Training Module-2

Vector Morphology and Bionomics

Developed under GEF Funded Project on

Development and Promotion of Non-POPs Alternatives to DDT
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Training Programme on
Integrated Vector Pest Management (IVPM)

Executed by
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Developed by

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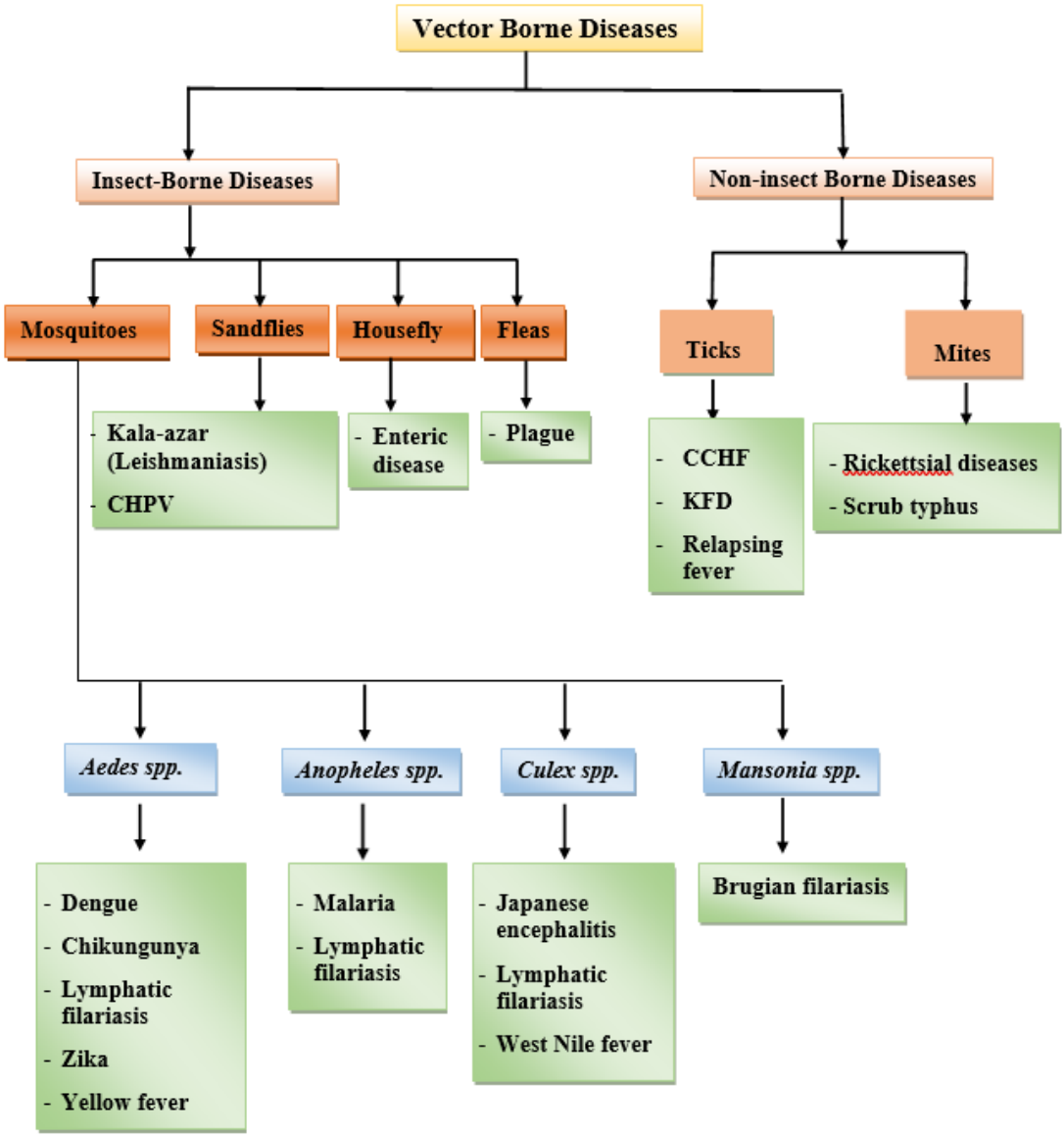
CCHF	Crimean-Congo haemorrhagic fever
CDC	Centers for Disease Control and Prevention
CHPV	Chandipura virus
DDT	Dichlorodiphenyltrichloroethane
IVM	Integrated Vector Management
JE	Japanese Encephalitis
KFD	Kyasanur Forest Disease
Km	Kilometer
mm	Millimetre
m	Metre
VBD	Vector Borne Disease
WHO	World Health Organization


Vector Borne Diseases
Insect-Borne Diseases
Non-insect Borne Diseases
Mosquitoes
Sandflies
Housefly
Fleas
Ticks
Mites
- Kala-azar (Leishmaniasis)
- CHPV
- Enteric disease
- Plague
- CCHF
- KFD
- Relapsing fever
- Rickettsial diseases
- Scrub typhus
Aedes spp.
Anopheles spp.
Culex spp.
Mansonia spp.
- Dengue
- Chikungunya
- Lymphatic filariasis
- Zika
- Yellow fever
- Malaria
- Lymphatic filariasis
- Japanese encephalitis
- Lymphatic filariasis
- West Nile fever
Brugian filariasis

Vector Morphology and Bionomics

Learning Objectives

By the end of the training programme, participants should be able to…….

- Define the vector
- Describe the morphological characteristics of adult and immature stages of mosquitoes and non-insect vectors
- Describe about the biology and ecology of insect and non-insect vectors

1. Vector mosquitoes

Vectors are living organisms that can transmit infectious pathogens between humans or from animals to humans. Mosquitoes are vectors, which transmit communicable diseases of significant public health concern such as Malaria, Dengue, Chikungunya, Japanese Encephalitis, Lymphatic Filariasis, Zika etc. to humans through several pathogens, including arboviruses, protozoans and nematodes (Becker et. al., 2010). It is well known that under the influence of environmental conditions a vector species may show changes in the seasonal distribution in the same area of dominance. The increase in density of a vector species is very much dependent on favorable climatological factors for its breeding, and adult survival.

1.1 Introduction

While feeding on a host (human or animal), vector mosquitoes ingest pathogens, which are replicated or transformed and later transmitted to a new host. Often, once a vector becomes infected, they are capable of transmitting the pathogen for the rest of its life during each subsequent bite/blood meal (WHO, 2020). These vectors affect health systems through Vector Borne Diseases (VBDs) and cause millions of deaths annually.

During the field session, trainees should obtain information regarding immature aquatic and adult stages of vectors. Non-specialists can develop an interest in identifying and differentiating vectors and non-vectors. In most contexts, simple identification of vectors is possible up to the generic level but not up to the species level. Understanding life-cycle of a vector is another important skill for vector control and surveillance.

Studying the life-cycle by regular observation of the vector's developmental stages in artificial containers provides insight into their biology and helps to generate interest in communities participating in Integrated Vector Management (IVM). For example, people might not be aware that larvae present in water containers in and around their houses, developing into adult mosquitoes. Participant Trainees will learn to rear vectors from larval to adult stages to understand their life-cycle and recognise their developmental stages.

Vectors thrive in ecosystems that provide suitable habitats for breeding and appropriate conditions for feeding on human or animal hosts. The vectors of many diseases require water bodies to complete their life-cycle, and some vectors are selective in the types of water bodies, which they choose for laying their eggs. It is important to understand the breeding preferences of targeted vectors in planning vector control interventions so that the available limited resources are used efficiently and effectively. For better understanding of all aspects of vector ecology will inevitably yield numerous new and mutually complementary targets for integrated vector control. Therefore, ecology is a prerequisite to eradicate or eliminate VBDs and will be essential for sustaining success in the long term.

1.2 Mosquito vectors and classification

Mosquitoes are arthropods and are classified under the class Insecta. Further, they belong to the order Diptera and the family Culicidae. There are approximately 3600 species of mosquitoes, which are divided into three subfamilies: Toxorhynchitinae, Anophelinae, and Culicinae (Christophers, 1933). They have a worldwide distribution, occurring throughout the tropical, sub-tropical and northwards into an arctic circle. They are found at elevations of 3500 m and down mines to depths of 1250 m below sea level.

The most important mosquito vector species belong to the genera *Anopheles*, *Culex*, *Aedes* and *Mansonia*. The *Anopheles* species are vectors of malaria; *Aedes* species are important vectors of Dengue, Chikungunya and Zika; *Culex* species transmit *Wuchereria bancrofti*, as well as arboviruse causing JE and *Mansonia* species transmit *Brugia malayi*.

Classification of mosquito

Mosquitoes belong to phylum Arthropoda and superclass Hexapoda by having six jointed legs besides other taxonomic characters. Further, these are classified in order Diptera. The family Culicidae of suborder Nematocera includes mosquitoes nearly 110 genera/subgenera and about 3600 species with the most important genera viz. *Anopheles, Culex, Aedes* and *Mansonia*.

Phylum	**:**	Arthropoda
Superclass	**:**	Hexapoda
Class	**:**	Insecta
Order	**:**	Diptera
Suborder	**:**	Nematocera
Family	**:**	Culicidae

Subfamilies:

1. Anophelinae includes *Anopheles.*
2. Culicinae includes *Culex, Aedes* and *Mansonia.*

Characters of subfamilies

- Subfamily Anophelinae: The sterna and terga are wholly or largely devoid of scales.
- Subfamily Culicinae: The abdominal terga and sterna are densely covered by scales.

1.3 Morphological characters

Mosquitoes are distinguished from flies of a somewhat similar shape and size by:

- Possession of a conspicuous forward-projecting proboscis,
- Presence of numerous appressed scales on the thorax, legs, abdomen and wing veins,
- A fringe of scales along the posterior margin of the wings,
- A characteristic wing venation *i.e.,* the second, fourth and fifth longitudinal veins are branched.

Mosquitoes are slender and small insects, usually measuring about 3-6 mm in length. Some species are as small as 2 mm while others as long as 19 mm. They possess a pair of functional wings known as fore-wings and a pair of hind-wings, which are represented by a pair of small, knob-like halters. The mosquito body is mainly divided into head, thorax and abdomen (Figure- 1).

The head, thorax and abdomen are covered with scales and setae of different lengths, shapes and colouration, which can have significant genus and species-specific taxonomic importance. In most of the species, the colour of the scales may vary from white to almost black but is usually referred to as pale or dark in the description of the species. Pale and dark scales can be intermixed wherever they occur. Scale colouration can change in different light sources.

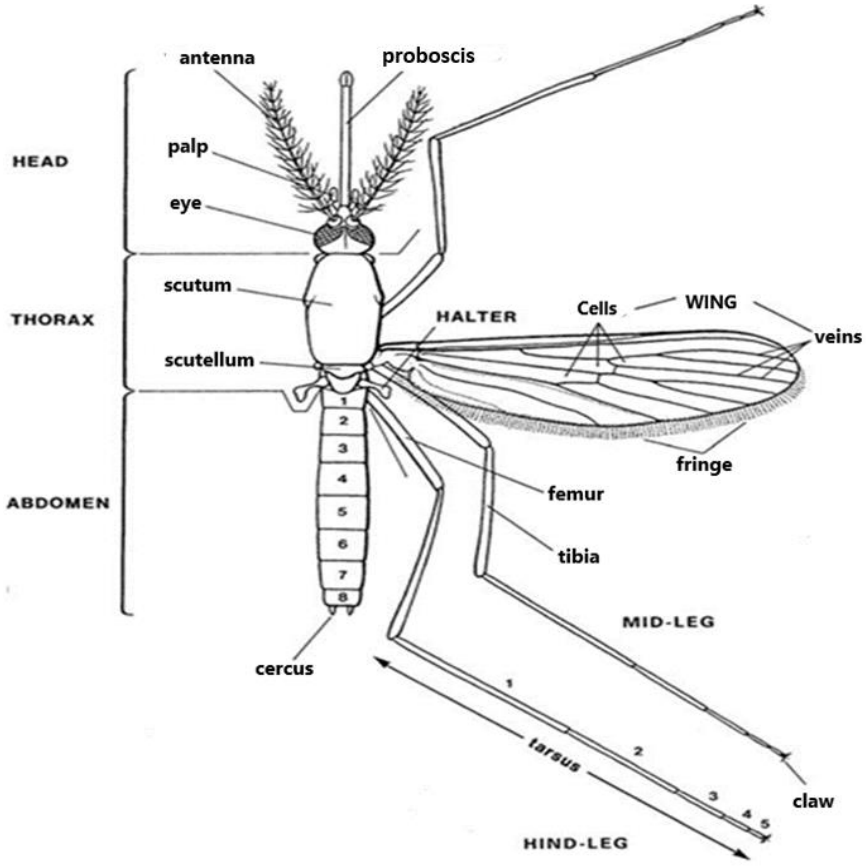


Figure- 1: Adult female mosquito (Mike, 2008)

Head

The Head is the most important part having all sensory organs like compound eyes, which are kidney-shaped, antennae, palpi and mouth parts (proboscis). A pair of filamentous and segmented antennae is located in between the eyes. Mosquitoes can be identified as male or female by examination of their antennae. Individuals with

feathery plumose appearance of antennae are males, while those with only short and rather inconspicuous antennal hairs or pilose antennae are females. Just below the antennae, there is a pair of palpi, which in female anophelines are pointed apically, while in males they are dilated or clubbed. In female culicines, the palpi are very short or one-third of proboscis, while in males they are long. A single long proboscis arises between the palpi, which contains the piercing and sucking type of mouthparts in females. In mosquitoes, the proboscis characteristically projects forward (Figure- 1).

Mouthparts

The appendages of mouthparts, which are associated to oral cavity are commonly known as the proboscis. In female mosquitoes, piercing and sucking types of mouthparts are present, while in male mosquitoes piercing and sucking mouthparts are absent. The proboscis is long and projects conspicuously forward in both males and females. The largest components of the mouthparts are- paired mandibles, paired maxillae, hypopharynx, labrum and labium (Figure- 2a). The uppermost structure *i.e.*, labrum is slender, pointed and grooved along its ventral surface. The flexible gutter-shaped labium, which terminates in a pair of small flap-like structures is called labella. In cross-section, the labium is seen to almost encircling all other components of the mouthparts and it serves as a protective sheath (Figure- 2b).

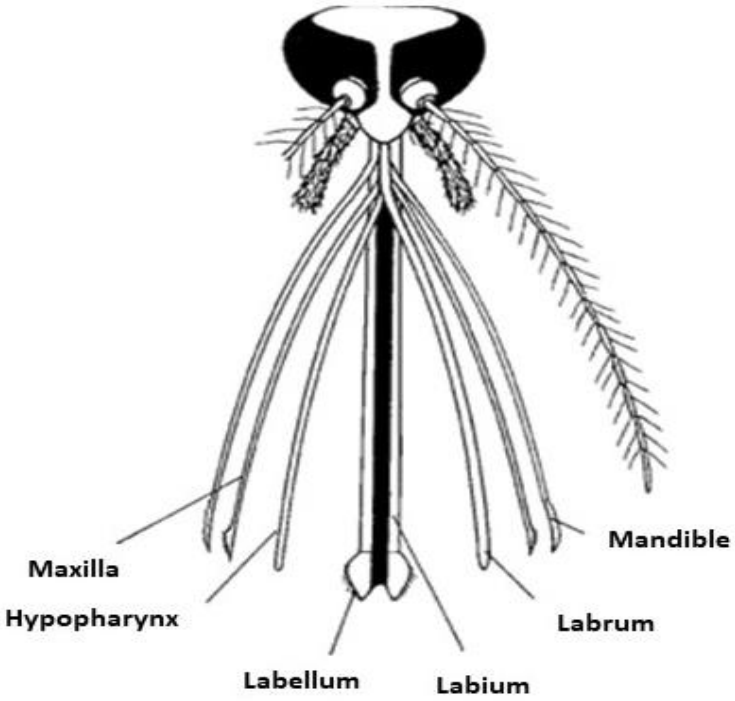


Figure- 2a: Mouthparts of mosquito (Barnitharan et al., 2018)

The mandible and the maxilla are modified into long needle-like and knife-like structures respectively, which are the main piercing organs used to cut the skin of the host. When a female mosquito bites a host, the labella at the tip of the fleshy labium fits on the skin, which cannot pierce the skin but curves backwards. This allows the paired mandibles, paired maxillae, labrum and hypopharynx to penetrate the host's skin. Saliva is pumped down through the hypopharynx from a pair of trilobed salivary glands, situated ventrally in the anterior part of the thorax. Mosquito saliva acts as an anticoagulant. In males, both mandibles and maxillaries are reduced or lacking and cannot be used for piercing or biting the host.

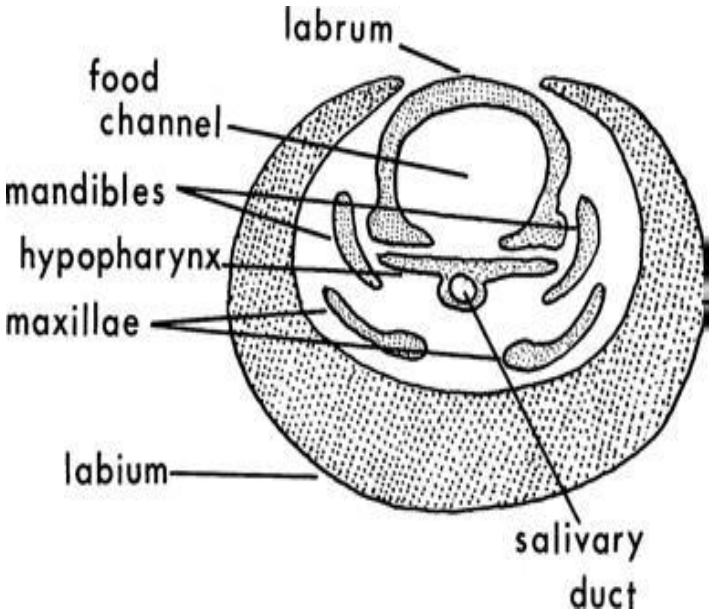


Figure- 2b: Cross-sectional structure of mosquito mouthparts

(Barnitharan et al., 2018)

Thorax

Thorax is divided into three parts known as the prothorax, mesothorax and metathorax. The thorax is covered dorsally and laterally with scales, which may be dull or shiny, white, brown or black colored, depending on the species. Wings and halteres both arise from thorax. The wings are long and relatively narrow. While resting, mosquitoes place the wings across each other over the abdomen like a closed pair of scissors. The hind (metathoracic) wings are modified into dumb-bell shape, called the halteres. Each pair of legs is associated with each thoracic segment. Legs are long and slender and covered with scales, which are usually brown, black or white

and may be arranged in patterns, often in the form of rings. The thoracic legs are composed of the coxa, trochanter, femur, tibia and tarsus (Figure- 1).

Abdomen

The abdomen is composed of 10 segments, but only the first seven or eight are visible. Mosquitoes in the subfamily Culicinae usually have the abdomen covered dorsally and ventrally with mostly brown, blackish or whitish scales. In the Anophelinae, however, the abdomen is almost or entirely, devoid of scales. Small openings called spiracles line both sides of the abdomen, allowing the mosquitoes to respire. The last abdominal segment of a female mosquito terminates in a pair of small finger-like cerci, whereas in the male there is a pair of prominent claspers, comprising part of the male external genitalia.

The abdomen is thin and slender in unfed mosquitoes, but after females have taken blood meal from a suitable host (only female bites), the abdomen resembles an oval red balloon and becomes greatly distended. When the abdomen is full of developing eggs it is also dilated but is whitish and not red in appearance. Female mosquito acquires blood meal, which contains protein as it is essential for the development of eggs.

2. Vector of Malaria

In India, nine vector species viz. *Anopheles culicifacies* (rural, peri-urban areas), *An. stephensi* (urban areas), *An. fluviatilis* (hills and foot-hills), *An. minimus, An. baimaii* was formerly known as *An. dirus* (north-eastern states) and *An. epiroticus* was formerly known as *An. sundaicus* (Andaman and Nicobar Islands), *An. varuna* (Andhra Pradesh, Jharkhand and Odisha), *An. annularis* (central India and Odisha) and *An. philippinensis* (deltaic West Bengal and north-east India) transmit malaria. The first six species are primary vectors whereas rest three are secondary vector species.

2.1 *Anopheles* mosquito

Mosquitoes of the genus *Anopheles* have been incriminated in the transmission of malaria.

Classification

Phylum	**:**	Arthropoda
Superclass	**:**	Hexapoda
Class	**:**	Insecta
Order	**:**	Diptera
Family	**:**	Culicidae
Subfamily	**:**	Anophelinae
Genus	**:**	*Anopheles*

2.1.1 External morphology

The body of the adult *Anopheles* mosquito is dark brown to black. The female *Anopheles* mosquito has distinct characteristics that differentiate it from other types of mosquitoes.

Adult

Adult *Anopheles* usually rests with their bodies at an angle to the surface that is with the proboscis and abdomen in a straight line or head down bottom up. Some species rest at almost right angles to the surface but in case of *An. culicifacies* the angle is

much smaller. Unlike culicines, the dorsal and ventral surfaces of the abdomen are almost or entirely, devoid of appressed scales. In both male *Culex* and *Anopheles* genera, the palpi are as long as the proboscis but in male *Anopheles*, are distinctly swollen at their ends and are said to be clubbed. In female *Culex*, palpi are shorter than proboscis whereas, *Anopheles* have palpi long or equal to proboscis (Figure- 3).

Most of the Anopheline mosquitoes have spotted wings (Figure- 4), *i.e.*, the dark and pale scales are arranged in small blocks or areas on the veins. The number, length and arrangement of these dark and pale areas differ considerably in different species and provide useful taxonomical characters for species identification.

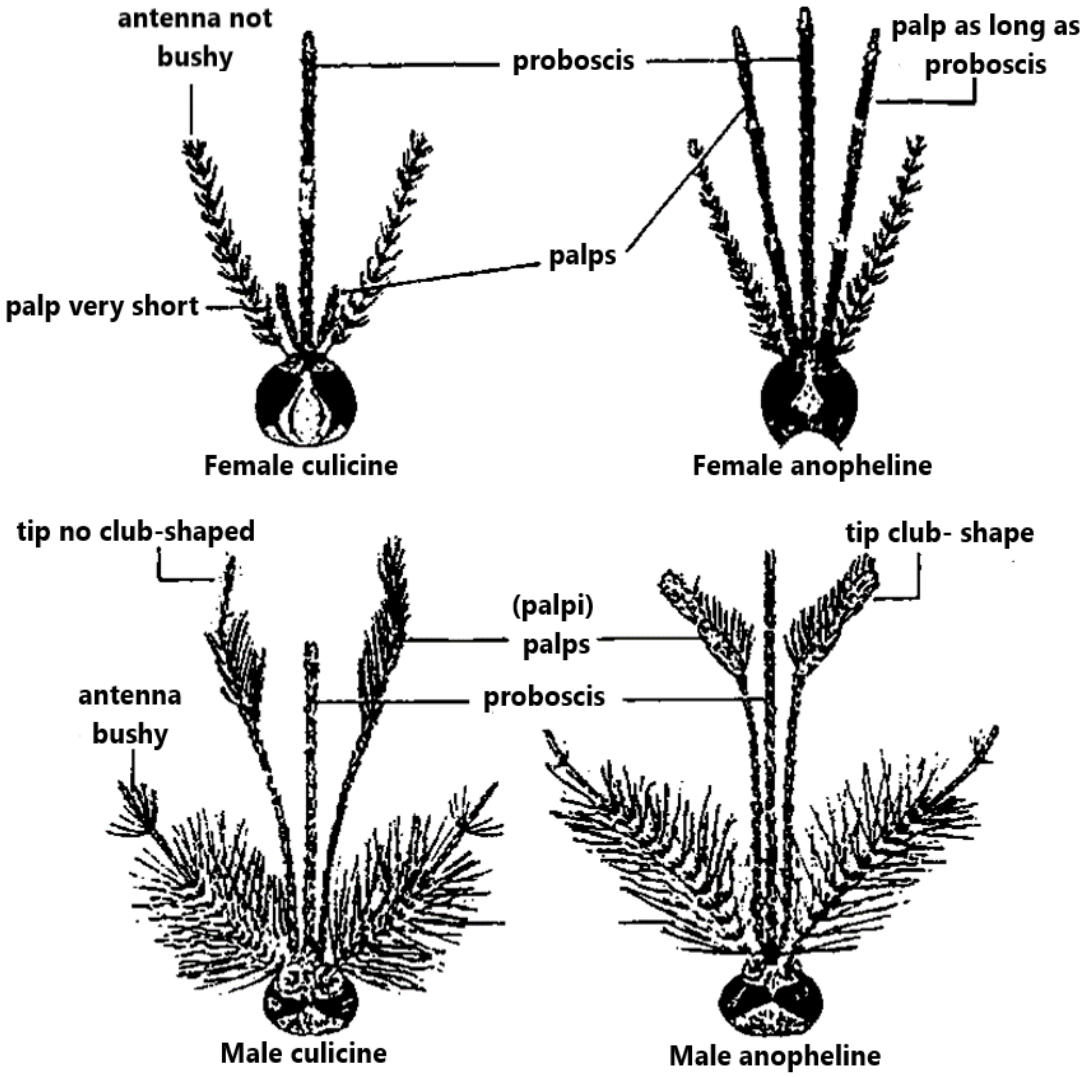


Figure- 3: Adult culicine and anopheline mosquito (WHO, 1995)

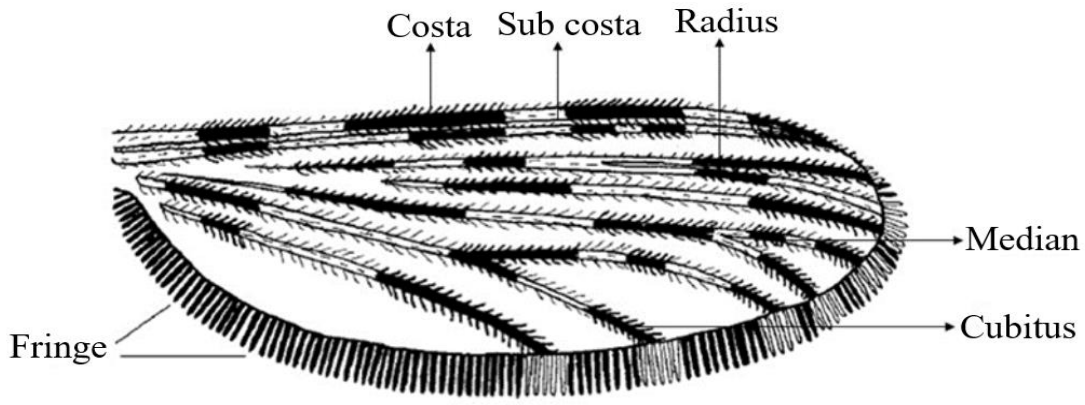


Figure- 4: *Anopheles* wing (Mike, 2008)

Egg

Anopheline mosquito-eggs are elongated and unique as they acquire float (air-filled sacs) on either side and show a typically boat-shaped appearance (Figure- 5) that helps them to float on the water surface.

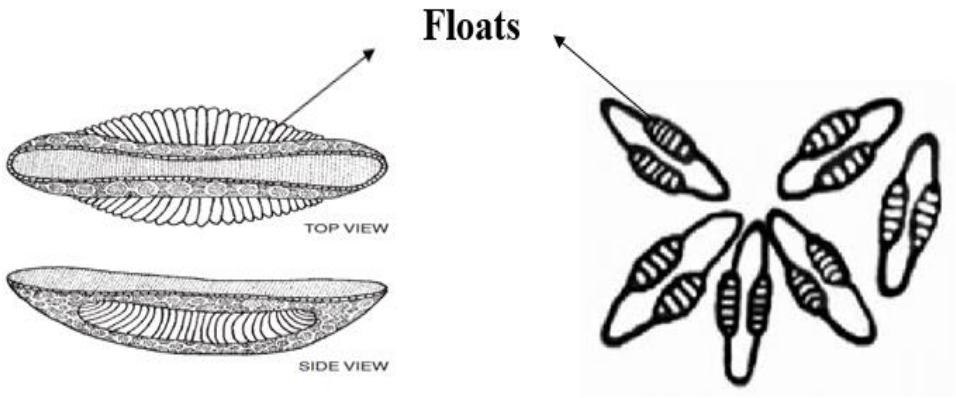


Figure- 5: *Anopheles* eggs (Mike, 2012; WHO, 2013)

Larva

The larva (plural- larvae) lives in the water and comes to the surface to breathe. Larvae shed (moult) their skin four times, growing larger after each moult and each moulted form is consecutively known as 1st, 2nd, 3rd and 4th instar. Anopheline larvae do not have a siphon and lie parallel to the water surface to get a supply of oxygen through a breathing opening (posterior spiracle). A tergal plate and paired palmate hair are present dorsally on most abdominal segments 1-8 (Figure- 6). Laterally on

each side of segment 8 and 9 are combined comb-like structure with teeth known as pecten.

The larvae feed on microorganisms and organic matter in the water. They are surface feeders and thus spend most of their time at the water surface. Larvae are known as 'Wrigglers' since they seem to move in that manner. During the fourth moult *i.e.* 4th instar larva transform into a pupa.

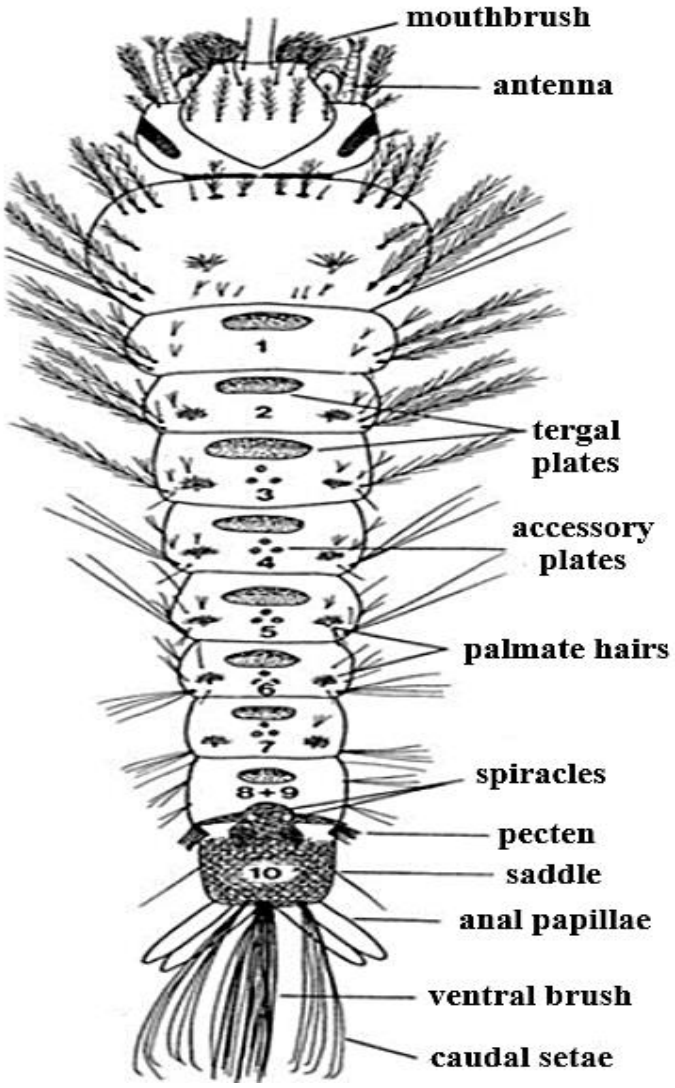


Figure- 6: *Anopheles* larva (Mike, 2008)

Pupa

The body of pupa (plural- pupae) is divided into two parts *i.e.*, Cephalothorax and abdomen. The head and thorax are combined to form the cephalothorax, which dorsally has a pair of respiratory trumpets. Pupal abdominal segments have numerous short setae and segments 2-7 or 3-7 have additional short peg-like spines (Figure- 7).

The respiratory trumpets of anopheline pupae are short and broad distally, thus appearing conical. The pupal stage is a non-feeding stage of development and can withstand in this stage until the unfavourable conditions. Pupae are mobile, responding to changes in light and moving (tumbling) with a flip of their tails towards the bottom or protective areas. After completion of development, the pupal skin splits and the adult mosquito (imago) emerges.

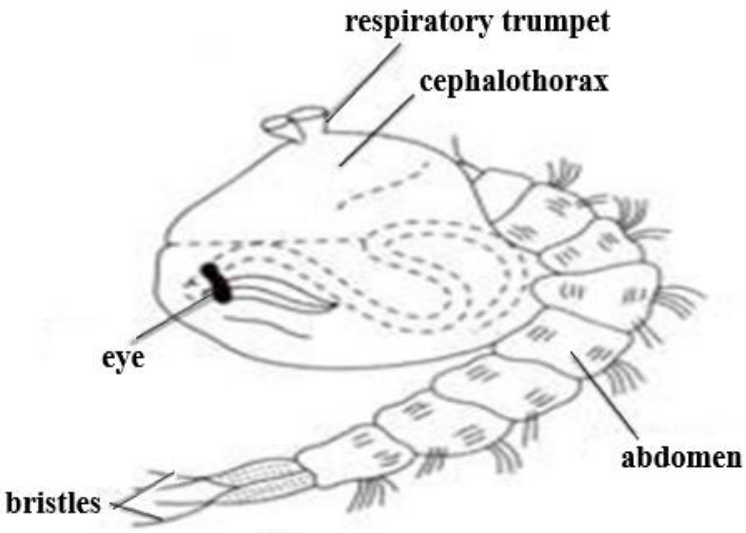


Figure- 7: *Anopheles* pupa (Becker et al., 2010)

2.1.2 Vector biology

Life cycle of *Anopheles* mosquito (Malaria vector)

The *Anopheles* mosquitoes go through all four stages in their life cycle: egg, larva, pupa and adult (Figure- 8). The first three stages are aquatic and last about 7-14 days. The time variation for development depends on temperature and nutritional factors.

Egg

Adult mosquitoes usually mate within a few days after emerging from pupal stage. Female mosquito usually requires a blood meal for the development of eggs. Female *Anopheles* lays nearly 50-200 small brown or blackish boat-shaped eggs on surface of the water (Figure- 5). The eggs are laid singly and hatch within two to three days after oviposition. The oviposition sites are rain pools, streams, swamps, canals, rice fields,

water tanks and sometimes dirty water. Each species of mosquito prefers a particular type of habitat for oviposition.

Larva

After 2-3 days, the small larva emerges from the egg. The wriggler grows in size and moults four times (four larval instars). After 1-2 days, it becomes second instar, followed by the third and fourth instars. The larva remains as fourth instar for 3-4 more days changing to become a pupa. The total time spent in the larval stage is generally 7-10 days at the normal condition. *Anopheles* larvae are filter-feeders and feed on organic matter from the environment and microorganisms notably plant debris, algae, diatoms, bacteria, yeasts, protozoans and crustaceans etc. During feeding, larvae rotate their heads through 180º so that the ventrally positioned mouth brushes can sweep the underside of the water surface. Larvae may easily disturb by shadows or vibrations and respond by swimming quickly to the bottom of the water and swim back to surface after some seconds or minutes.

Pupa

Fourth instar larva shed larval skin and becomes pupa. The comma-shaped pupa normally remains floating at the water surface, but when disturbed, they swim vigorously down to the bottom with characteristic jerky movements. The pupal period lasts 2-3 days in tropical countries but sometimes as long as 1-2 weeks in cold climates, after which the adult mosquito emerges.

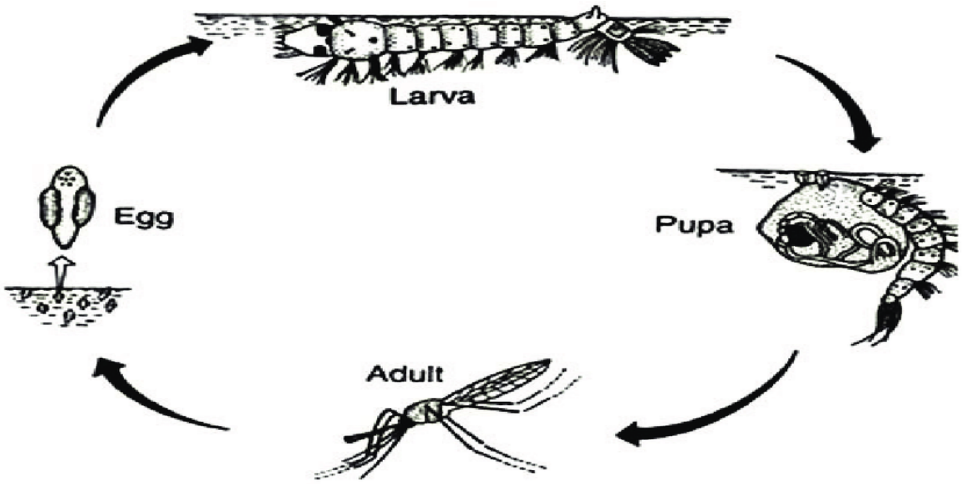


Figure- 8: Life cycle of *Anopheles* mosquito (Baranitharan et al., 2018)

Adult

The pupal skin splits along the back between the trumpets and the adult or imago emerges. Head comes out first and legs in last with well-developed wings. The imago sits on the empty split pupal skin for some time and as soon as the legs, wings and body become sufficiently hard, it flies away. The adult mosquitoes either take shelter in the adjoining vegetation or flies away to nearest human dwellings or cattle sheds. After mating and blood feeding, female Anopheles lays eggs and then the cycle continues. Anopheline mosquitoes rest with their bodies at an angle to the surface *i.e.* with the proboscis and abdomen in a straight line or head down bottom up.

2.1.3 Vector ecology

Malaria is transmitted by female *Anopheles* mosquito bite, which gets infected through a blood meal taken from an infected person. A single infected mosquito, during her lifetime, may infect several persons. The feeding and resting habits of mosquitoes are of great importance in vector control programmes and they must be well understood. Most anopheline mosquitoes bite at night, some bite shortly after sunset while others bite later, around midnight or the early morning. In India, malaria is mainly caused by two major malaria parasites namely *Plasmodium falciparum* and *P. vivax*.

Bionomics of Primary Vectors

a) *Anopheles culicifacies*

Distribution

This species is found in India and nearby countries ranging from Afghanistan, Bangladesh, Cambodia, Southern China, Iran, Laos, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand, Vietnam and Yemen. *An. culicifacies* is among the most widely distributed mosquito species in India and occurs in all mainland zones including Kashmir and high elevations in the Himalayas excluding

Anopheles culicifacies

the islands of Andaman and Nicobar and Lakshadweep. It has a sphere of influence in Maharashtra, Uttarakhand, Uttar Pradesh and Bihar.

Breeding places

An. culicifacies breeds in rainwater pools and puddles, borrow pits, river bed pools, irrigation channels, seepages, rice fields, wells, pond margins, sluggish streams with sandy margins and occasionally in brackish waters (Figure- 9). Extensive breeding of *An. culicifacies* is generally encountered following monsoon rains.

Surface water tank **Irrigation canal**

Figure- 9: *Anopheles culicifacies* breeding places

Resting habits

Rests during daytime in human dwellings and cattle sheds, rests mainly indoors after feeding (endophilic).

Biting time

Biting is throughout the night but peak biting is from 19.00 to 04.00 hrs.

Feeding habits

Adults prefer domestic animals but commonly bite humans indoors or outdoors (endo or exophagic).

Flight range

Normally has a flight range of about 1-3 kms.

b) *Anopheles stephensi*

Distribution

Widely distributed in India except higher altitudes; found sporadically in the north-east (especially in towns). *An. stephensi* is a subtropical species and also distributed across the middle east and South Asia region, covering countries such as Afghanistan, Bahrain, Bangladesh, China, Egypt, India, Iran, Iraq, Oman, Pakistan, Saudi Arabia, and Thailand.

Anopheles stephensi

Breeding places

It breeds in fresh and brackish water such as wells, overhead and ground level water tanks, cisterns, rain water collections in roof gutters, peri domestic containers, and underground water storage tanks (Figure- 10). In Thar Desert, it breeds and rests in the water storage tanks called 'tankas' in the rural areas.

Resting habits

They rest in human dwellings and cattle sheds. Inside human dwellings they may rest on hanging objects, behind curtains, etc., outdoor resting has been observed in wells and underground cement tanks.

Sump tank

Stagnant water at construction site

Figure- 10: *Anopheles stephensi* breeding places

Biting time

Biting is throughout the night but peak biting is from 19.00 to 04.00 hrs.

Feeding habits

Mainly zoophagic, but may feed indoor and outdoor (endophagic and exophagic) indiscriminately on man and cattle, particularly at high-density levels.

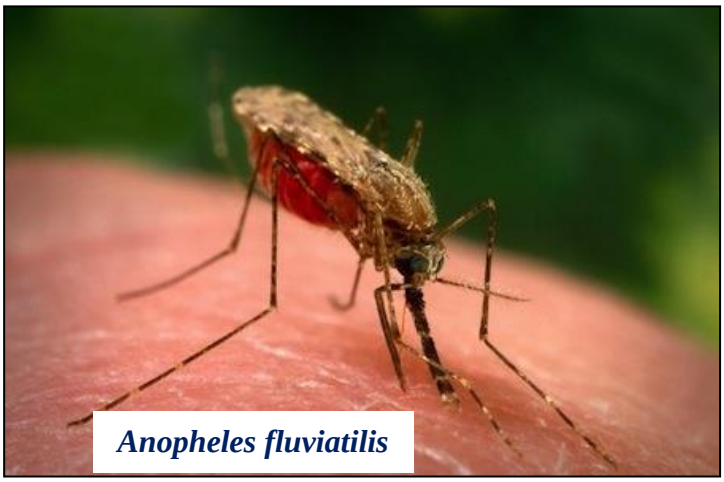
Flight range

The flight range is about 1-3 km.

c) *Anopheles fluviatilis*

Distribution

Widely distributed in the foothill areas including both, peninsular and north-east India and also distributed in China, Thailand, Vietnam, Nepal, Pakistan and Iran.



Anopheles fluviatilis

Breeding places

Breeds typically in slow running streams, seepages and irrigation channels; also recorded from rice fields and shallow wells (Figure- 11). During heavy rains the breeding of *An. fluviatilis* is often flushed out.

Resting habits

Rest indoors in human dwellings and cattle sheds.

Biting time

Generally, enters houses at dusk and completes feeding before midnight with peak from 21.00 to 23.00 hrs.

River edges with stagnant water

Paddy field

Figure- 11: *Anopheles fluviatilis* breeding places

Feeding habits

This species is in general highly anthrophagic and shows a zoophagic tendency in northern India.

Flight range

Flight range is about 0.5 to 1.5 km.

d) *Anopheles minimus*

Distribution

Distribution is restricted to the north-eastern states in India. This species was thought to be eliminated as a result of insecticidal spraying in 1950 and 1960 but reappeared in late 1970. It is a very efficient vector of malaria.

Anopheles minimus

Breeding places

An. minimus breeds in shaded slow flowing streams with grassy margins, swamps, ditches, channels, shallow earth wells (Figure- 12); occasionally found to breed in borrow pits, rice fields and seepage from flowing water.

Stagnant water stock inside forest **Well**

Figure- 12: *Anopheles minimus* breeding places

Resting habits

It rests in houses and cattle sheds, and prefers to rest on the lower portions of walls.

Feeding habits

Highly anthropophilic.

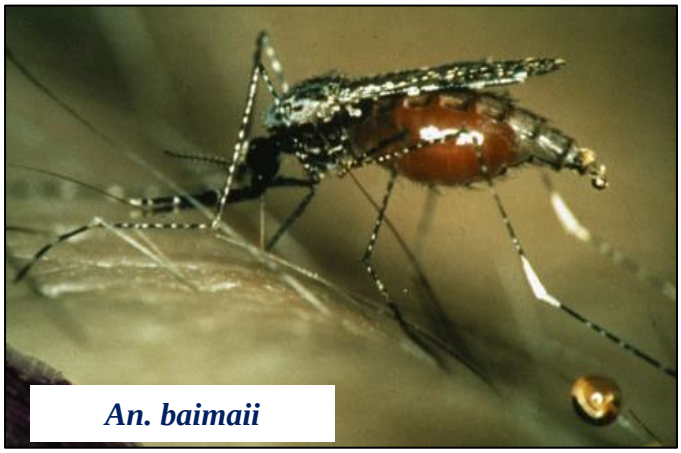
Flight range

Normally 0.5 km but can disperse up to 2 km from the original locality.

e) *Anopheles baimaii (*formerly known as ***An. dirus)***

Distribution

Anopheles baimaii is distributed in eastern Asia such as Myanmar, Thailand, Cambodia, Laos, Vietnam, and Hainan island in China. In India, *An. baimaii* distribution is restricted to the forested areas of north eastern states.



An. baimaii

Breeding places

Breeds in pools and rain water collections in deep forest and forest fringes, stream margins with decaying organic matter and animal foot prints during high monsoon (Figure- 13).

Water bodies in forest area

Figure- 13: *Anopheles baimaii* breeding places

Resting habits

Enters human dwellings to bite and rest, but tends to leave houses soon after a blood meal.

Biting time

The peak biting activity is from 22.00 to 02.00 hrs.

Feeding habits

High preference for human blood but also bites monkeys, other primates and cattle, endophagic and exophagic.

Flight range

Flight range varies from 1.0 to 2.0 km.

f) *Anopheles epiroticus* (formerly known as *An. sundaicus*)

Distribution

Anopheles epiroticus is distributed in coastal Odisha, Andhra Pradesh, West Bengal, south Nicobar, Andaman and Indonesian islands. Presently it is prevalent in Andaman and Nicobar Islands.

Breeding places

Breeds in brackish water pools with algae, margins of mangroves, lagoons and swamps (Figure- 14).

Coastal shoreline

Mangroves

Figure- 14: *Anopheles epiroticus* breeding places

Resting habits

Rest indoors in human dwellings, cattle sheds and mixed dwellings.

Biting time

Biting goes on throughout the night but peak biting is from 20.00 to 02.00 hrs.

Feeding habits

Prefers to bite human beings.

Flight range

The flight range is about 1.0 to 3.0 km.

3. Vectors of Lymphatic Filariasis and Japanese Encephalitis

Culex spp. mosquitoes are important vectors of Lymphatic Filariasis (LF) and arboviral diseases such as Japanese Encephalitis. *Culex quinquefasciatus*, the common house mosquito, the potential vector of bancroftian filariasis is the most widely distributed mosquito in India. *Culex tritaeniorhynchus, Cx. pseudovishnui* and *Cx. vishnui* are important vectors of Japanese Encephalitis (Reuben et al., 1994).

3.1 *Culex* mosquito

Culex mosquitoes are found more or less worldwide, but they are absent from the extreme northern and southern parts of the temperate zones.

Classification

Phylum	**:**	Arthropoda
Superclass	**:**	Hexapoda
Class	**:**	Insecta
Order	**:**	Diptera
Family	**:**	Culicidae
Subfamily	:	Culicinae
Genus	**:**	*Culex*

The species belonging to Culicinae subfamily are referred to as 'culicine mosquitoes'. In some areas, they pose a considerable nuisance. *Culex* breeds in association with human habitations and rice fields. The *Culex vishnui* subgroup includes *Culex tritaeniorhynchus, Cx. pseudovishnui* and *Cx. vishnui*.

3.1.1 External morphology

Adult

The thorax, legs and wing veins of the adult are covered with pale-coloured, often brown scales. The abdomen is covered with brown or blackish scales occurring on most segments. Adults are recognized more by their lack of ornamentation than by any striking diagnostic characters. The tip of the female abdomen is not pointed but

rounded. Claws on all tarsi are simple and have a pair of small pulvilli (Figure- 15). Palpi are much shorter than proboscis in the female, whereas palpi are about as long as proboscis in male (Figure- 3).

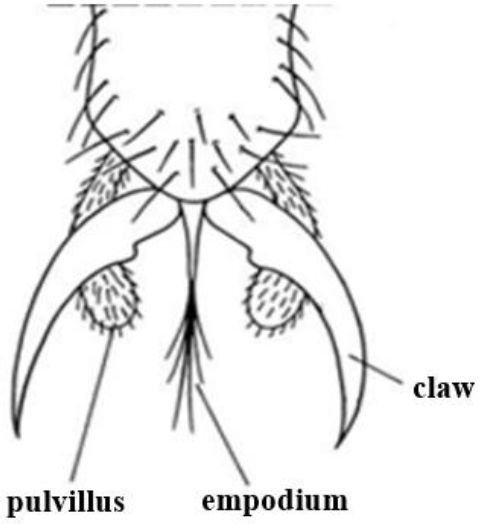


Figure- 15: Tarsal claws, pulvilli in *Culex* mosquito (Mike, 2008)

Egg

The *Culex* females lay eggs in rafts comprising several hundred eggs (which can comprise up to about 300 eggs) locked together in a boat-shaped structure. Eggs are brown colored, long and cylindrical, laid on the water surface (Figure- 16). Cement-like substance binds the eggs to each other; adhesion is due to surface forces holding the eggs together. The anterior pole of each egg has a hydrophilic inner surface, which lies on the water surface, the outer surface is hydrophobic. Surface tension helps to keep the egg-raft in position on the water.

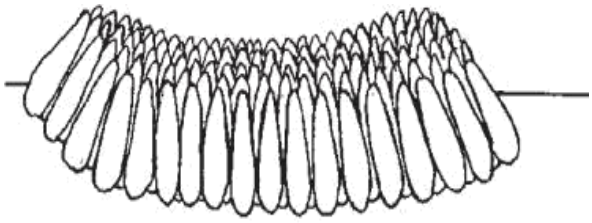


Figure- 16: *Culex* egg raft (Mike, 2008)

Larva

All *Culex* larvae have a long and narrow siphon (Figure- 17). There is always more than one pair of sub-ventral tufts of hair on the siphon. These hair tufts may consist of

very few short and simple hairs. Larvae hang upside down at an angle from the water surface when they are getting air. There are no abdominal palmate hairs or tergal plates on *Culex* larvae.

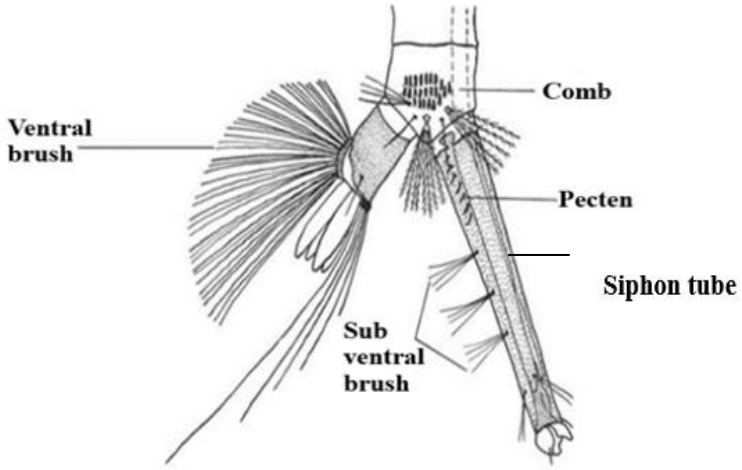


Figure- 17: Terminal abdominal segments of a *Culex* larva (Service, 1980 a)

Pupa

Pupa commonly referred to as 'Tumbler', comma shaped, 3-4 mm long, 1-1.5 mm broad in size and very active in the water. The length of respiratory trumpets is generally longer and more cylindrical. Abdominal segments from 2 to 7 lack peg-like spines, although they have numerous setae.

3.1.2 Vector biology

Life cycle

The life cycle of *Culex* mosquito from egg to adult stage (Figure- 18) is completed in 10-14 days. It is associated with urbanization, especially in towns with poor and inadequate drainage and sanitation. An understanding of the biology of these mosquitoes is a very essential prerequisite for developing control strategies.

Egg

Eggs are laid upright on the water surface and are placed together to form an egg raft, which can comprise up to about 300 eggs. *Culex* mosquito breeds in tin cans, barrels, horse troughs, ornamental ponds, swimming pools, puddles, ditches, partially blocked drains, septic tanks, marshy areas and village pots, especially abandoned ones in

which water is polluted and unfit for drinking. *Culex* mosquitoes usually lay eggs at every third night during entire adult stage. Eggs hatch after 24-48 hours into free swimming larvae.

Larva

The larva hatches from the eggs and undergoes through four instars before developing into pupa after seven days. There are four larval stages; each stage subsequently moults to another stage.

Pupa

Pupae are aquatic and do not feed but they breathe at the surface of the water. The pupal stage lasts from 1 to 2 days. Adult emerges by splitting the pupal case and rests on the surface of the water (Figure- 18).

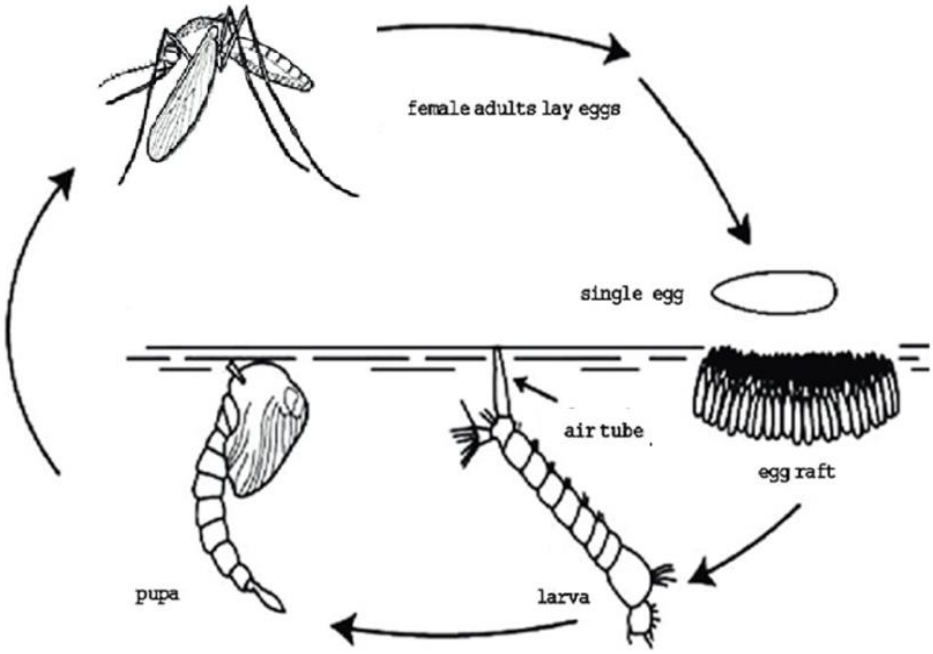


Figure- 18: Life cycle of *Culex* mosquito (Baranitharan et al., 2018)

Adult

After emergence, adult rests with the thorax and abdomen more or less parallel to the surface. Adult mosquitoes are terrestrial and capable of flying. Females feed mostly

on animal and human blood for the development of their eggs. The males are purely phytosuccivorous forms feeding on plant sap. They rest during the day and emerge in the dim light of dawn and dusk. The medically most important species, *Culex quinquefasciatus*, a vector of bancroftian filariasis, is found nearby water polluted with organic debris such as rotting vegetation, household debris and excreta.

3.1.3 Vector ecology

Culex quinquefasciatus is a vector of Lymphatic filariasis, and breeds in association with human habitations. It is the most common house frequenting mosquitoes. Another species *i.e.*, *Culex tritaeniorhynchus* is an important vector of Japanese encephalitis and breeds in paddy fields (Figure- 20).

Breeding places

Culex quinquefasciatus breeds in fresh and polluted water in ground pools, drainages, open pits, and various kinds of artificial containers, especially abandoned ones in which water is polluted (Figure- 19).

Drainage **Open choke pit**

Figure- 19: *Culex quinquefasciatus* breeding places

Resting and feeding habits

Culex quinquefasciatus is mostly indoor feeder and highly anthropophilic; but also feeds on domestic animals (zoophagic) at night time. It rests outdoor or indoor (exophilic or endophilic) at daytime.

Rice field **Shallow ditches at field**

Figure- 20: *Culex tritaeniorhynchus* breeding places

Flight range

The *Culex* mosquito's average flight range is 2-3 kms.

4. Vectors of Dengue, Chikungunya and Zika

Two medically important species viz. *Aedes aegypti* and *Ae. albopictus* have the potential to transmit several viruses related to Dengue, Chikungunya, Zika and Yellow fever.

4.1 *Aedes* mosquito

Classification

Phylum	**:**	Arthropoda
Superclass	**:**	Hexapoda
Class	**:**	Insecta
Order	**:**	Diptera
Family	**:**	Culicidae
Subfamily	:	Culicinae
Genus	**:**	*Aedes*

Aedes is a genus of mosquitoes originally found in tropical and subtropical zones, but now it is found in all continents except Antarctica. Some species have been spread by human activities. *Aedes* species have worldwide distribution. The geographical range extends well into northern and arctic.

4.1.1 External morphology

Adult

Aedes males and females are different in size, males have plumose antennae and maxillary palpi in females have shorter palpi and non-plumose antennae. Many, but not all *Aedes* adults have conspicuous patterns on the thorax formed by black, white or silvery scales. In some species, scales are yellow and brownish.

Scales on the wing veins of *Aedes* mosquitoes are narrow and mainly black. Abdomen consists of eight segments covered with black and white scales forming distinctive patterns in both males and females. In females, the abdomen is pointed at its tip. *Ae. aegypti* can be differentiated from most of the other members of culicinae by their pointed abdomen and the absence of spiracular bristles. Legs have a dark and white ring spot (Figure- 21). *Ae. aegypti* is readily recognized by the lyre-shaped silver

markings on the scutum region (Figure- 22a), whereas, *Ae. albopictus* has median longitudinal white stripe of scutum (Figure- 22b).

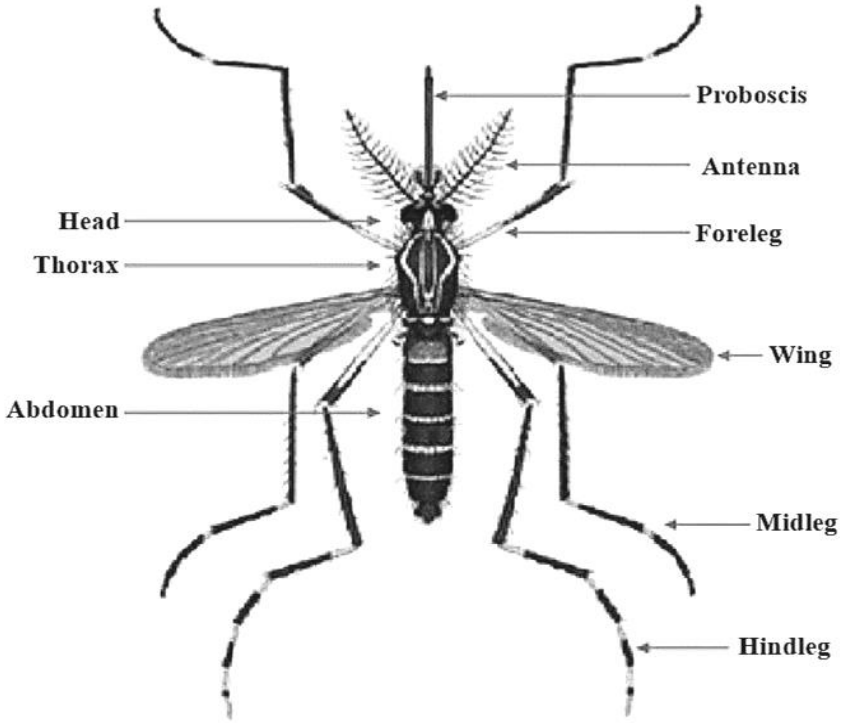
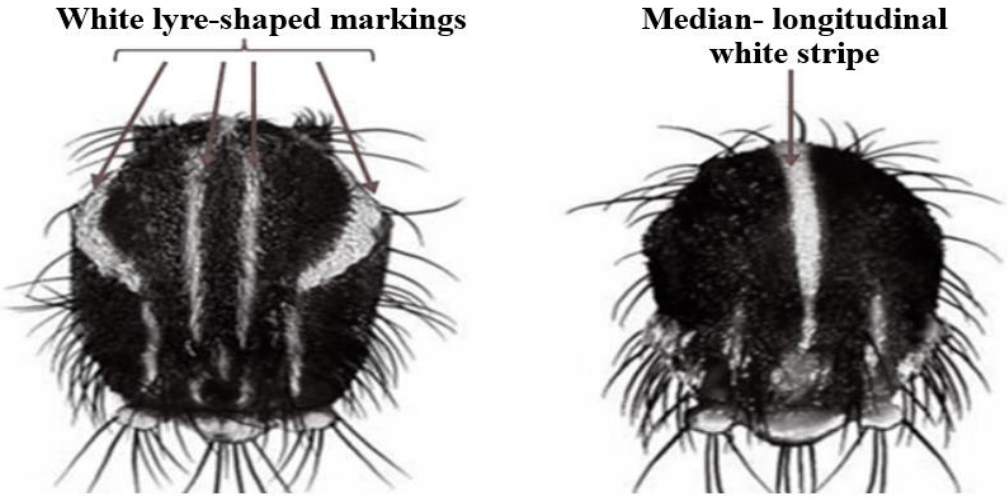


Figure- 21: Adult *Aedes aegypti* mosquito (ENV/JM/MONO, 2018)

Clypeus region of female *Ae. aegypti* has two silvery white dots, which are absent in *Ae. albopictus* females and in males.



(a) (b)

Figure- 22: Thorax region of adult *Aedes* mosquitoes

(a) *Ae. aegypti* (b) *Ae. albopictus* (ENV/JM/MONO, 2018)

4.1.2 Vector biology

Life cycle

The entire life cycle, from an egg to an adult takes approximately 10 to 12 days (Figure- 24). The developmental cycle depends directly on the presence of water and ambient temperature.

Egg

Adult female mosquitoes lay their eggs on damp surfaces in areas such as tree holes and man-made containers like barrels, drums, jars, pots, buckets, flower vases, plant saucers, tanks, discarded bottles, tins, tyres, desert coolers etc. and many other places where rain-water may stagnate or is stored. Eggs are laid on the inner wall of containers with water just above the waterline. Eggs are usually black, ovoid in shape, and are always laid singly.

Aedes mosquitoes generally lay 100 whitish eggs at a time, which turn shiny black within minutes. Eggs can survive for very long periods in a dry state, often for more than a year, however, they hatch immediately once submerged in water. Only a very small amount of water is sufficient to attract a female *Aedes* mosquito for oviposition.

Larva

After hatching from eggs, larvae feed on organic matter in the water, such as algae and other microscopic organisms. *Aedes* larvae have a short barrel-shaped siphon with only one pair of sub ventral tufts, which arises about one-quarter or more from the base of the siphon (Figure- 23). Larvae occur in small containers and habitats like tree holes, plant axil, ground pools, rock-pools water-storage pots, discarded tyres, coconut shells and manmade containers.

*Aede*s larvae are active, show serpentine movement, and typically hang upside down at an angle from the water surface, where they use a short thick respiratory siphon to take oxygen from the atmosphere.

Pupa

After the fourth instar, the larvae enter the pupal stage. Pupal stage lasts for two days. Adults emerge by splitting the pupal case.

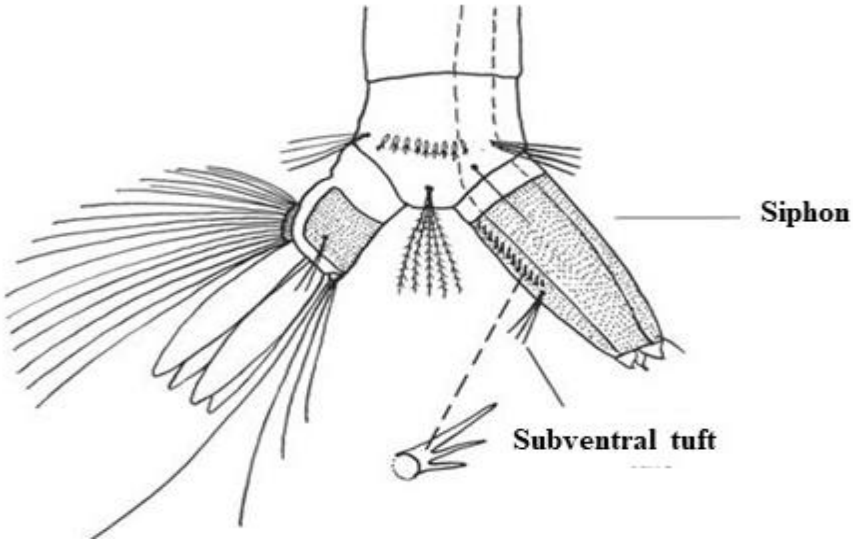


Figure- 23: Terminal abdominal segments of *Aedes* larva (Service 1980 a)

Adult

After emergence, female *Aedes* mosquitoes feed on human blood for developing eggs. After feeding, female mosquitoes rest for the digestion and development of eggs.

4.1.3 Vector ecology

Aedes aegypti* and *Aedes albopictus

Ae. aegypti is one of the most widely distributed mosquito in the world and has considerable medical importance as a vector of Dengue, Chikungunya, Zika and Yellow fever. *Ae. aegypti* mosquitoes prefer to bite human beings and prefer to live near the human habitations. *Aedes* is a basically forest mosquito that has become adapted to rural and urban human environments. They can be found inside houses, and buildings, mainly biting during the day or early evening. Adults usually rest outdoors before and after feeding. The density of *Aedes* mosquitoes is more during monsoon and post-monsoon season. In dry or water scarcity areas, the vector density is linked to water storage practices. *Ae. aegypti* originated from Africa and is now established throughout the tropics and subtropics.

Ae. albopictus is a secondary vector in sylvatic areas. It is a feral species and spread disease in built-up areas, particularly in plantation areas of parks and gardens. It also co-breeds in peri-domestic locations in the trash. *Ae. albopictus* originated from

South-East Asia and has spread to parts of Africa, America, and Europe by the transportation of used car tyres where egg masses are deposited.

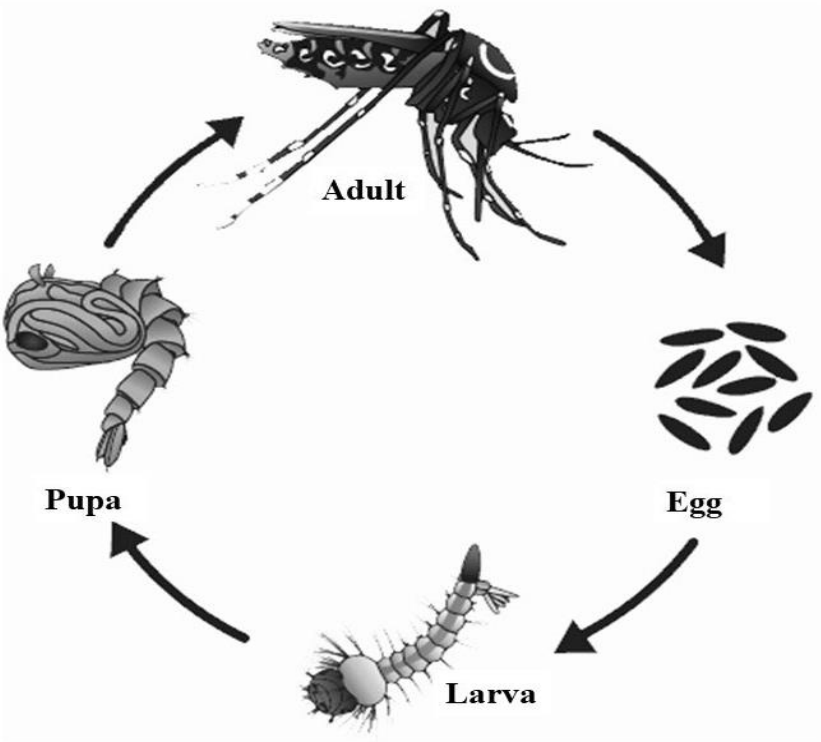


Figure- 24: Life cycle of *Aedes* mosquito (CDC)

Breeding places

Ae. aegypti prefers to breed in man-made containers (Figure- 25), whereas, *Ae. albopictus* prefers natural habitats as shown in Figure- 26.

Resting habits

Ae. aegypti prefers to rest in dark corners of houses, on dark clothes, umbrellas, under furniture and beds, shelves, coolers, behind hangings cloths and shoes, besides household articles, curtains, etc. but rarely on walls.

Feeding habits

Female *Aedes* mosquitoes are mostly anthropophilic and bite during day hours.

Flight range

The average flight range in *Aedes aegypti* is 100 to 300 metres, whereas, *Ae. albopictus* can fly up to 400 metres

Figure- 25: *Ae. aegypti* mosquito breeding places

Figure- 26: *Ae. albopictus* breeding places

5. Vector of Brugian Filariasis

The *Mansonia annulifera, Ma. uniformis,* and *Ma. indiana* are important vector species for Brugian Filariasis in India.

5.1 *Mansonia* mosquito

Classification

Phylum	**:**	Arthropoda
Class	**:**	Insecta
Order	**:**	Diptera
Family	**:**	Culicidae
Subfamily	:	Culicinae
Genus	**:**	*Mansonia*

Mosquito species belong to *Mansonia* genus are generally largely characterized by the presence of broad and asymmetrical scales on the wing veins. There is often a mixture of dark and pale scales that impart a speckled appearance to the wings. They breed in ponds and lakes containing certain aquatic plants, especially floating vegetation like *Pistia stratiotes* and *Eichhornia crassipes.*

5.1.1 External morphology

Adult

Typically, adults have the legs, palpi, wings and body covered with a mixture of dark (usually brown) and pale (usually white or creamy) scales, giving the mosquito a rather dusty appearance. The adults are highly ornamented mosquitoes and can easily be distinguished from the other genera by their broad asymmetrical and speckled wings. The scattering of dark and pale scales on the wing veins gives the wings an appearance of sprinkled salt and pepper (Figure- 27).

Figure- 27: *Mansonia* mosquito wing (Mehlhorn, 2008)

Egg

Eggs are dark brown or blackish in colour and cylindrical, but have a tube-like extension apically, which is usually darker than the rest of the egg (Figure- 28). The eggs are laid in star-shaped clusters, which are glued under the surface of floating vegetation. Each cluster may contain 80 to 120 eggs.

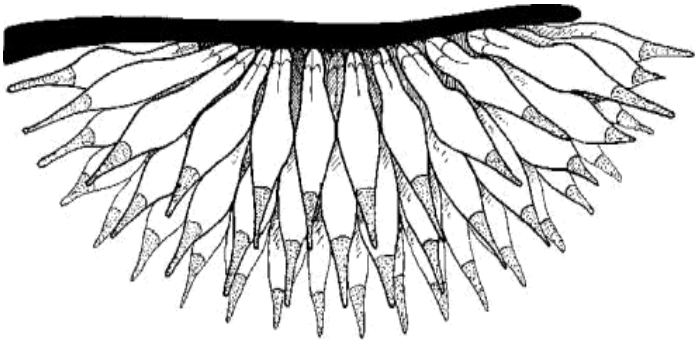


Figure- 28: *Mansonia* eggs (Mike, 2012)

Larva

Mansonia larvae have a specialized siphon adapted for piercing aquatic plants to breath (Figure- 29 a, b). The siphon tends to be conical, with the apical part darker, heavily sclerotized, it has teeth and curved hairs, which assist the larva to attach with plant roots to insert its siphon.

Pupa

At the end of the larval phase, IVth instar larva changes in pupa. The pupal stage lasts for 24 to 48 hours under optimum conditions. *Mansonia* pupa is a non-feeding stage and is very active. It respires through a pair of breathing trumpets. The pupal respiratory trumpets are also inserted into plant roots for respiration as shown in Figure- 29 c.

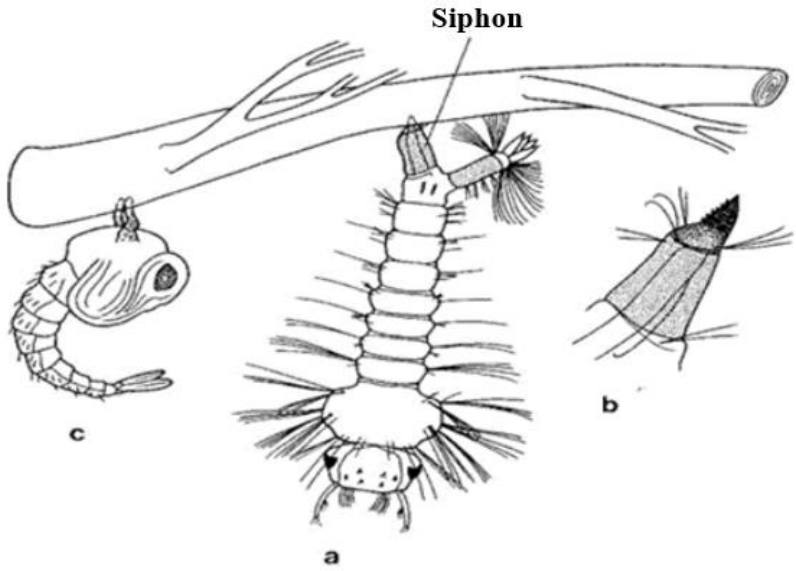


Figure- 29: Immature stages of *Mansonia* mosquito (Service, 1980 b)

5.1.2 Vector biology

In life cycle of *Mansonia* mosquito, usually egg, larva, pupa and adult are distinguished from their shape and size (Figure- 30). The cycle from egg to adult takes about 21-24 days depending on climatic factors. A female mosquito can lay over 250 eggs at one time, which are glued to the undersurface of floating water plants. Within 48 hours, the eggs hatch and 1st instar larvae emerge through a circular slit made at the spicular end almost akin to the dehiscence of a pod.

After emergence, all larvae immediately seek out a suitable rootlet and get attached to it by its modified siphon tube. The siphon tube of larvae is highly chitinized, serrated along one margin and provided with four hooks at the tip to facilitate uninterrupted attachment. The attachment continues during the pupal stage as well, and all the moulting takes place in the attached condition. The tips of the breathing trumpets of the pupae are also modified for attachment. The larvae and pupae need such attachment for the purpose of obtaining oxygen available in the air spaces of floating vegetation.

Just before the emergence of the adult, the pupae get detached from the root and come to surface and the adults escape through the slit on the pupal skin. The cycle from egg to adult takes about 21 to 24 days depending upon climatic factors. The life-cycle of *Mansonia* is presented in Figure- 30.

5.1.3 Vector ecology

The *Mansonia* mosquito is associated with the transmission of brugian filariasis. In India, important vector species are *Ma. indiana, Ma. annulifera* and *Ma. uniformis.* Among the three species, *Ma. annulifera* is considered to be the most important vector of the brugian infection by virtue of their higher anthropophilic, endophilic and endophagous nature. *Ma. uniformis,* the next important species is more zoophagic and is mostly confined to cattle sheds and other outdoor situations. *Ma. indiana* occurs in very low densities and thus, does not play an active role in the disease transmission.

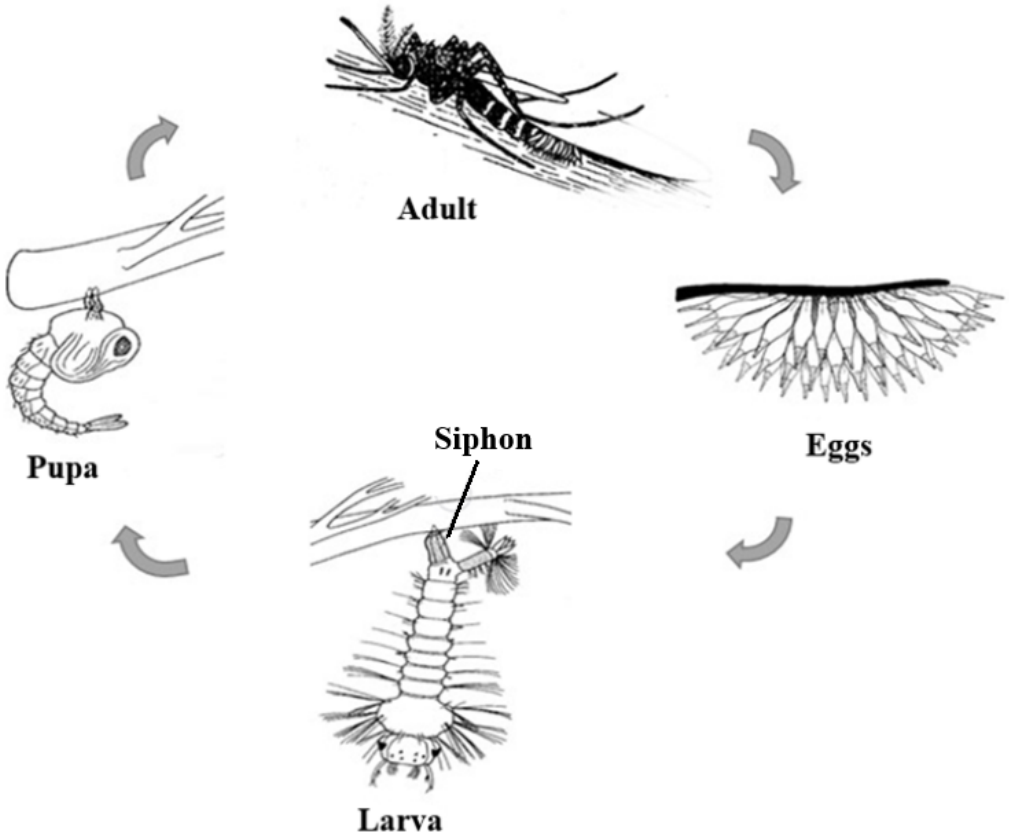


Figure- 30: Life cycle of *Mansonia* mosquito (Mattingly, 1972; Mike, 2012)

The infected and infective mosquitoes of both species are found throughout the year if the survival conditions are favorable. The observation in Kerala showed that wherever *Salvinia* host plants completely replaced *Pistia,* then *Ma. uniformis* densities were much higher than that of *Ma. annulifera* and the transmission intensity shifted to the latter half of the year.

Breeding places

Mansonia spp. breed in fresh water ponds, lakes, swamps and channels with floating vegetation (Figure- 31). *Ma. annulifera* breeds in *Pistia* plant, while *Ma. uniformis* prefers to breed in *Salvinia* plant. Larvae and pupae get the oxygen available from air spaces of the floating vegetation.

Figure- 31: *Mansonia* mosquito breeding places

Resting habits

Ma. annulifera is endophilic, endophagous and rests in dark corners of the house. *Ma. uniformis* and *Ma. indiana* mostly confined to cattle sheds and other outdoor situations.

Biting time

They are endophagous and active throughout the night with the peak biting activity in the first and second quarter of the night.

Feeding habits

Ma. annulifera is highly anthrophagic, while *Ma. uniformis* is more zoophagic.

Flight range

These mosquitoes are silent in flight with limited flight range.

6. Vector of Kala-azar

Phlebotomus argentipes is the only known vector of visceral leishmaniasis (VL) or Kala-azar in India. Sandflies have significant importance to public health in many parts of the world as they are vectors of the causative agents of leishmaniasis. *Phlebotomus papatasi* is also the vector of zoonotic cutaneous leishmaniasis in the human.

6.1 Sandflies (*Phlebotomus*)

In phlebotomine sandflies, vein 2 branches twice, which do not branch in other subfamilies of Psychodidae, although this may not be apparent unless most of the hairs are rubbed from the wing veins. There are five genera of sandflies among them *Phlebotomus* and *Sergentomyia* in the old world and *Lutzomyia* in the new world serve as vectors of VL. Sandflies are small, about 3 mm in length, being typical for many species. They are noted for hairy bodies, wings and relatively long legs.

Classification

Phylum	**:**	Arthropoda
Class	**:**	Insecta
Order	**:**	Diptera
Family	**:**	Phlebotominae
Genus	**:**	*Phlebotomus*

6.1.1 External morphology

Adult phlebotomine flies are readily recognized by their minute size (usually less than 5 mm long), hairy appearance, relatively large black eyes and long and stilt-like legs (Figure- 32). The head, thorax, wings and abdomen are densely covered with long hairs. At rest, the wings are held dorso-laterally upward and in a characteristic upright V-formation, unlike most other biting flies. The 16-segmented antennae are long and composed of small bead-like segments having short hairs; antennae are similar in both sexes. The mouthparts are short and inconspicuous and adapted for blood-sucking in females. At their base, there is a pair of five-segmented maxillary palpi, which are relatively conspicuous and drooping downwards.

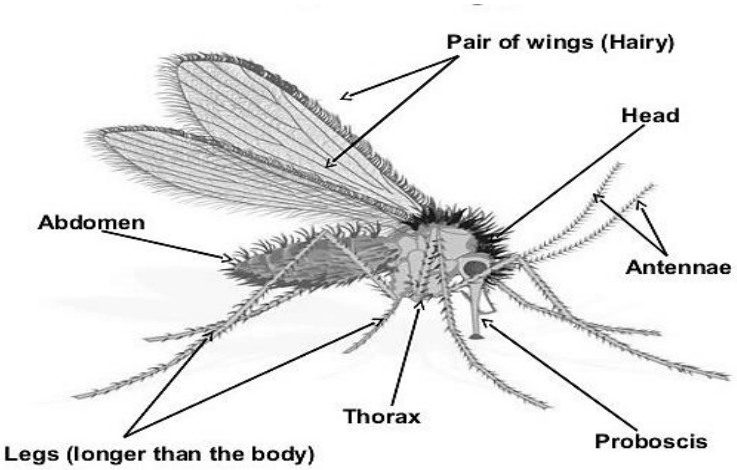


Figure- 32: Adult sandflies (*Phlebotomus*) (Sharma, 2014)

Thorax bears a pair of wings and 3 pairs of legs. Wings are upright, lanceolate, densely hairy and devoid of scales. Legs are slender and longer than the body. The abdomen is moderately long and more or less rounded at the tip in females. In males, it terminates in a prominent pair of genital claspers, which gives the end of the abdomen an upturned appearance. Identification of adult phlebotomine sandflies to species level is difficult and usually necessitates the examination of internal structures, such as the arrangement of the teeth on the cibarial armature, the shape of the spermatheca in females and the structure of the external genitalia in males (terminalia). The spermatheca in *P. papatasi* is 8-9 segmented and cylindrical, while it is 15-17 segmented and carrot shaped in *P. argentipes*.

6.1.2 Vector biology

Life cycle of sandfly

Sandflies have an extended, complete life cycle (egg, larva, pupa and adult), which generally lasts for 1 to 2 months (Figure- 33). In temperate climates, overwintering in one of the life stages may further extend the life span.

Egg

Female sandflies lay about30-70 eggs singly on moist soil or in small cracks and holes in the ground at each oviposition. Eggs are laid individually in small batches in protected areas with high humidity and sufficient organic matter to serve as food for the larvae. They are more or less ovoid in shape and usually brown or black in color, which hatch within 4 to 20 days.

Larva

The larvae are small and caterpillar-like with a well-developed head capsule and numerous brushes-like or spatulate setae on the body and long caudal setae that are nearly as long as the body. The first instar larvae have an egg-bursting spine on the head capsule and one pair of caudal setae. The II, III and IV larval instars have two pairs of caudal setae, but otherwise, except for size, appear similar to the first instar larvae (Figure- 33). In the IV instar, larvae bear a darker sclerotized plate on the dorsum of the last abdominal segment. The development time for some sandfly larvae may be as short as 18 days but it may be prolonged to months during cold weather in temperate zones. Larvae feed on dead organic matter and are found living in moist areas, such as in animal burrows. Before transforming into a pupa, the matured IV instar larva ceases to feed and seeks a place to pupate that is usually drier and perhaps more protected and anchors itself to a surface, such as a leaf or stone.

Pupa

Prior to pupation, the larva assumes an almost erect position in the habitat, the skin then splits open and the pupa wriggles out. The larval skin is not completely cast off but remains attached to the end of the pupa. The presence of this skin, with its characteristics of two pairs of caudal bristles, aids in the recognition of the phlebotomine pupa (Figure- 33). Sandflies are immobile during this stage and do not eat. The pupal stage usually lasts for 7-12 days; males usually emerge before females.

Adult

The life cycle from oviposition to adult emergence is 30-60 days. It is usually difficult to find larvae or pupae of sandflies in the field. Sandflies emerge at night, shortly after they develop their wings, which are of characteristic V-shape when erected. Adult male and female sandflies feed on sugary sap from plants but females in addition suck blood from a variety of vertebrates. The female *Phlebotomus* species bites mammals including humans. Sandflies are active during the early morning and evening hours when temperatures are cooler and humidity is lower. Most species feed outdoors (exophagic) but some species also feed indoors (endophagic). Some species are autogenous and they can lay eggs without blood-feeding.

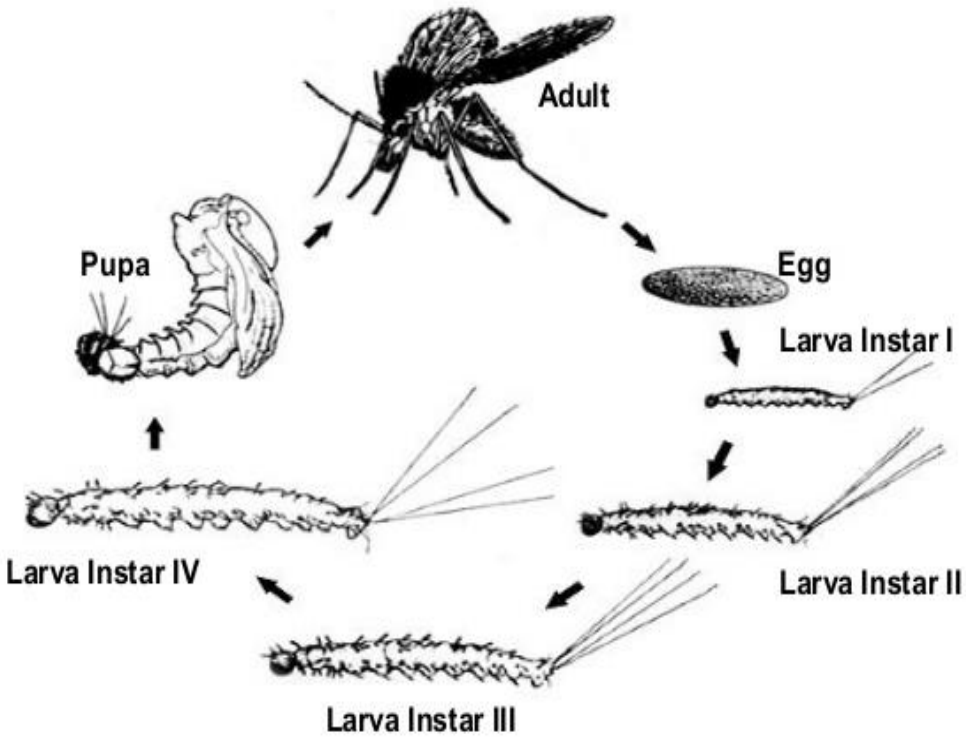


Figure- 33: Life cycle of sandflies (*Phlebotomus*) (Sharma, 2014)

6.1.3 Vector ecology

Leishmaniasis is one of the VBDs transmitted by sandfly. Visceral leishmaniasis or kala-azar is transmitted by the bite of infected sand flies. *Phlebotomus argentipes* is the only known vector of Kala-azar in India. The seasonal prevalence of this species varies from area to area depending upon the ecological conditions. Adult sandflies are small, fuzzy, weak fliers and usually disperse 100 m or less from their larval habitats but some species have been hopping up to 2.2 km over a few days. When close to a host, sandflies may have a characteristic hopping type of flight, so there may be several short flights and landings before females settle on a host. Even a light wind inhibits flight activities and biting. Because of their very short mouthparts, sandflies are unable to bite through clothing.

During the day, adult sandflies rest in sheltered dark and humid sites, but on dry surfaces, such as in animal burrows, termite mounds, tree-holes, cracks, crevices etc. in the ground and inside human and animal habitations. Sandflies commonly rest in houses (endophilic) before or after feeding on humans and are often referred to as domestic or peri-domestic species. Sandflies are commonly more or less found

throughout the year in tropical areas, but some species may have well-marked changes in abundance of adults related to the dry and wet seasons.

Phlebotomus argentipes

Distribution

Phlebotomus argentipes is found throughout the year in the majority of areas of prevalence with complete absence in winter. Though sandflies are not found at the altitude above 600 metres, sporadic occurrence in India has been recorded in Kasauli at a height of 1200 meters and 1300 metres in Pauri Garhwal in Himalayas.

Phlebotomus argentipes

Breeding places

Breeds in humid soil, which is rich in organic matter and near cattle sheds and mud-houses (Figure- 34).

Figure- 34: *Phlebotomus argentipes* breeding places

Resting habits

Resting sites include cracks and crevices, burrows, tree holes, termite hills, earthen mounds, under stone and foliage etc.

Feeding habits

Feeding activity is influenced by temperature, humidity and air movement. Most species feed at dusk and during the night when the temperature falls and humidity rises, although daytime biting can occur indoors in darkened rooms or among shaded vegetation, especially if disturbed by human activity.

Biting habits

They are opportunistic feeders and mostly zoophagic. Longevity under lab conditions rages from 23-37 days but in field conditions from 16-20 days.

Flight range

These are poor flyers and mostly hop covering a distance of less than 50 cm.

7. Vector of Plague

Oriental rat flea (*Xenopsylla cheopis*) is the principal vector of plague (caused by *Yersinia pestis*- a bacterium) and murine typhus (caused by *Rickettsia typhi*- a bacterium) in many tropical and subtropical parts of the world.

7.1 Fleas (*Xenopsylla*)

There are about 2500 species of fleas in about 220 genera, but only a few act as vectors. Fleas are small, wingless insects with a characteristic jumping movement and occur almost worldwide.

Classification

Phylum	**:**	Arthropoda
Class	**:**	Insecta
Order	**:**	Siphonaptera
Family	**:**	Pulicidae
Genus	**:**	*Xenopsylla*

7.1.1 External morphology

Adult fleas are oval-like in shape and relatively small (1-6 mm); they are compressed laterally and vary from light to dark brown. Wings are not present but have three pairs of powerful legs, with hind legs specialized for jumping. Bristles and small spines are covered on the body and legs (Figure- 35). Head is immobile, its shape is highly variable and may be useful in species identification. The head has a pair of conspicuous eyes (a few species are eyeless) and short three-segmented more or less club-shaped antennae lie in depressions behind the eyes.

The mouthparts are pointed downwards and consist of well-developed tooth-like spines known as the genal comb or genal ctenidium, which is present along the bottom margin of the head. The thorax has three distinct parts: pro-, meso- and metathorax. The posterior margin of the prothorax bears tooth-like spines forming the pronotal comb. The mesopleuron is located above the middle pair of legs and is divided into two parts by a thick vertical rod-like structure called the meral rod, pleural rod or just rod (Figure- 36).

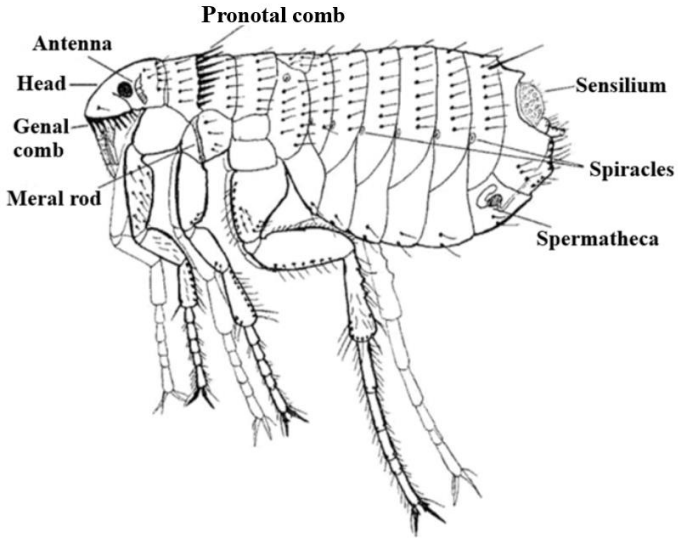


Figure- 35: External morphology of adult flea (Service, 1980 c)

In female fleas, the tip of the abdomen is more rounded than in males (sharp end). One or two distinct brownish spermathecae lodge in the abdominal sixth to eight segments. It is not epidemiologically important to distinguish the sexes because both take blood-meals and can be vectors. The sensilium, a sensory dome-shaped structure having setae is present dorsally on eighth segment. It helps to detect vibrations, temperature and host. Adults of *Xenopsylla cheopis* lack both, a pronotal and a genal comb (Figure- 36).

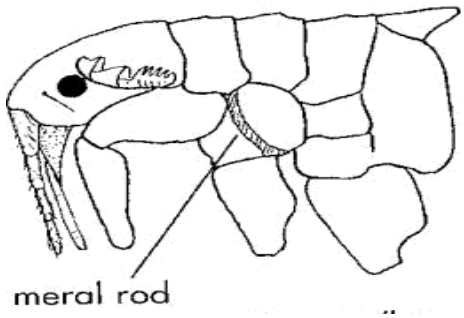


Figure- 36: Presence of meral rod and absence of genal, pronotal comb in the species of *Xenopsylla cheopis* (Service, 1980 c)

7.1.2 Biology and ecology

Fleas avoid light and are mostly found among the hairs or feathers of their hosts or on clothes. The life cycle of fleas comprises egg, larva, pupa and adult (Figure- 37). Both sexes take blood-meals from humans or animals, such as dogs, cats, and commensal rats. Most flea species feed on one or two host species, but in the absence of their normal host they feed on humans or other animals. A gravid female leaves the host

and deposits the eggs in debris of host dwelling, such as rodent burrows. Fleas lay their eggs while they are still on the host but due to non-sticky nature, they soon fall off the host and are mainly found in areas, where hosts spend most of the time.

Eggs are very small (0.1-0.5 mm), oval, white or yellowish in color and lack any visible pattern. Fleas lay 300-1000 eggs in batches during a whole lifetime of 3-25 days. Eggs usually hatch after 2-5 days depending on temperature and humidity. A small miniature legless larva emerges from the egg. Larva has a small brownish head with pair of small antennae followed by 13 pale brown, distinct and more or less similar segments. Each segment has a circle of setae near the posterior border. The segment ends in a pair of finger-like ventral processes termed as anal struts. The larva is very active, avoids the light and feeds on organic matter. Mature larvae are 4-10 mm in length.

There are three larval instars and larval period lasts normally for 2-3 weeks. At the end of larval period, larva spins a loose whitish cocoon from silk produced by its salivary glands. About 2-3 days after having spun a cocoon around itself the larva pupates within the cocoon. Adults may remain alive in their cocoons for 4-12 months or sometimes for over a year. The adult fleas are fully grown within 1-2 weeks but it emerges from the cocoons after a stimulus. In optimum conditions, development from egg to adult takes 4-5 weeks. The life cycle duration depends on environmental condition. The adult flea species can jump about 20 cm vertically and 30 cm or more horizontally. It has very large legs, which allow them to jump from one nest to another. An elastic protein called resilin allows fleas to store up energy and use it for jumping. To jump, the flea must use its small muscles and unhook the catch, thrusting the flea into a majestic backflip. Fleas cannot control the direction of the jump; they simply land, wherever the flip takes them. The ideal temperature range for *X. cheopis* is about 65 to 80°F.

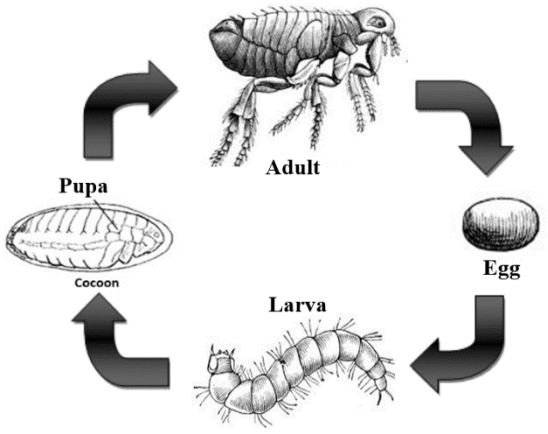


Figure- 37: Life cycle of a flea (CDC)

8. Vector of Enteric diseases

The *Musca domestica* is of most medical importance as it can be vector of helminths, fecal bacteria, protozoans and viruses, resulting in the spread of enteric diseases. Flies are attracted to food sources around homes and businesses, including food waste. They also feed and breed on dead animals, drains and faeces, where they come into contact with many pathogenic microorganisms.

8.1 Housefly (*Musca domestica*)

There are nearly 4200 species and 190 genera belonging to the family Muscidae. Almost 70 species of house fly are belonging to the genus *Musca*. The house fly, *Musca domestica* is the most common of all domestic flies found all over the world. This species is always found in association with humans or the activities of humans. The house fly is a well-known cosmopolitan pest of both farms and houses.

Classification

Phylum	**:**	Arthropoda
Class	**:**	Insecta
Order	**:**	Diptera
Family	**:**	Muscidae
Genus	**:**	*Musca*

8.1.1 External morphology

House flies are medium-sized about 6-9 mm long, varying in colour from light to dark grey with some dark marking. They have four rather broad black longitudinal stripes on the dorsal surface of the thorax. The head is hemispherical and bears two lateral compound eyes. Two small aristate antennae are placed at the front of the head in a depression between the two compound eyes. Each antenna has three segments of which the third is the largest, and bears the arista. Antennae (not easily seen) are concealed in depressions in front of the face. The mouthparts are of sponging and lapping type and are used for sucking of liquid food.

The thorax is formed of three segments pro, meso and metathorax. Each thoracic segment bears a pair of lateral legs. Mesothorax bears a pair of wings and prothorax

bears a pair of spiracles, close to the wings (Figure- 38). The house fly has vein 4 bending up sharply to join the costa close to vein 3, this is an important character, which helps to distinguish *Musca* spp. from other species (Figure- 39). All three pair of legs has paired claws and a pair of pulvilli, which are responsible for picking up pathogens.

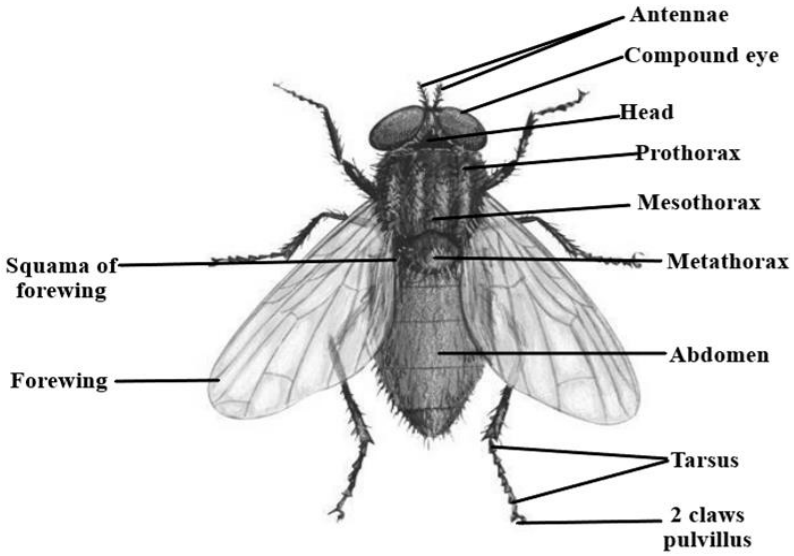


Figure- 38: House fly (*Musca*) (WHO)

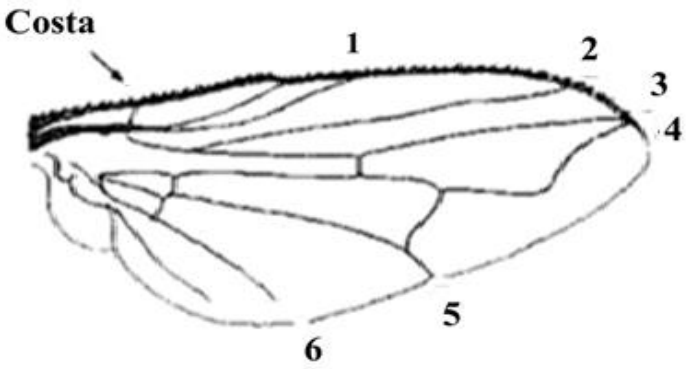


Figure- 39: Wing of house fly (*Musca)* (Mike, 2012)

The abdomen consists of 8 segments in males and 9 segments in females. The First 5 segments in females are externally visible. The last 4 segments are normally retracted but they extend to make the ovipositor when the female lays eggs. This allows females to bury the eggs a few millimetres below the surface. Females are slightly larger than males. The abdomen is grey or yellowish with a dark midline and irregular

dark markings on the sides. The sexes can be readily separated by noting the space between the eyes, which in females is almost twice as broad as in males.

8.1.2 Biology and ecology

House flies live in both urban and rural areas, but are mostly associated with urban areas, especially where humans are present. Dung heaps, garbage cans, mammalian road kill etc. are the best environment for larvae to develop. They are most active and live longest in temperatures between 10°C to 26.6°C. Adult house flies are inactive at temperatures below 7.2°C and die when temperature is below 0°C and above 44.4°C. The life-cycle of house flies is distinguished in four stages such as egg, larva, pupa, and adult (Figure- 41). Eggs are usually laid in masses on organic material like manure and garbage (Figure- 40). The adult house fly can lay up to 500 eggs in several batches of 75 to 150 eggs over the life time. The maximum egg production occurs at temperature between 25°C to 30°C. Egg hatching take place within a few hours depending on the temperature.

Figure- 40: House fly breeding places

The larva is known as maggot and has a small head followed by an 11-segmented cylindrical body. Larvae feed on decomposing organic material. There are three larval instars (Figure- 41). The speed of larval development depends on the abundance of food and temperature. Third instar larvae often move to drier ground and burrow into the soil or hide under objects for pupation. Pupation begins with the larval skin contracting, hardening and turning dark brown, resulting in a barrel-shaped structure called puparium. This stage lasts for 3-5 days. The adult fly emerges from its puparial case by pushing off its anterior end and crawling out and after a short period, it flies away. It takes nearly 49 days to complete life cycle.

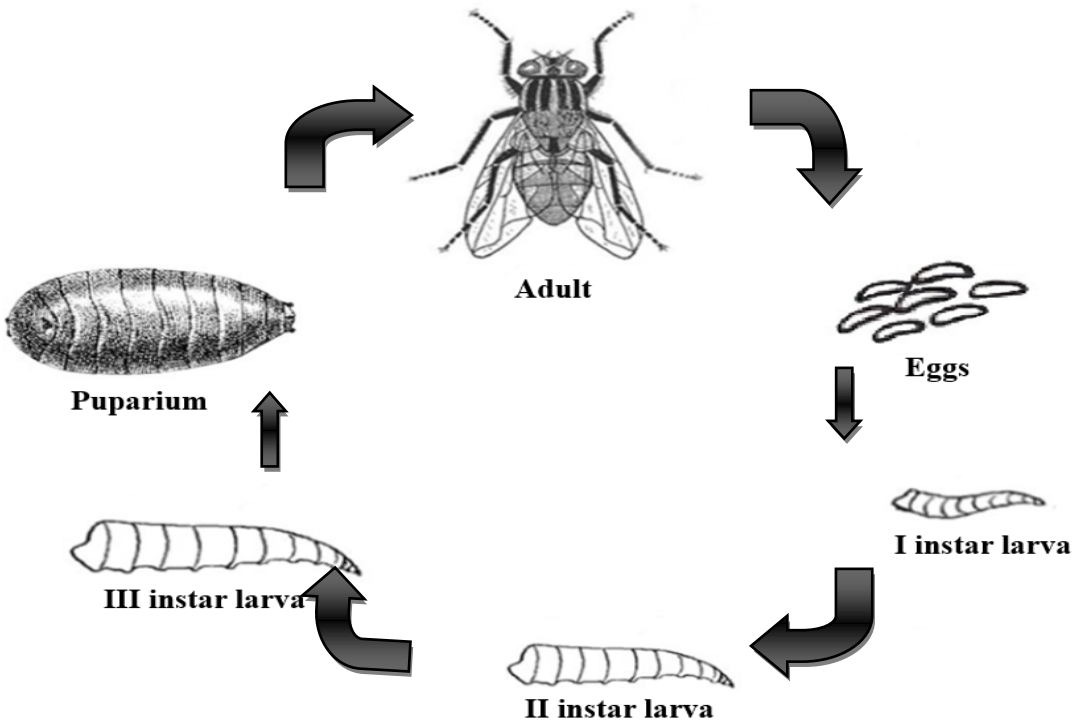


Figure- 41: Life-cycle of housefly (Mike, 2012)

9. Non-Insect vectors of CCHF, KFD and Scrub Typhus

There are non-insect bloodsucking species such as ticks and mites. Some mites live in people's skin, e.g. the mites that cause scabies. Other mite species and ticks may take blood meals from humans and play an important role in transmitting scrub typhus, Crimean-Congo haemorrhagic fever (CCHF) and Kyasanur Forest disease (KFD). Unlike adult insects, they have only two main sections to their body and adults have four pairs of legs.

Ticks

Ticks belong to the phylum Arthropoda and they are obligate blood feeders. They are classified into three families mentioned as Ixodidae (hard ticks), Argasidae (soft ticks), and Nuttalliellidae (limited to Tanzania and South Africa). More than 900 species of ticks have been reported in the world. Ticks not only cause physical damage to their hosts by sucking blood and injuring the skin, but many of these tick species also can transmit pathogens to their host. The population of ticks in any region depends upon various factors such as climate, the presence of predators, and competitor species. A number of tick genera are capable of becoming infected with CCHF virus, but the most efficient and common vectors for CCHF appear to be members of the *Hyalomma* genus, particularly *Hyalomma anatolicum* species. Hard ticks like *Hemaphysalis spinigera* and *H. turturis* are the reservoir of Kyasanur Forest Disease Virus (KFDV) and once infected, remain so for whole life.

9.1 Soft Ticks (Argasidae)

The soft ticks belong to the family Argasidae. Currently, the family Argasidae comprises genera viz. *Antricola*, *Argas*, *Nothoaspis*, *Ornithodoros*, and *Otobius*, and have 193 species. Soft ticks can live for several years in arid conditions and are resistant to desiccation. Soft ticks are very common in South Asia with the highest biodiversity of ticks worldwide and are known to transmit Relapsing fever, a bacterial disease. Tickborne relapsing fever (TBRF) is transmitted to humans through the bite of infected soft ticks. *Borrelia* bacteria that cause TBRF are transmitted to humans through the bite of infected "soft ticks" of the genus *Ornithodoros*.

Classifications

Phylum	**:**	Arthropoda
Class	**:**	Arachnida
Order	**:**	Ixodida
Family	**:**	Argasidae

9.1.1 External morphology

The adult soft ticks are flat and oval in outline, have leathery, wrinkled bodies and are usually covered with fine tubercles or granulations. The mouthparts termed as capitulum (gnathosoma) or false head are situated ventrally and not visible dorsally in the nymphs and adults (Figure- 42). This one character separates adults and nymphal soft ticks from hard ticks (Ixodidae), but the larvae of both soft and hard ticks have the capitulum projecting forward and clearly visible dorsally. The four segmented palpi are leg-like and the powerful cutting chelicerae have teeth at their tips. Both the chelicerae and hypostome, which have teeth arranged in several longitudinal rows, penetrate the host body during feeding. The four pairs of legs terminate in a pair of claws. Males and females look very similar and are usually difficult to separate, although blood-engorged females can be considerably larger than males because they ingest much more blood. However, both sexes feed on blood and can consequently be disease vectors also, it is therefore, insignificant to distinguish the sexes.

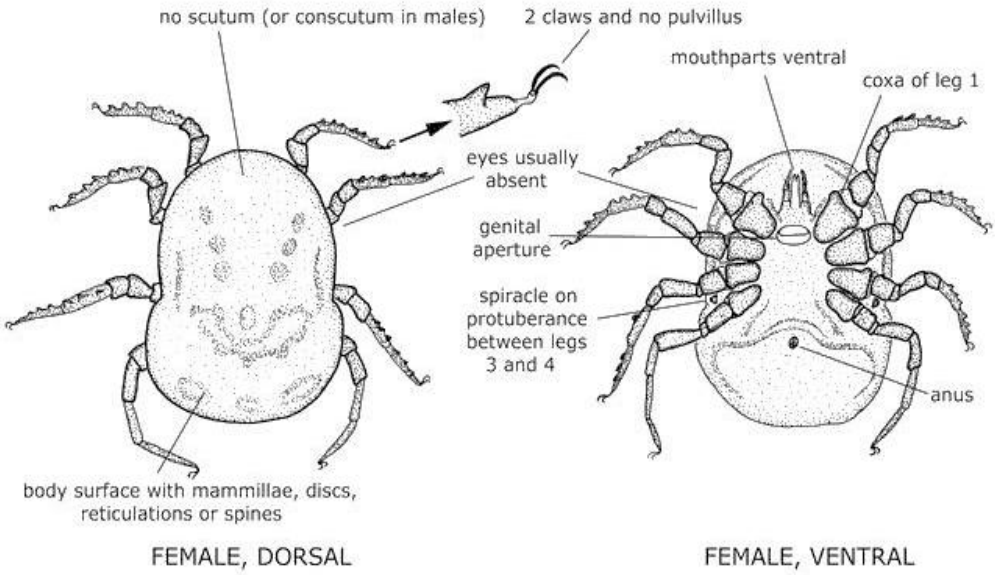


Figure- 42: External morphology of adult soft ticks (Barker et al., 2014)

9.1.2 Biology and ecology

Adults of soft tick are flat and oval in outline and have tough, leathery, wrinkled bodies. Mouthparts are basically situated underneath the body and are not visible from above. The eggs are laid in the places where adults rest e. g., cracks and crevices in the walls and floors of houses and furniture. The larva, the five nymphal stages and the adults all actively search for a host. Feeding lasts for 30 minutes and after which ticks drop to the ground.

Soft ticks live apart from their hosts and are most common in the nests and resting places of the animals on which they feed. Their habits are comparable to those of bedbugs. Ticks often emerge from hiding places at night to suck the blood of humans and animals. Some species are common on travel routes, in rest houses and camping sites and in caves and crevices. Soft ticks show strict, narrowly defined temperature and humidity tolerances for development and activity, reflecting the conditions of their microhabitat. Soft ticks are adapted to live in the nest or regular resting sites of their hosts, often waiting for months or even years for the host.

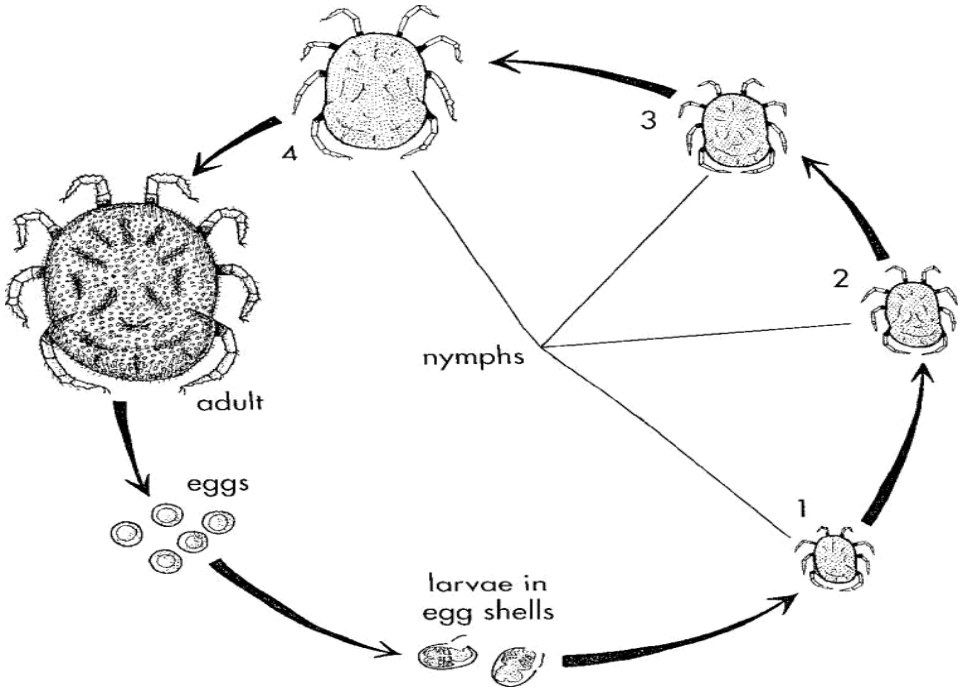


Figure- 43: Life-cycle of soft ticks (Argasidae) (Rozendaal, 1997)

9.2 Hard Ticks (Ixodidae)

The Ixodidae or hard ticks have ovoid or pear-shaped bodies, which become engorged with blood, after feeding. They have eight legs. Hard ticks have a hard shield on their

dorsal surfaces and a beak-like structure at the front containing the mouthparts, whereas, soft ticks have their mouthparts on the underside of their bodies. There are 14 genera and 702 species of hard ticks. Medically the more important genera are *Ixodes, Dermacentor, Amblyomma, Haemaphysalis, Rhipicephalus* and *Hyalomma*. Hard ticks are vectors for arboviral diseases such as Kyasanur Forest Disease (KFD), Crimean Congo Haemorrhagic Fever (CCHF) and many other diseases such as Colorado Tick fever, spotted fever etc.

Classifications

Phylum	**:**	Arthropoda
Class	**:**	Arachnida
Order	**:**	Ixodida
Family	**:**	Ixodidae

9.2.1 External morphology

The adult hard ticks are dorsoventrally flat, oval in shape and about 2-23 mm long. Females are usually bigger than males because they take large amount of blood meals during feeding.

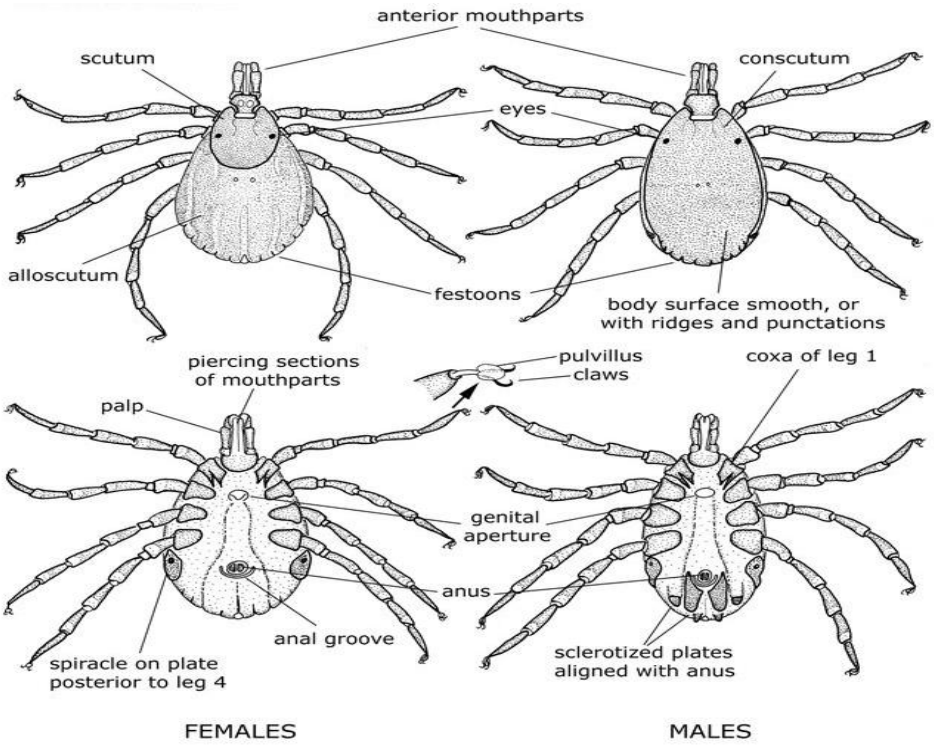


Figure- 44: External morphology of adult hard ticks (Barker et al., 2014)

The capitulum (mouthpart) or false head forward projects from the body and is visible from above, thus distinguishing adult hard (ixodid) ticks from soft (argasid) ticks (Figure- 42). Also, in hard tick's club-shaped palpi are present rather than leg-shaped ones as in soft ticks. The mouthparts are getting firmly attached to the host due to cement-like substance from the salivary gland, which ensures continued attachment during their long feeding times (days to weeks). Hard ticks have a scutum, which is absent in soft ticks (Figure- 43). In males, the scutum is large and it covers the entire dorsal surface of the body, whereas in females it is smaller (Figure- 44) in the larval and nymphal stages the scutum is small in both sexes. There are four pairs of legs, with each leg ending in a pair of claws.

9.2.2 Biology and ecology

Adult hard ticks lay eggs in large numbers. Larvae length varies from 0.5 to 1.5 mm (Figure- 45). They can climb up vegetation and remain on it for one to four weeks, until a suitable host passes by, then climb on to it and attach themselves at a preferred feeding site, such as ears or on the eyelids. After feeding, ticks drop to the ground and seek shelter in cool places under stones and leaf litter, where they lay their eggs.

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

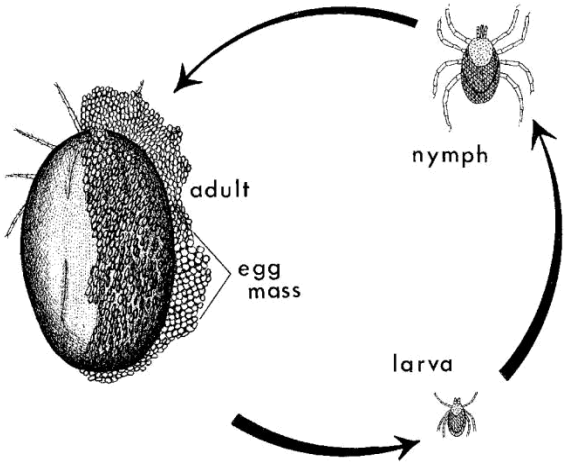


Figure- 45: Life cycle of hard ticks (Ixodidae) (Rozendaal, 1997)

9.3 Mites (Trombiculidae)

Trombiculidae is a family of mites, including more than 2000 species of which around 20 species commonly attack people. The family has a more or less worldwide distribution. In India, *Leptotrombidium delicense* is a medically important species, which is a vector of scrub typhus (caused by *Orientia tsutsugamushi*). In many parts of the world, other trombiculid mites cause itching and dermatitis known as scrub itch, autumnal itch or trombidiosis.

Classifications

Phylum	**:**	Arthropoda
Class	**:**	Arachnida
Order	**:**	Trombidiformes
Family	**:**	Trombiculidae
Genus	**:**	*Leptotrombidium*

9.3.1 External morphology

Adults of trombiculid mites are small (1-2 mm), usually reddish, and covered with numerous feathered hair on the dorsal and ventral sides giving them a velvety appearance. Thorax bears four pairs of legs and each leg is provided with paired claws distally. Palpi and mouthparts project in front of the body and are visible (Figure- 46). Nymphs resemble adults but are smaller (0.5-1.0 mm) and the body is less densely covered with feathered hair. Only the larvae are parasitic and bite the humans or animals hence, they become disease vectors. Adults and nymphs do not bite thus, do not contribute in transmission. Larvae are known as chiggers and they are very small (0.15-0.3 mm). Larval size increases six-fold after blood feeding. Larva has three pairs of legs, with each leg terminating in a pair of relatively large claws.

9.3.2 Biology and ecology

The life cycle of trombiculid mites has been divided into various larval and nymphal stages (Figure- 47). Females lay spherical eggs on grasses, leaves or bushes, even on soil surface and neglected gardens. In hot climates, egg-laying (oviposition) continues uninterrupted for a year or more but oviposition ceases during the cooler months and adults enter into partial or complete hibernation. After about 4-7 days the eggshell

splits and the six-legged larva does not emerge but remains quiescent within the eggshell for about 7 days.

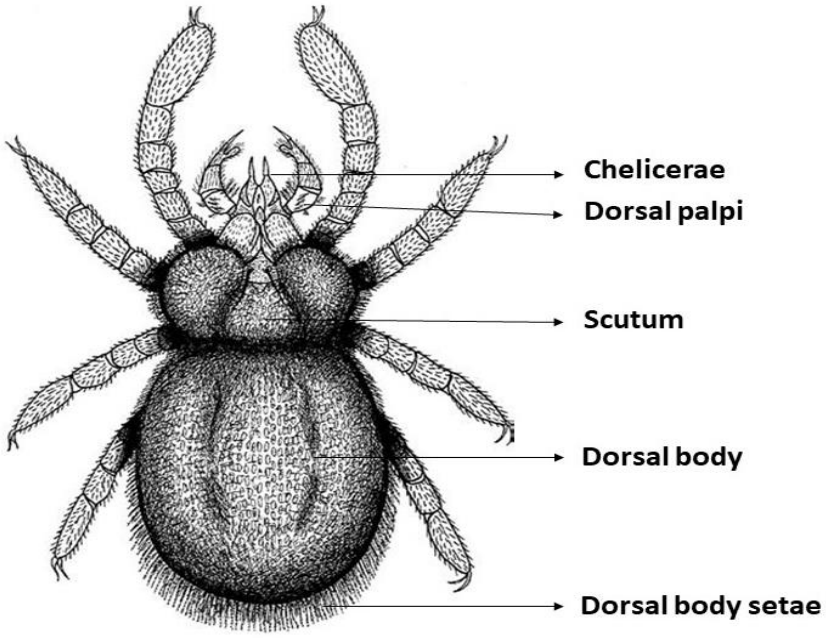


Figure- 46: External morphology of *Leptotrombidium* mites (Mike, 2012)

The larva crawls out of the eggshell and becomes very active, swarming over the ground, climbing up grasses and other small plants or low-lying vegetation. These larvae called 'chiggers', attach themselves to birds and mammals especially rodents and also to people walking through infested vegetation. After getting attached to a suitable animal host, larvae assemble where the skin is soft and moist, such as ears, genitalia and around the anus. They commence feeding on serum exudate, lymph and other fluid. Some trombiculid mites remain attached to their hosts for up to a month, but the *Leptotrombidium* vectors of scrub typhus remain on people for only about 3-10 days.

These chiggers may take 2-12 days for engorgement after which, they drop off and remain quiescent for about 10 days just below the surface of the soil or underneath the debris. Then they get transformed into an inactive protonymph stage, subsequently four-legged active deutonymph stage and adult stage (Figure- 47). Adults resemble nymphs but are larger and like them are free-living and feed on small soil-inhabiting animals. The life cycle generally takes 40-75 days but may differ due to environmental conditions.

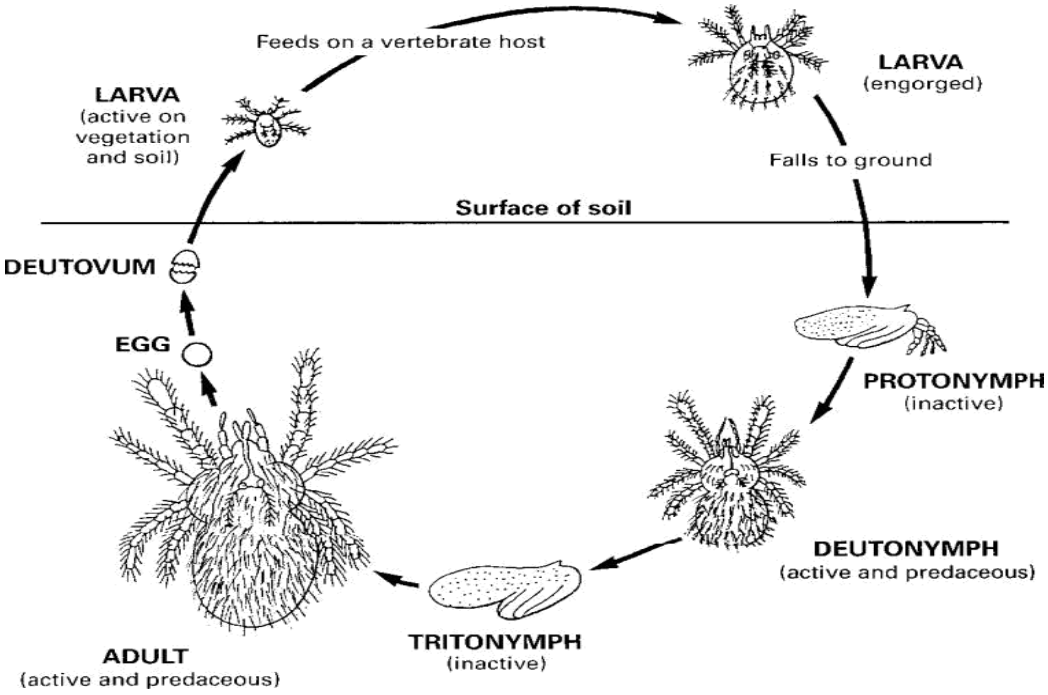


Figure- 47: Life cycle of *Leptotrombidium* mites (Mike, 2012)

10. Glossary

Acetylcholinesterase

Acetylcholinesterase is a type-B carboxylesterase enzyme located primarily in the synaptic cleft with a smaller concentration in the extra junctional area.

Active ingredients

An active ingredient is the element or substance in an insecticide that gives repelling or killing power or biologically active.

Adulticides

Type of insecticides used to kill adult insects or pests.

Alkaloids

Cyclic organic compound containing nitrogen in a negative oxidation state, which is of limited distribution among living organisms.

Adult susceptibility test

Adult susceptibility bioassay is a direct response-to-exposure test; it measures mosquito mortality to a known standard dose of a given insecticide (*i.e.*, the diagnostic or discriminating concentration).

Advocacy

Advocacy is a process by an individual or group, which aims to influence public policy and resource allocation decisions within political, economic, and social systems and institutions. Advocacy can include many activities that a person or organization undertakes including media campaigns, public speaking etc.

Aerosol

An aerosol is a suspension of small particles in air or another gas.

A*f*I

Annual *falciparum* Incidence is calculated as total positive *Plasmodium falciparum* in a year x 1000 divided by total population.

Antibody

Antibodies are substances, which are formed in the serum and tissue fluids in response to an antigen and react with that antigen specifically and in some observable manner.

Antibiotic

Antibiotics are molecules that kill or stop the growth of, microorganisms, including both bacteria and fungi.

Anganwadi

It is a rural child care center in India, providing care for mothers and young children in a rural area.

API

The Annual Parasite Incidence (API) is a malariometric index to express malaria cases per thousand population. API refers to high and moderate malaria transmission risk areas.

Arbovirus

A virus that multiplies in a blood-sucking arthropod and is principally transmitted by the bite of arthropods to vertebrate hosts.

ASHA

Accredited Social Health Activist (ASHA) is one of the key components of the national health mission (earlier national rural health Mission), which provides every village in the country with a trained female community health activist.

Aldrin

A brown, water-insoluble, toxic solid consisting of more than 95 percent of the chlorinated hydrocarbon C12H8Cl6: is used as an insecticide.

Alpha-cypermethrin

Alpha-cypermethrin is a pyrethroid insecticide consisting essentially of two of the four cis isomers comprising cypermethrin. Alphacypermethrin is a highly active broad-spectrum insecticide,

effective by contact and ingestion against target pests.

Amastigotes

The nonmotile, parasitic form in the life cycle of some protozoans and especially Leishmania that usually develops in the cells of vertebrate hosts and occurs as a minute, ovoid or spherical body with a prominent, rod-shaped kinetoplast and a rudimentary, internal flagellum arising from a basal body.

Amplifying hosts

It is a host in which infectious agents multiply rapidly to high levels, providing an important source of infection for vectors in vector-borne diseases.

Anthropogenic factors

Anthropogenic factors of the environmental changes influence the organic world and are introduced into nature by human activity. In reworking nature and adapting it to their own needs, people influence the lives of animals and plants by altering their habitats. The influence may be indirect or direct.

Anthropophilic

Anthropophilic is associated with humans or attracted to humans, especially for food sources.

Antibodies

Antibodies are substances, which are formed in the serum and tissue fluids in response to an antigen and react with that antigen specifically and in some observable manner.

Antigens

An antigen is a substance that, when introduced into a body evokes an immune response to produce a specific antibody with which it reacts in an observable manner.

API

The Annual Parasite Incidence (API) is a malariometric index to express malaria cases per thousand population. API refers to high and moderate malaria transmission risk areas.

Arbovirus

Arbovirus is an arthropod-borne virus. A virus that multiplies in a blood-sucking arthropod and is principally transmitted by the bite of arthropods to vertebrate hosts.

Arthropods

An animal of the phylum Arthropoda, characterized by the presence of a segmented body, an exoskeleton, jointed appendages, a dorsal blood vessel, a haemocoel and a ventral nerve cord.

Aspirator

It is a device to collect small insects and other invertebrates. The aspirator is having one tube through which they are sucked into the bottle, and another, protected by muslin or gauze, which sucks insects.

Autochthonous

Originating or formed in the place where found; indigenous.

Bacillus thuringiensis

Bacillus thuringiensis (Bt) is an aerobic, spore-forming, gram-positive, rod-shaped bacterium distributed widely in the natural environment. It's used to control mosquito larvae as known as larvicide or bacterial larvicide.

Bacteria

Bacteria are prokaryote single-celled micro-organisms with a simple nucleus intermediate in size between protozoa and rickettsia.

Bacterial larvicides

The bacteria like *Bacillus thuringiensis* var. *israelensis* and *Bacillus sphaericus* have been used extensively for mosquito control and be effective and safe for non-target organisms cohabiting with mosquito larvae.

Bait

Bait is the active placement or manipulation of edible or inedible items, to attract or distract potential prey, facilitating prey capture.

Bancroftian filariasis

Bancroftian filariasis is a disease caused by a nematode of the genus *Wuchereria*, that is transmitted in larval form by mosquitoes.

Behaviour Change Communication

The changes that the intended audiences are expected to make in their behaviour and the expected changes in the factors that influence behaviour such as knowledge, attitudes and perceptions.

BG-sentinel trap

The BG-Sentinel mosquito trap is essentially a collapsible, fabric container with a white lid with holes covering its opening. In the middle of the gauze cover, the air is sucked into the trap through a black catch pipe by an electrical fan, drawing approaching mosquitoes into a catch bag.

Bioassay

Bioassays are methods that utilize living materials to detect substances or determine the potential toxicity of chemicals or contaminated matrices. They are widely used to screen for potentially hazardous chemicals in contaminated soils, potable and wastewater, foods, and other materials.

Biological control

Deliberate introduction of biological agents such as pathogens, parasites and predators (especially fish) to control arthropod population.

Bioaccumulation

Bioaccumulation is defined as the accumulation of chemicals in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, and pore water in the sediment

Biodegradation

Biodegradation means that the decaying of all organic materials is carried out by a huge assortment of life forms comprising mainly bacteria and fungi, and other organisms.

Botanical larvicides

The plant products used to kill or control mosquito larvae are called botanical larvicides.

Botanical pesticides

The plant products used to kill or control the pest are called botanical pesticides.

Bristles

A large seta or short stiff coarse hair or filament.

Brugia malayi

Brugia malayi is a nematode, filarial worm, one of the causative agents of Brugian filariasis in humans.

Canals

Canals are artificial (manmade) channels, generally regular in shape, which are constructed to convey water to the farm fields from a river or reservoir.

Capitulum

Anterior body of mites and ticks including the mouthparts (also commonly known as the gnathosoma).

Capsule suspension

Capsule suspensions are water-based slow-release formulations containing active ingredients encapsulated inside polymer microcapsules. The CS formulations are very useful to provide a prolonged effect for controlling target pests.

Carbamates

Synthetic insecticides are derivatives of carbamic acid, e.g., carbaryl and propoxur.

Carcinogens

The term "carcinogen" denotes a chemical substance or a mixture of chemical substances which induce cancer or increase its incidence.

Chelicera

The paired piercing appendages present as mouthparts of mites and ticks.

Chemical control

The use of chemicals to disrupt the life cycle of vectors at different stages of their life cycle is known as chemical control.

Chemosterilant

Chemicals used to induce sterility, but not usually death, in arthropods to control them, e.g., *apholate* and *tepa*. Chemo Sterilized insects are sometimes used in the genetic control of insect vectors.

Chemoprophylaxis

Chemoprophylaxis is the administration of drugs to prevent the development of a disease.

Claws

A hooked structure curved at the end of the leg of an insect, which is usually paired.

Climate

Climate is the average weather condition of the earth's surface over a long period of time, taking into account temperature, precipitation, humidity, wind, barometric pressure, and other phenomena.

Clypeus

Clypeus is the area of the facial wall of an insect's head between the labrum and the frons, usually separated from the latter by a groove.

Cocoon

Cocoon is the protective formation of the pupae of many insects. The cocoon is usually woven of silk thread secreted by the larva before pupation.

Cold fogs

With cold fogs the droplets are formed by the mechanical breaking up of the spray mixture, either by passing it through high-pressure nozzles or by passing a slow stream of the mixture through a high-velocity vortex of air.

Collaboration

It is a process in which entities share information, resources, and responsibilities to jointly plan, implement and evaluate a program of activities to achieve a common goal.

Community

Community is a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations or settings.

Communicable diseases

Communicable diseases spread from one person to another or from an animal to a person through any medium. The spread often happens via airborne viruses or bacteria, but also through blood or other bodily fluid.

Congenital malaria

Congenital malaria, occurring as a result of vertical transmission of parasites from mother to child during pregnancy or prenatally is a rare clinical condition. It occurs as a consequence of clinical attacks of malaria during pregnancy but also may be detected rarely in infants of asymptomatic women, where the diagnosis may be missed.

Concentration

The amount of solute dissolved in a unit amount of solvent.

Conventional SIT

Mass rearing of mosquitoes followed by manual sex separation to assure that exclusively males are to be sterilized by ionizing radiation and further released to

mate with wild females resulting in no progeny.

Conjunctivitis

Conjunctivitis refers to any inflammatory condition of the Conjunctiva. It is the most common cause of "red eye". Virus and bacterial conjunctivitis is the most common cause of infectious conjunctivitis.

Crystal protein

Crystal proteins made by the bacterium *Bacillus thuringiensis* (*Bt*) are pore-forming toxins that specifically target invertebrates (insects and nematodes) and are generally innocuous to mammals.

Cytoplasmic Incompatibility

Cytoplasmic incompatibility occurs when factors in the cytoplasm of the two gametes are not compatible, resulting in the death of the zygote.

Death rate

Death rate or mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

Definitive host

Host in which parasites reach to maturity. This rarely occurs in arthropod vectors, but the noted exception is the development of malarial parasites, involving sexual reproduction, in mosquitoes. See Intermediate host.

Degeneration

A morbid change consisting in a disintegration of tissue/in substitution of a lower form for a higher form of structure

Deltamethrin

Deltamethrin is an insecticide belonging to the pyrethroid family. Pyrethroids are man-made versions of pyrethrins, natural insecticides from chrysanthemum flowers.

Demography

Demography is the study of human populations with respect to their size, structure and dynamics.

Dengue Virus (DENV)

The dengue virus (comprises four distinct serotypes- DEN-1, DEN-2, DEN-3 and DEN-4), which belong to the Genus Flavivirus, family Flaviviridae.

Deutonymph

It is the second nymph stage of a mite.

Dieldrin

Dieldrin is an organochlorine compound resulting from the epoxidation (carbon-carbon double bond into oxiranes) of the double bond of aldrin. It is the active metabolite of the pro insecticide aldrin. It has a role as a xenobiotic and a carcinogenic agent. It is an organochlorine insecticide, an organochlorine compound and an epoxide. It derives from aldrin.

Diflubenzuron

Diflubenzuron is a direct-acting insecticide normally applied directly to plants or water against mosquito and noxious fly larvae.

Disability

A physical or mental condition that limits a person's movements, senses or activities.

Disease morbidity

Morbidity is the state of being symptomatic or unhealthy for a disease or condition. It is usually represented or estimated using prevalence or incidence.

Distribution

In epidemiology, distribution means the frequency and pattern of health-related characteristics and events in a population.

Dominant lethal

A dominant lethal mutation occurs in a germ cell and results in the death of the fertilized egg or developing embryo.

Dose

Dose is a quantity of an insecticide, medicine or drug taken or recommended to be taken or used at a particular time.

Ecological interrelationships

Ecological interrelationships describe the interactions between and among the organisms within their environment.

Ecology

Ecology is the study of the interaction between living organisms, including humans, and their physical environment.

Ecosystem

The living community of plants and animals in any area together with the non-living components of the environment such as soil, air and water, constitute the ecosystem.

Ecosystem integrity

Ecosystem integrity is defined as the system's capacity to maintain structure and ecosystem functions using processes and elements characteristic of its eco region.

Electric vaporizer

Electric vaporizers enable harmful flies and mosquitoes to be removed from indoor spaces owing to the vaporization of the natural and herbal volatile oils in liquid form by means of electricity.

Emulsifiable Concentrate

Emulsifiable concentrates are typically optically transparent oily liquid formulations that are prepared by dissolving a certain amount of pesticide in organic solvents (such as benzene, toluene, xylene and solvent oil), which may also contain surfactants and other additives. These systems are then diluted with water before application, which leads to the spontaneous formation of an oil-in-water emulsion that contains pesticides inside the oil droplets.

Emulsifiable concentration

Emulsifiable concentrates are typically optically transparent oily liquid formulations that are prepared by dissolving a certain amount of pesticide in organic solvents (such as benzene, toluene, xylene, and solvent oil), which may also contain surfactants and other additives.

Endemic

Endemic refers to the constant presence or usual prevalence of a disease or infectious agent in a population within a geographic area.

Endocrine disruption

An endocrine disruptor is an exogenous substance or mixture that alters the function (s) of the endocrine system and consequently causes adverse health effects in an intact organism, its progeny, or population.

Endophagic

An insect that feeds indoors..

Endophilic

Insects, such as some mosquitoes, tend to inhabit or rest indoors before or after blood-feeding.

Endosymbiont

Endosymbionts are organisms that

form a symbiotic relationship with another cell or organism.

Endrin

Endrin is a white crystalline, odourless solid dissolved in a liquid carrier. It is water emulsifiable. Endrin is used as a pesticide to control insects, rodents, and birds.

Entomological surveillance

Periodic collection of data related to knowledge of local vector species and their susceptibility to insecticides, as well as on vector and human behaviors that may allow mosquitoes to avoid contact with interventions and thereby maintain

residual transmission, which is essential to inform vector control strategies and track their impact on disease.

Entomology

Entomology is the science dealing with the scientific study of insects.

Environment

Environment is a complex of many variables, which surrounds man as well as living organisms. The environment includes water, air and land and the interrelationships, which exist among and between water, air and land and human beings and other living creatures such as plants, animals and microorganisms.

Environmental management

Environmental management consists of actual decisions and action concerning policy and practice regarding how resources and the environment is appraised, protected, allocated, developed, used, rehabilitated, remediated and restored.

Environmental Modification

A form of environmental management consisting in any physical transformation that is permanent or long-lasting of land, water and vegetation aimed at preventing, eliminating or reducing the habitat of vectors without causing an unduly adverse effect on the quality of the human environment.

Environmental protection act

The act relates to the protection and improvement of the human environment and the prevention of hazards to human beings, other living creatures, plants and property. The Act is an “umbrella” legislation designed to provide a framework for central government coordination of the activities of various central and state authorities established under previous laws, such as the Water Act and the air Act.

Enzootic cycle

The sylvatic cycle is the fraction of the pathogen population's lifespan spent cycling between wild animals and vectors. Pathogens that contain a sylvatic cycle include trichinosis, dengue viruses, *Yersinia pestis*.

Enzyme

Enzymes are biological catalysts (also known as biocatalysts) that speed up biochemical reactions in living organisms and which can be extracted from cells and then used to catalyze a wide range of commercially important processes.

Epidemic

The occurrence of more cases of

disease than expected in a given area or population during a particular period.

Epidemiology

Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations and the application of this study to the control of health problems.

Epithelium

Epithelium represents an interface between the internal and the external environment.

Epizootic

Disease events in an animal population are analogous to an epidemic in humans. An epizootic may be restricted to a specific locale (an "outbreak"), general (an "epizootic"), or widespread ("panzootic").

Epizootics

An epidemic outbreak of the disease in an animal population, often with the implication that it may extend to humans.

Eradication

It is the permanent reduction to zero of the worldwide incidences of infection caused by a specific agent as a result of deliberate efforts.

Esterification

Esterification is the general name for a chemical reaction in which two reactants (typically an alcohol and an acid) form an ester as the reaction product.

Evaluation

Evaluation is a systematic determination of a subject's merit, worth and significance, using criteria governed by a set of standards. It can assist an organization, programme, design, project or any other intervention or initiative to assess any aim, realizable concept/proposal, or any alternative, to help in decision-making.

Evaporation

Evaporation can be defined as the process where a liquid is transformed into its gaseous state.

Excavation

Excavation means loosening and takeout materials leaving space above or below ground.

Exophagic

Insects, such as some mosquitoes, feed outdoors.

Exophilic

Insects, such as some mosquitoes, tend to inhabit or rest outdoors.

Exotic fish

A number of fish species have been imported from foreign countries and introduced for culture. Since these fishes are not the natives, they are called exotic fishes.

Exotic species

Exotic species often referred to as alien, non-native, non-indigenous, or introduced species, are those that occur in areas outside of their natural geographic range.

Extraction

Extraction is a process in which one or more components are separated selectively from a liquid or solid mixture.

Extrinsic incubation period

The interval between the acquisition of an infectious agent by a vector and the vector's ability to transmit the agent to other susceptible vertebrate hosts. E.g., in malaria - the extrinsic incubation period is 10-20 days.

Fauna

The aggregate of animal species inhabiting a particular region. The fauna of a region evolves historically from various animal groups known as faunistic complexes.

Fecundity

Fecundity is the physiological maximum potential reproductive output of an individual (usually female) over its lifetime and represents one of the major cornerstones of theoretical and applied population biology.

Fertility

Fertility is the natural capability to produce offspring. As a measure, the fertility rate is the number of offspring born per mating pair, individually or population-wise.

Fertilizer

A chemical or natural substance is added to soil or land to increase its fertility.

Flooding irrigation

Surface or flood irrigation is the application of water by gravity flow directly onto the soil. Flood irrigation is the oldest irrigation method, and in its uncontrolled form is a natural phenomenon on which many areas still base their crop cycle.

Fogging

Fogging is defined as space spraying of insecticide against mosquitoes to prevent an outbreak of mosquito-borne infection.

Food chain

The sequence of transfers of matter and energy in the form of food from organism to organism.

Forest ecosystems

A forest ecosystem is a community formed by plants and animals of that particular area that interact with the chemical and physical features of the environment in which they live.

Formulation

Putting together the components in appropriate relationships or structures according to a specific given formula. It is often used in a way that includes dosage in dispersible form.

Gametocytes

A gametocyte is a eukaryotic germ cell that divides by mitosis into other gametocytes or by meiosis into gametes during gametogenesis. The sexual stage of the malarial parasite in the blood may produce gametes when taken into the mosquito host; it may be male (microgametocyte) or female (macrogametocyte).

Gastrointestinal

Related to the stomach and intestine.

Genal comb

The genal comb is a row below the head, which is horizontally placed and is present in the back of the pronotum of a flea.

Gene coding

A mapping between tri-nucleotide sequences called codons and amino acids; every triplet of nucleotides in a nucleic acid sequence specifies a single amino acid.

Gene expression

Gene expression is the process by which the genetic code, the nucleotide sequence, of a gene is used to direct protein synthesis and produce the structures of the cell.

Genes

A gene is the basic physical and functional unit of heredity.

Genetic modifications

Genetically Modified Organisms (GMOs) can be defined as organisms in which the genetic material (DNA) has been altered in a way that it does not occur naturally by mating or natural recombination.

Genitalia

It's one of the reproductive organs of both sexes of insects.

Genome

A genome is an organism's complete set of DNA, including all of its genes. Each genome contains all of the information needed to build and maintain that organism.

Genotypes

Genotype is the complete gene set of the organism.

GIS

A Geographic Information System (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.

Globalization

The term broadly refers to the expansion of global linkages, the organization of social life on a global scale. Globalization is a multifaceted phenomenon, which encompasses economic, social, political, technological and cultural dimensions.

Granules

Granules are agglomerates of powdered materials prepared into larger, free-flowing particles. They typically fall within the range of 850 µm to 4.75 mm in size. The shape of granules is generally irregular.

Gravity

Any two objects that have mass attraction towards each other with a force, we call gravity.

Habitat

Usually means the physical environment in which an animal lives, e.g., the skin in the case of scabies mites, streams for simuliidae larvae and animal nests for many ixodid ticks.

Hazardous pesticides

Hazardous Pesticides means pesticides that are acknowledged to consist particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or Global Harmonized System (GHS) or their listing in relevant binding international agreements or conventions.

HBI

The Human Blood Index (HBI) represents the proportion of blood meals derived from humans by mosquito vectors. It may be used to estimate the human biting habit, an important component of vectorial capacity, as a proxy measure of malaria transmission.

Health hazard chemicals

Health hazard chemicals means chemicals for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees.

Homeostasis

Homeostasis is the body's automatic tendency to maintain a relatively constant internal environment in terms of temperature, cardiac output, ion concentrations, blood pH, hydration, dissolved CO_2 concentration in blood, blood glucose concentration, concentrations of wastes, etc.

Homologous chromosome

Homologous chromosomes are made up of chromosome pairs of approximately the same length, centromere position, and staining pattern, for genes with the same corresponding loci. One homologous chromosome is inherited from the organism's mother; the other is inherited from the organism's father.

Host

An organism infected with or is fed upon by a parasitic or pathogenic organism (e.g., nematodes, fungi, viruses etc.). It is also described as an animal or plant that nourishes or supports a parasite.

Hotspot

It refers to areas of elevated disease burden or high transmission efficiency. Hotspot can also refer to an area with a high risk for infectious disease emergence or reemergence.

Humidity

The amount of moisture or water vapor present in the air. The absolute humidity changes as air temperature or pressure changes, if the volume is not fixed. The term "humidity" is a general term to quantify the amount of water vapor in the gas.

Hybrid sterility

Hybrid sterility is defined as the inhibition and suppression of the reproductive capacity of F1 or later-generation hybrids between genetically different strains or populations usually belonging to different species.

Hydraulic

It is denoting or relates to a liquid moving in a confined space under pressure.

Hypnozoites

Hypnozoites are dormant forms in the life cycles of certain parasitic protozoa that belong to the phylum Apicomplexa and are best known for their probable

association with latency and relapse in human malarial infections caused by *Plasmodium ovale* and *P. vivax.*

Hypostome

The central unpaired holdfast organ of the tick capitulum; the hypostome is covered with recurved spines that enable it to serve as an anchoring device while the tick feeds.

Immigration

It is the number of individuals of the same species that have come into the habitat from elsewhere during the period under consideration.

Immunity

The term 'immunity' is defined as resistance exhibited by the host against any foreign antigen including microorganisms. This resistance plays a major role in the prevention of infectious diseases. Immunity may be innate or acquired.

Immuno-suppressed

Immuno-suppression involves an act that reduces the activation or efficacy of the immune system. Some portions of the immune system itself have immuno-suppressive effects on other parts of the immune system, and immune-suppression may occur as an adverse reaction to the treatment of other conditions.

Impoundments

Impoundments are a common characteristic of human-dominated rivers and offer a means by which water travel time could be managed to promote denitrification.

Incidence

It is defined as the number of new

cases occurring in a defined population during a specified period of time.

Incubation period

The time interval between invasion by an infectious agent and appearance of the first signs or symptoms of the disease.

Indicators

A quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention.

Indoor Residual Spray

IRS involves coating the walls and other surfaces of a house with a residual insecticide. For several months, the insecticide kills mosquitoes and other insects that come in contact with these surfaces.

Infection

It means the entry and development or multiplication of a pathogenic agent in the body of humans or animals.

Infectivity rate

It is typically used to measure the frequency at which disease spreads within a defined population during a specified time frame.

Infestation

It means the external invasion or colonization of animals or their immediate surroundings by arthropods, which may cause clinical signs or are potential vectors of pathogenic agents.

Ingredients

An ingredient is a substance that forms part of a mixture.

Insect Growth Regulators (IGRs)

Sometimes known as insect development inhibitors. IGRs are a group of chemicals that either prevent the development of larvae into pupae or pupae into an adult.

Insecticide

Insecticides are toxic substance that is used to kill insects. Such substances are used primarily to control pests that infest

cultivated plants or to eliminate disease-carrying insects in specific areas.

Insecticide resistance

The ability of arthropods to tolerate doses of insecticides, which would prove lethal to the majority of normal (susceptible) individuals of the same species.

Insecticide-Treated Nets

Insecticide-Treated Nets (ITNs) are a form of personal protection, which are simple mosquito nets that have been treated with an insecticide. These nets require 're-dipping' to restore the insecticide element every 6-12 months.

Integrated Pest Management

Integrated Pest Management **(**IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties.

Integrated Vector Management

Integrate Vector Management (IVM) is a rational decision-making process for the optimal use of resources for vector control. The approach seeks to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of disease-vector control. The ultimate goal is to prevent the transmission of vector-borne diseases such as malaria, dengue, Japanese encephalitis etc.

Intensity

Intensity refers to the rate at which the activity is being performed or the magnitude of the effort required to perform an activity or exercise.

Intermediate host

Ordinarily, a necessary host and one in which only the immature stages occur in the host, for example- The human body is an intermediate host for Plasmodium parasite.

Invertebrates

Invertebrates belong to the animal kingdom. They lack a backbone and have soft bodies because they don't have an internal skeleton (endoskeleton) for support although, some of them possess an exoskeleton that encompasses the entire body. Invertebrates do not possess lungs since they respire through their skin and are heterotrophic.

Irrigation

The process of supplying water to land by artificial means. Its basic objective is to supplement the natural supply of water, for raising crops with an economic and efficient system. Controlling and harnessing various natural resources. To achieve it, irrigation systems are required.

Isomers

If two or more different compounds have the same molecular formula, they are known as isomers.

Labium

A lower mouthpart of an insect that is formed by the second pair of maxillae united in the middle line formed by a fusion in embryonic life of separate right and left maxilla.

Labrum

An upper or anterior mouthpart of an arthropod consists of a single median piece, which forms the floor of the mouth in mandibulate insects with many sensory structures.

Landfills

The landfill is defined as a "facility in which solid waste from municipal and/or industrial sources is disposed of in the land.

Larval density

Larval density is the number of larvae collected to the number of dips made.

Larval habitat

These are the places where eggs are laid, larvae hatch, instars moult, pupate, and adults emerge. They may be natural or man-made, permanent or temporary, large or small.

Larvicide

A larvicide is an insecticide that specifically targets the larval life stage of an insect. Larvicides may be contact poisons, stomach poisons, growth regulators, or (increasingly) biological control agents and are most commonly used against mosquitoes.

Lethal mutation

A type of mutation in which the effect(s) can result in death or reduce significantly the expected longevity of an organism carrying the mutation.

Light trap

Light trapping is the most common and regular sampling technique. Nocturnal arthropods particularly insects are attracted by artificial light sources therefore light traps have been widely used to collect nocturnal insects.

LLINs

LLIN is a mosquito net impregnated with insecticide. The insecticide is cleverly bounded within the fibres that make up the netting and is 'slow released' over a 4-5 years period.

Longevity

How long an organism lives, is often expressed as the mean expectancy of life. Vector longevity is one of the most important factors in disease transmission dynamics and vector control.

Lymph node

The lymph nodes are organized lymphoid organs that contain lymphocytes within a fine reticular stroma.

Lymphatic system

The lymphatic system is part of the vascular system and an important part of the immune system, comprising a large network of lymphatic vessels that carry a clear fluid called lymph directionally towards the heart.

Mammalian toxicology

Mammalian Toxicology surveys

chemical agents and examines how such chemicals impact Mammalian health, emphasizing the importance of minimizing environmental exposure to chemical and physical hazards through media like contaminated water, soil and air.

Mammals

Mammals are various warm-blooded vertebrate animals of the class mammalian, including humans, characterized by a covering of hair on the skin and, the presence of milk-producing mammary glands in females for nourishing the young.

Man Hour Density

Man Hour Density (MHD) is an important index to determine relative densities of mosquitoes to compare the prevalence of vectors in the same areas of seasons, months or years or to compare different places also.

Management

Management is the organizational process that includes strategic planning, setting objectives, managing resources, deploying the human and financial assets needed to achieve objectives, and measuring results.

Mandible

The jaws present in biting and chewing insects. Mandibles can be needlelike piercing organs, present in mosquitoes, or tooth-like present in chewing lice.

Maxilla

The second pair of jaws in chewing insects is persistent when the mouth is modified.

MDA

Mass Drug Administration (MDA) is the administration of anti-malarial treatment to every member of a defined population or every person living in a defined geographical area at approximately the same time and often at repeated intervals.

Mechanical control method

Mechanical control methods involve the complete or partial removal of plants by mechanical means, including harvesting, shredding, mowing, rototilling, rotovating and chaining.

Meral rod

A vertical thickening of the body wall (mesopleuron part) of the thorax of fleas.

Merozoite

Daughter cell resulting from schizogony (merogony).

Metamorphosis

The relatively abrupt change in body form between the immature and sexually mature adult stages.

Microcephaly

Microcephaly is a birth defect where a baby's head is smaller than expected when compared to babies of the same sex and age.

Microfilaria

First-stage juvenile filaria nematodes are usually found in the blood or tissue fluids of the definitive host.

Mists

Mists are dispersions of liquids in gases. They are formed during the nebulization of liquids, during condensation from the vapour phase and during chemical processes (for example oil mist, and hydrogen chloride in damp air).

Monocytes

Monocytes are a type of white blood cell that fights off pathogens. Monocytes are the biggest type of white blood cell in the immune system. Firstly, they are formed in the bone marrow, which is released into our blood and tissues. When certain germs enter the body, they quickly rush to the site for attack.

Morphology

Morphology is the study of the shapes and arrangement of parts of organisms, in order to determine their function, their development, and how they may have been shaped by evolution.

Mortality

A mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

Mortality rate

A mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

Moulting

Moulting is the process of producing a new cuticle and the subsequent shedding of the old cuticle.

Mutagenesis

Mutagenesis refers to those changes in the genetic material in cells brought about spontaneously either by chemical or physical means whereby successive generations differ in a permanent and heritable way from their predecessors.

Mutation

A mutation is a heritable change in the genetic material that is not due to genetic recombination. The mutation alters the structure or number of genes or entire chromosomes.

Neglected tropical disease

The diverse group of communicable diseases that prevail in tropical and subtropical regions countries e.g., malaria, chikungunya, dengue, lymphatic filariasis.

Nematodes

A member of phylum Nematoda comprising elongated cylindrical worms, parasitic in animals or plants or free-living in soil or water.

Neurotoxicity

Neurotoxicity refers to the direct or indirect effect of chemicals that disrupt the nervous system of humans or animals. Numerous chemicals can produce neurotoxic diseases in humans, and many more are used as experimental tools to disturb or damage the nervous system of animals.

N-methyl Carbamates

Methyl carbamate (also called methylurethane, or urethylane) is an organic compound and the simplest ester of carbamic acid (CH_3NO_2).

Nocturnal

Some organisms are active during the night therefore they are called as nocturnal. e.g., microfilariae of Wuchereria bancrofti nocturnally periodic.

Non-target biota

Non-target organisms/ species are not the direct targets for their control or management.

Nozzles

A nozzle is a simple device used to break apart a fluid flow into a spray pattern. It atomizes liquid into droplets, disperses the droplets in a specific pattern, metres liquid at a certain flow rate and provides hydraulic momentum.

Nymph

Nymphs are the immature form of an insect, such as an apterygote arthropod, which does not pass through a pupal stage during metamorphosis. Nymphs resemble adults' stages but are smaller and lack fully developed wings and genitalia.

Oil in water emulsion

Oil-in-water emulsions are conventionally defined as thermodynamically unstable systems which include two immiscible liquids (generally water and oil), in which oil is distributed into the water.

Omnivorous

Omnivores consume materials from different trophic levels of the food web. Many, if not most, aquatic animals eat more than one type of food during their lifespan, both from the plant as well as animal origin.

Organization

A social unit of people, systematically structured and managed to meet a need or to pursue collective goals continuingly.

Outbreak

Outbreak is an occurrence of significantly more cases of disease than expected in a given area among a specific group of people over a particular period of time.

Palmate hair

Palmate hair is the hair of seta with flattened, movable, usually horizontal branches radiating from a common point on a short stem.

Parasite

A parasite is a microorganism, which lives on a living host and derives nutrition from the host, without any benefit to the host.

Parasitemia

The presence of parasites in the blood.

Passive Surveillance

Regular reporting of disease data by all institutions that see patients (or test specimens) and are part of a reporting network is called passive surveillance.

Pathogens

A pathogen is defined as an organism causing the disease to its host. Pathogens are taxonomically widely diverse and

comprise viruses and bacteria as well as unicellular and multicellular eukaryotes.

Pathogenesis

The parasite or pathogen can interfere with one or more of the essential functions of the plant or animal.

Persistent Organic Pollutants

Persistent Organic Pollutants (POPs)

are chemicals of global concern due to their potential for long-range transport, persistence in the environment, ability to bio-magnify and bioaccumulation in ecosystems, as well as their significant negative effects on human health and the environment.

Pesticide

Pesticides are chemical compounds that are used to kill pests e.g., DDT, Malathion, Pyrethrum etc.

Pests

Pest is an insect (or organism) that causes harm to humans, their livestock, crops or possessions. Pest includes nematodes, weeds, bacteria, insects, fungi, molluscs, phytoplasma, viruses and viroids.

Pesticides

Pesticides are chemical compounds that are used to kill pests.

Phagocytes

A cell that can engulf particles, such as bacteria and other microorganisms or foreign matter. Principal phagocytes include neutrophils and monocytes, both of which are types of white blood cells.

Phytochemicals

Phytochemicals are defined as bioactive nutrient plant chemicals in fruits, vegetables, grains, and other plant foods that may provide desirable health benefits beyond basic nutrition to reduce the risk of major chronic diseases.

Pleural rod

Pleural rod is a vertical ridge that divides the mesosternum (thoracic plate above the coxa of the 2ndpair of legs).

Pneumonia

Pneumonia is "a severe form of an acute lower respiratory infection that specifically affects the lungs" and is typically caused by bacteria.

Pneumonic plague

Infection of the lungs by Yersina pestis, the bacterial agent that causes plague (a human disease).

Polarity

In chemistry, polarity refers to the way in which atoms bond with each other.

Population density

Population density is defined as the number of persons per square kilometre. It is an important index of population, which shows the concentration of the population in a particular area.

Predator

An animal that feeds upon other animals (prey) that are either smaller or weaker than itself.

Prevalence

Prevalence measures the amount of disease in a population at a given time and can be expressed as a percentage. The point prevalence is a single assessment at a fixed point in time, whereas the period prevalence is the percentage of a population who has the disease at any time within a stated period.

Proboscis

In invertebrates, the term usually refers

to tubular mouthparts used for feeding and sucking. The proboscis is used to describe an elongated nose or snout.

Progeny

The product of reproduction or replication, also known as offspring.

Proliferation

To proliferate normally means to increase rapidly in number or quantity, or to grow or reproduce by rapid production of new parts (biological).

Promastigotes

A stage in the unicellular life-cycle, typically trypanosomes, where the flagellum is anterior to the nucleus and free from the cell body.

Pronotal comb

The pronotal comb is a row behind the head, at the back of the pronotum.

Prothorax

The first thoracic segment bears the anterior legs but no wings.

Protonymph

It is the first instar of the growth and developmental stage in mites.

Protozoa

Protozoa are single-celled, animal-like organisms.

Protozoan

Single-celled animals with at least one well-defined nucleus, some of which are pathogenic.

Public health

Public health is the science of protecting and improving the health of people and communities.

Public health entomology

Public health entomology focuses on the population biology of vector-borne infections, seeking to understand how such pathogens perpetuate over time and attempting to devise methods for reducing the burden that they impose on human health.

Pulvilli

The expanded terminal structure of the pretarsus of some genera of mites, which may be membranous bell- or sucker-like discs.

Radiation

Energy moving in the form of particles or waves. Familiar radiations are heat, light, radio, and microwaves.

Recrystallization

The process of recrystallization involves the dissolution of the solid in an appropriate solvent at an elevated temperature and the subsequent re-formation of the crystals upon cooling so that any impurities remain in the solution.

Remote sensing

Remote sensing is science of obtaining information about an object or feature without physically coming in contact with that object or feature. The process infers surface parameters from measurements of electromagnetic radiation (EMR) from the earth's surface. This EMR can either be reflected or emitted from the Earth's surface. It is a useful tool for vectorborne diseases.

Repellents

Substances applied to skin, clothing,

or other surfaces, which discourages insects (particularly mosquitoes) to sit, climb or bite. Repellents are used to repel mosquitoes, ticks, flies, and other biting insects.

Reservoir

Reservoirs are those water bodies formed or modified by human activity for specific purposes, in order to provide a reliable and controllable resource.

Resistance

A genetic change in an organism in response to selection by drugs/pesticides, which may impair control in the field.

Sanitation

Sanitation refers to the provision of facilities and services for the safe management of human excreta from the toilet to containment and storage and treatment onsite or conveyance, treatment and eventual safe end use or disposal.

Schizonts

Mature malaria parasite in host liver cells (hepatic schizont) or red blood cells (erythrocytic schizont) that is undergoing nuclear division by a process called schizogony.

Scutum

The sclerotized plate on the dorsal surface of Ixodidae hard ticks, also known as the dorsal shield.

Serotype

A group within a single species of microorganisms such as bacteria or viruses share distinctive surface structures.

Slide *falciparum* Rate (S*f*R)

Percentage of slides found positive for P. falciparum parasite from examined slides.

Slide Positivity Rate (SPR)

Percentage of slides found positive for malaria parasite from examined slides.

Social mobilization

Social mobilization is the process of bringing together all societal and personal influences to raise awareness of and demand for health care, assist in the delivery of resources and services, and cultivate sustainable individual and community involvement.

Space spraying

A space spray – technically a fog (sometimes referred to as an aerosol) – is a liquid insecticide dispersed into the air in the form of hundreds of millions of tiny droplets less than 50 μm in diameter. It is only effective while the droplets remain airborne.

Species

A group of individuals in natural populations that can inter-breed by mating within the group and producing fertile progeny; individuals are usually similar in appearance and behavior.

Spermatheca

The spermatheca is a single pouch-like structure connected by the median oviduct through spermathecal duct, which receives spermatophore during copulation. In higher diptera, there is three spermatheca present.

Spinosad

Spinosad is a naturally derived fermentation product, which has demonstrated insect control activity against a large number of pests. The product is isolated from actinomycetes *Saccharopolyspora spinosa*.

Spiracles

A breathing pore is an external aperture and is sometimes guarded by the valves from which the oxygen is inhaled and carbon dioxide is exhaled into the environment. The number of spiracles may vary from species to species and in generalized insects 2 thoracic and 8 abdominal spiracles are present.

Spiracular bristles

It is a stiff hair-like structure of any of several tracheal openings in the exoskeleton of an insect, spider, or another terrestrial arthropod.

Sporogony

The sexual stage in the life cycle of a sporozoan parasite, with the development of the zygote into one or several haploid spores, each containing a distinctive number of sporozoites.

Sporozoite rate

Sporozoite rate is the number of mosquitoes infected with sporozoites divided by the total number of mosquitoes

examined using each respective method of mosquito collection, expressed as a percentage.

Sporozoites

It refers to the minute, motile, an infective form of certain protozoa, which infects the host cells. For example, sporozoites of *plasmodium* are the infective protozoans, injected by the mosquito.

Sterilization

Sterilization describes a process that destroys or eliminates all forms of microbial life and is carried out in healthcare facilities by physical or chemical methods.

Stylostome

The feeding tube produces around the mouth parts of trombiculid mites in the skin of the host.

Surveillance

Systematic ongoing collection, collation, and analysis of data and the timely dissemination of information to those who need to know so that action can be taken.

Susceptibility

Susceptibility means "the state of being susceptible" or "easily affected."

Tarsi

It is the jointed appendages attached at the apex of the tibia and bears the claws and pulvilli.

Temephos

Temephos is a non-systemic organophosphorus insecticide, mainly used as a larvicide to control mosquitoes.

Thermal fogging

Thermal fogging is the generation of ultra-fine droplets in a range of 1-50 µm using thermo- pneumatic energy. The fluid to be fogged is first vaporized by an increase in temperature and the vapour is then condensed upon introduction to the cooler atmospheric air.

Thorax

The thorax or chest is a part of the anatomy of various animals located between the neck and the abdomen. The thorax includes the thoracic cavity and the thoracic wall.

Toxicity

Toxicity can be defined as the relative ability of a substance to cause adverse effects in living organisms.

Transgenic strain

Organisms into which genetic material from another organism has been experimentally transferred.

Transmission intensity

The frequency with which people living in an area are bitten by anopheline mosquitoes carrying human malaria sporozoites

Transovarial transmission

The transmission of an infectious agent from parent to offspring via infection of the developing egg, which subsequently results in infectious adult arthropods is an important transmission mechanism among viruses in the order Bunyavirales.

Transstadial transmission

It occurs when a pathogen remains with the vector from one life stage to the next.

Trophozoites

It is the general term for the active, feeding, and multiplying stages of most protozoa. In parasitic species, this is the stage usually associated with pathogenesis.

Tropical countries

Tropical countries are those that lie within the region that lies between the tropic of cancer and the tropic of Capricorn. India is therefore a tropical country.

Urbanization

Urbanization is an index of transformation from traditional rural economies to modern industrial ones. It is a progressive

concentration of the population in urban units.

Vaccine

Vaccines are biological agents that elicit an immune response to a specific antigen derived from an infectious disease-causing pathogen, that enhance immunity against disease and either prevents (prophylactic vaccines) or, in some cases, treats disease (therapeutic vaccines).

Vector

Vector is described as an arthropod or any living carrier that transports an infectious agent to a susceptible individual. Transmission by a vector may be mechanical or biological e.g., mosquito, bed bugs, ticks, mites, fleas etc.

Vector Borne Diseases (VBDs)

Infectious diseases of animals and humans caused by pathogenic agents such as bacteria, helminths, protozoa and viruses transmitted by hematophagous arthropod vectors, which include bedbugs, biting midges, black flies, fleas, kissing bugs, lice, mites, mosquitoes, sandflies and ticks, among others.

Vector density

The prevalence of vectors in a particular area is termed as vector density.

Vector incrimination

The vector capable to transmit the pathogen to an uninfected host is called vector incrimination.

Vectorial capacity

It is a measurement of the efficiency of vector-borne disease transmission.

Vegetation

Vegetation can be defined as an assemblage of plants of one-to-many species growing in areas of different sizes.

Vegetation manipulation

Vegetation manipulation refers to any human interference with the normal processes in the plant's life in order to stimulate or retard growth, to change its shape or growth model, or to stimulate or retard flowering and fruit set by applying physical or chemical procedures.

Vertebrates

Vertebrates are members of the larger phylum chordata. The distinct feature is presence of the vertebral column, or backbone, which surrounds and protects the main nerve cord. Other major chordate features at some point in their life cycles includes notochord, dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail.

Vertebrate Animals

An animal with a skull, which surrounds the brain and a skeleton of bone or cartilage, including the spine of vertebral bones surrounding a spinal cord of nerves; includes mammals, aves, fishes, reptiles and amphibians.

Vertical transmission

Transmission of an infection from a mother to her offspring during the perinatal period (the period immediately before and after birth). Transmission might occur across the placenta, in the breast milk, or through direct contact during or after birth. eg., HIV, hepatitis B and hepatitis C.

Veterinary

Relating to the diseases, injuries, and treatment of farm and domestic animals.

Vicinity

The area or region near or about a place; surrounding district; neighbourhood.

Virology

Virology is the study of viruses, complexes of nucleic acids and proteins that have the capacity for replication in animal, plant and bacterial cells.

Virulence factors

It determines the degree to which the pathogen causes damage, invasion, and infectivity.

Volume Median Diameter (VMD)

The volume median diameter is the diameter half the volume of the aerosol particles contained in particles with larger diameters and half is contained in particles with a smaller diameter.

Waterholes

Wildlife water holes are an important habitat component for a variety of wildlife. They provide drinking water for many wild animal species including bats, wild boars, elephants turkeys and deers and these also serve as breeding habitat for many amphibians.

Wetlands

Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.

Wettable powder

Water dispersible powder technical grade insecticide diluted with an inert carrier (dust) and to which a wetting agent or surfactant has been added. The resultant wettable powder is then mixed with water for spraying onto the surface.

Zoonotic disease

A disease that can be transmitted from animals to people or, more specifically, a disease that normally exists in animals but that can infect humans. There are multitudes of zoonotic diseases.

Zoophagic

Zoophagic is defined as feeding on animals or animal matter; specifically (of a mosquito) feeding on animals other than humans.

Zoophilic

Zoophilic mosquitoes are mosquitoes that prefer animals for blood.

Zygote

Cell that forms by the union of a male and female gametes.

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