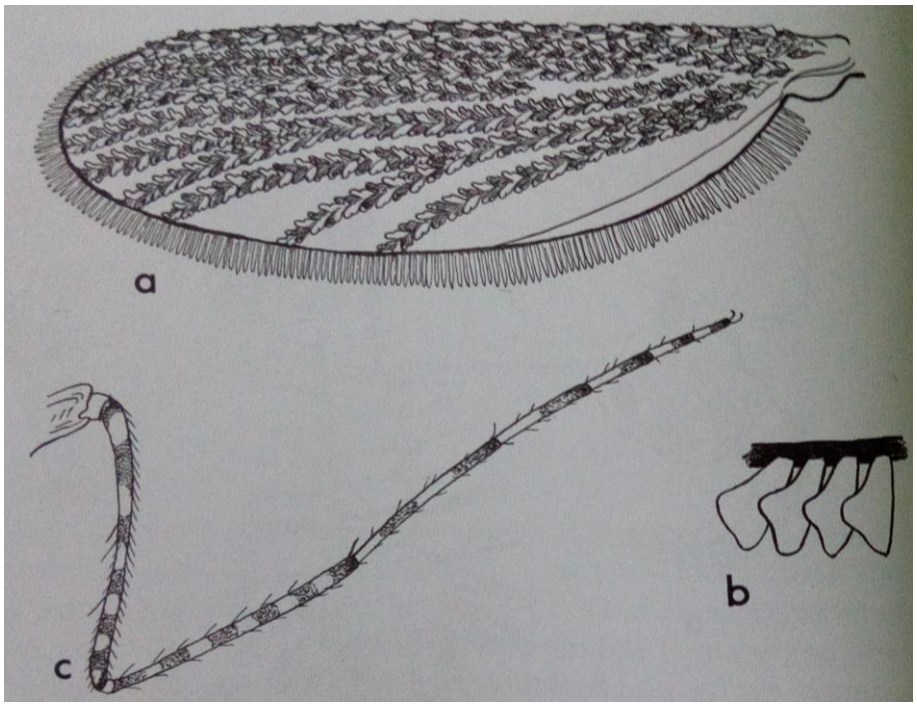


Eggs of *Mansonia* glued to the undersurface of floating vegetation



Immature stages of *Mansonia* mosquitoes.

(a). Pupa with respiratory trumpets inserted into an aquatic plant
(b). Larva with siphon inserted into a plant for respiration
(c). Larval siphon showing serrated structures



Mansonia mosquitoes.

(a). Wing showing speckled distribution of dark and pale scales on wing veins
(b). A few scales on a wing vein showing their broad scales
(c). Leg showing the dark and pale banding pattern