BIOL 356 – ECONOMIC ENTOMOLOGY

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Economic entomology

- Is a field of entomology, which involves the study of insects that benefit or harm humans, domestic animals, and crops.
- Insects that cause losses are termed as pests.
- Species that cause indirect damage by spreading diseases are termed as vectors.
- Those that are beneficial include those reared for food such as honey, substances such as lac or pigments and for their role in pollinating crops and controlling pests.

Insect vectors of Human Diseases

- Majority of insect vectors of human diseases ar e found in the order of Diptera.
- In tropical and subtropical regions insects play a role in transmitting protozoa, viruses and nem atodes.
- Such pathogens are the causative agents of man y human diseases, including malaria, dengue, y ellow fever, onchocerciasis, filariasis and trypan osomiasis (sleeping sickness)

- The transmission of disease-inducing pathogens fr
om one animal or human host to another by insects
may be by mechanical or biological
- **Mechanical transfer** is movement of a disease org
anism from one host to another by passive transfe
, with no biological cycle in the host
- **Biological transfer** is movement of a disease orga
nism from one host to another by one or more vec
ors in which there is a biological cycle of disease.
nvolves association of insect vector, pathogen and
host

Order Diptera

- **Charaterestics**
- **One pair** of membranous wings born on the mesothorax
- Hind wings reduced small knobbed struc tures
- Antennae **variable, often short, incon spicuous, and 3-segmented**

Characterestics of Diptera (cont.)

- Compound eyes large, sometimes mee ting on dorsal side of head
- Mouth parts sucking, maxillary palps well developed, labial palps lacking.
- Tarsi nearly **5- segmented**
- **Three suborders** are recognized in the order Diptera

1. **Suborder Nematocera**

- - Small, delicate flies.
  - Have long filamentous, feathery antennae composed of many similar, feely articulated segments (more than six).
  - The single pair of maxillary palps is three to five jointed
  - Wing vein R is 5-branched
  - R_{2+3} often forked (never forked in other suborders).
- Include mosquitoes (Culicidae), black flies and sand flies (Pschodidae)

2. **Suborder Brachycera**

- - Are small to large, stout bodied flies
- - Have short antennae, often composed of three segments and never more than six s egments (flagellomeres). The third segmen t is **sometimes annulated** (subdivided by rings).

- Maxillary palps are one or two jointed.

-R_s usually 3- branched (R_{4+5} forked). Anal cell generally longer than 2nd basal cell and in most cases closed near wing margin.

- Include horseflies (Family Tabanidae)

3. **Suborder Cyclorrhapha**

- Antennae 3-segmented, with an arista and ptilinum.

- Vein R_s 2-branched.

FAMILY CULICIDAE (MOSQUITOES)

- About 3400 species of mosquitoes have been described on a world-wide basis.
- The 3400 mosquito species found in the
  world are divided among 28 different ge
  nera.
- Mosquitoes are important as vectors of
  malaria, various forms of filariasis and n
  umerous arboviruses, the best known be
  ing dengue, yellow fever and West Nile v
  irus.

- The family Culicidae is divided into t hree subfamilies:

  - *Anophilinae*,
  - *Culicinae* and
  - *Toxorhynchitinae*.

Distribution

- Mosquitoes of the family Culicidae live worldwide, except in Antarctica, but require habitat with standing or slow moving fresh water for young to develop.

- The main genera *Anopheles*, *Aedes* and *Culex* are distributed worldwide; even above the Artic circle.

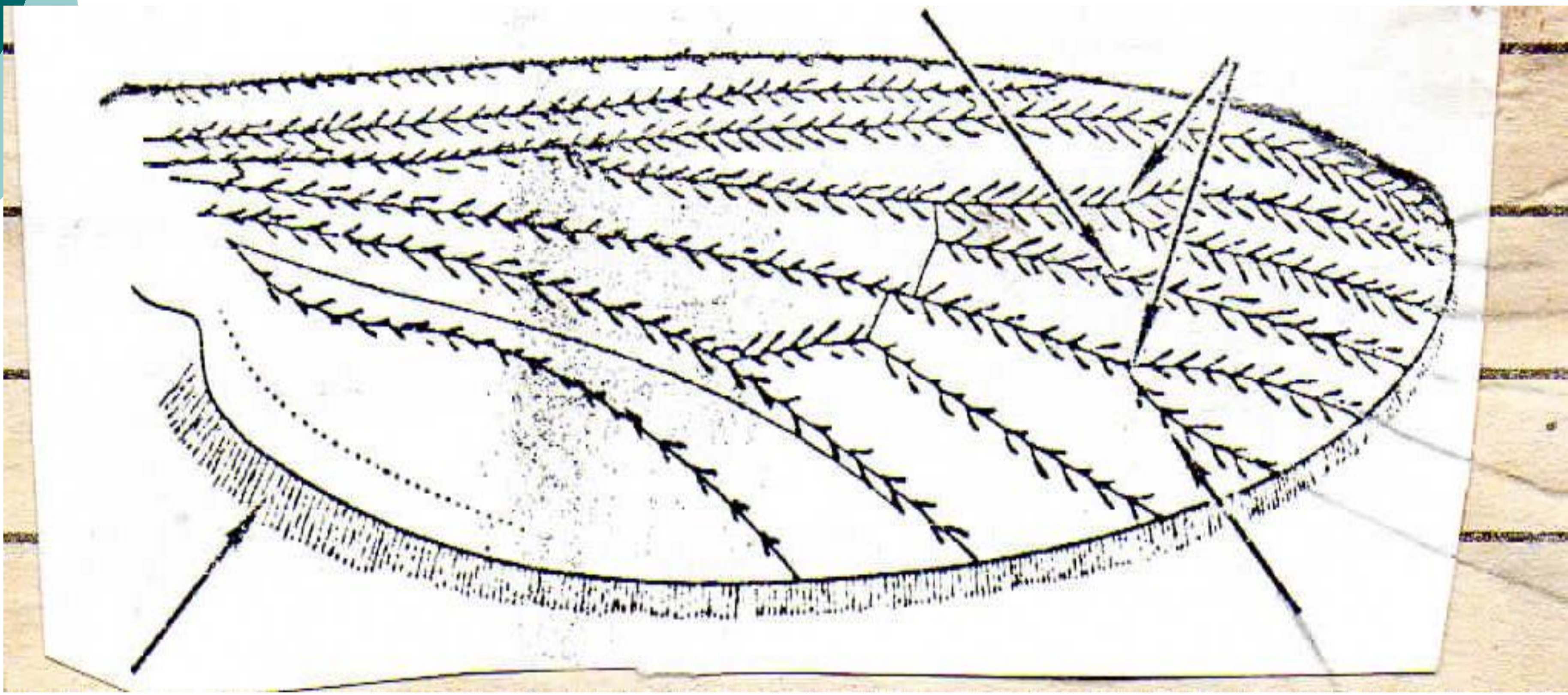
Mosquitoes as vectors of Diseases

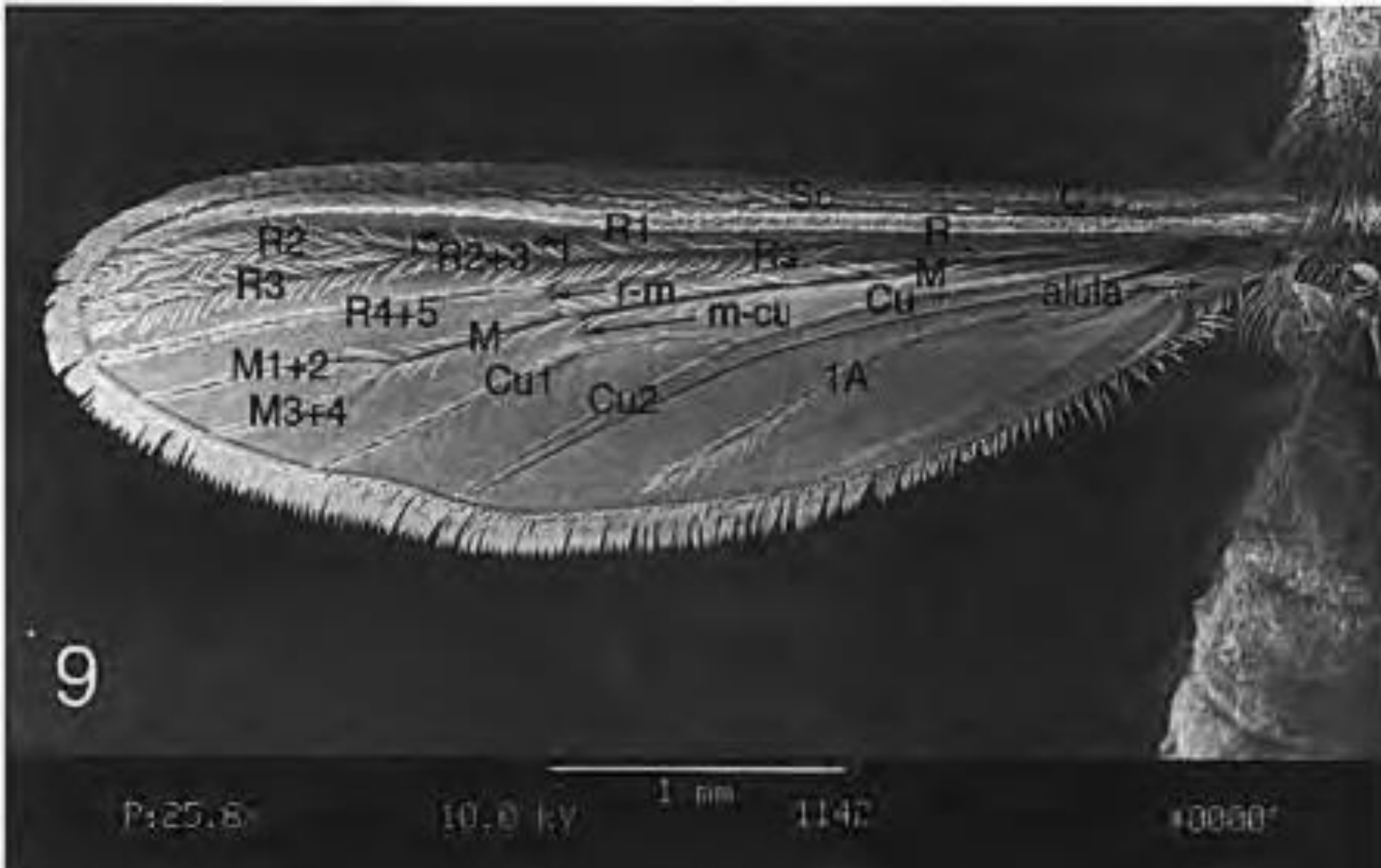
- Mosquitoes are the most important insects as far as human health is concerned.
- Mosquitoes can act as a vector for many disease-causing viruses and parasites.
- Infected mosquitoes carry these organisms from person to person without exhibiting symptoms themselves.

- Mosquito-borne diseases include:
- The parasitic disease malaria, carried by mosquitoes of the genus *Anopheles;*
- Lymphatic filariasis (elephantiasis) caused by a filarial worm and transmitted chiefly by species of *Culex.*
- The viral diseases yellow fever, dengue fever and Chikungunya, transmitted mostly by Aedes aegypti;
- West Nile virus is a concern in the United States,

Characteristics of mosquitoes

- Adults have a long forwardly directed proboscis, equal in length to head an d thorax combined.
- Wings long , narrow with scales alon g veins and wing margin.
- Distal part of the wing with an unfork ed vein between two forked veins




Sc
C
R2
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M1+2
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Cu2
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9
1 mm

- Mosquitoes have thin, long bodies and t hree pairs of extremely long legs.
- Also have feathery or hairy antennae.

Larvae of Mosquitoes

- Larvae are distinguished from other aqu atic insects by

- absence of legs
- presence of a distinct head bearing mouth brushes and antennae
- a bulbous thorax that is wider than the head and abdomen,

- posterior anal papillae and
- either a pair of respiratory openings (subfamily Anophelinae) or an elongate siphon (subfamily Culicinae) borne near the end of the abdomen.

Feeding

- Adult mosquitoes of both sexes feed on nectar juices, other fluids and de caying matter for flights energy.
- The larvae are filter feeders of organic p articulates.
- Anopheline and Culicine females also su ck blood (haematophagy) from other an imals such as mammals, birds, frogs, et c., each species of mosquito tending to have particular host preferences.

- Females do not require blood for their own survival but they do need supplemental substances such as protein and iron to develop eggs.
- Female mosquitoes hunt their blood host by detecting carbon dioxide (CO_2) and 1-octen-3-ol produced in breath and sweat.
- When a female mosquito senses CO2 in the air, she flies upwind until she finds the source.

- Carbon dioxide, which humans and other animals produce, is the key signal to mosquitoes that a potential blood meal is near.
- They've developed a keen sensitivity to CO_2 in the air. Once a female senses CO_2 in the vicinity, she flies back and forth through the CO_2 plume until she locates her victim.
- Mosquitoes locate blood host by scent, sight and heat.

- The majority of mosquitoes hunt and feed at night although some do so by day.
- Sensilla on the palps and antennae serve to detect the host.
- Each species has a well defined activity cycle; some attack at dusk, others around midnight or at other hours.

- Species showing strong attraction to man are said to be anthropophilic, or more strictly anthropophagic when man is bitten, as opposed to zoophilic or zoophagic species which attack other animals.
- Endophilic mosquitoes are those which favour houses or animal sheds for resting indoors, whereas exophilic species prefer to remain outdoors.

- Outdoor biting behavior is termed exophagy, as opposed to the endophagy of mosquitoes which enter dwellings to bite people or animals.
- Male mosquitoes tend to be less endophilic than females of the same species, while non-biting species seldom go indoors at all. Few species of the mosquitoes have man as their principal host.

- Anophelines show the most regular cycles of blood –feeding and egg laying.
- Mosquitoes of the genus *Toxorhynchites* do not suck blood.
- *Toxorhynchites* and some culines produce eggs autogenously, i.e without having fed on blood. Male and female mosquitoes may well live for several weeks, feeding repeatedly, under natural conditions.

- All the vectors of human malaria belong to the genus *Anopheles*. Various anophilines and especially culicines transmit arboviruses (viruses which multiply in an invertebrate vector and vertebrate) and filariasis of man.
- Mosquitoes also serve as the vectors of enzootic infections (i.e restricted to animals or birds) and some zoonotic diseases due to pathogens transmitted from animals to man. E.g yellow fever.

Breeding Areas

- Breeding places of mosquitoes are always in water.
- Mosquitoes will breed in practically any collection of water that stands longer than five to seven days.
- Different kinds of mosquitoes vary in their choice of breeding places.
- Some mosquitoes like sunlit places where as others prefer shade.
- Some prefer fresh water to stagnant water.

- Others prefer the brackish water of salt marshes.
- Common breeding sites are ponds, pools, slow-moving streams, inland swamps and bogs, salt marshes, ditches, tree holes, rock holes and manmade containers of water.
- Man made containers include wells, cisterns, rain barrels, roof gutters, road gutters, cans, buckets, drains cesspools, septic tanks, pit latrines and old tires that have been discarded.

Life Cycle

- Males and females mate during the first 3 to 5 days after they have emerged
- Females mate only once.
- Males generally live for only a week while the female live longer than 1–2 weeks in nature.
- Once a female has completely engorged, she flies to a shaded environment until her eggs are completely developed, usually 3 to 5 days.

- Once the eggs are developed the female is called a gravid female and she begins to search for a desirable place to lay her eggs.
- Generally a female will only live long eno ugh to lay 3 batches of eggs
- Eggs may be deposited on dump soil or vegetation, in moist tree holes or contai ners, and sometimes directly on to wate r.

The choices of specific oviposition sites by female mosquitoes determine the breeding places of each species.

- The eggs of Aedini usually undergo diapause to be able to withstand drought or winter.
- In other kinds of mosquitoes, eggs hatch within 1-2 days under optimal conditions after being laid.
- Flooding and decreasing oxygen concentration trigger the hatching of eggs that have undergone diapauses.

Larvae

- Larval development takes about a week for most tropical mosquitoes, but many temperate species over winter as larvae.
- The fourth stage larva moults to the pupal stage, from which the adult mosquito emerges after a few days.
- Larvae breathe air via a pair of posterior dorsal spiracles located on a characteristic “siphon” which is not developed in Anophelines

- The majority of mosquito larvae have m outhparts adapted for filter feeding.
- The diet of most mosquito larvae compri ses micro-organisms and detritus.
- Rates of mosquito larval growth are infl uenced by such environmental factors a s temperature, photoperiod, food supply and the degree of crowding.

- Larvae develop through 4 stages, or instars, after which they metamorphose into pupae.
- At the end of each instar, the larvae molt, shedding their exoskeleton, or skin, to allow for further growth.
- The process from egg laying to emergence of the adult is temperature dependent, with a minimum time of 7 days.

Pupae

- The pupae rests beneath the surface preparing for metamorphosis.
- Pupae do not feed.
- Eventually the pupal case splits along the back and the adult mosquito works its way out onto the surface.
- Wings and legs become extended and the body cuticle begins to harden within half an hour of eclosion.
- It takes ten to twelve days to complet life cycle from egg to adult

Adult

- The adult mosquito then flies to find a s helter and rest for several hours.
- Males are not able to copulate until their terminalia (extended genitalia) have tur ned upside down, a process known as hy popygial circumversion, taking about on e day for completion.
- Thereafter the males form large swarms usually around dusk with specific charact eristics at certain times daily.

- Female mosquitoes flying into or near a swarm are set upon by the males and copulation ensures.
- Once inseminated, a female mosquito carries in her spermathecae sufficient sperms for fertilization of all the eggs she may produce.
- Through the action of matrone, a hormone from male accessory glands, mated female mosquitoes normally become unwilling to accept sperms from additional males.

Medical and Economic Importance

- Mosquitoes are important because the females of many species are bloodsucking, they annoy humans and other animals, and they may transmit the pathogens that cause human and animal diseases.
- The pathogens transmitted by mosquitoes include viruses (arboviruses), filarial worms (helminths) and protozoa.
- Mosquitoes are the indirect cause of more morbidity and mortality among humans than any other group of organisms.

Control Measures

- Control measures against mosquitoes may be aimed at the larvae or at the adults.
- Measures aimed at larvae may involve the elimination or modification of larval habitats (for example drainage) or may involve the treatment of the larval habitat with insecticides.
- Measures aimed at the adults may be in the nature of preventives (the use of the protective clothing, screening and use of repellants) or insecticides (sprays or aerosols).

SUBFAMILY ANOPHELINAE

- The subfamily includes 478 formally reco gnized species.
- Anopheline is divided into three genera:
  1. *Anopheles* Meigen (nearly worldwide in distribution).
  2. *Bironella* Theobald – Confined to New Guinea and tropical Australia
  3. *Chagasia* Cruz – Neotropical region
- Mosquitoes belonging to these genera are referred to as “anophelines”.

Distribution

- Most species of the subfamily belong to the genus *Anopheles*, which occurs in the temperate, subtropical and tropical areas of the world except for groups of island in the Pacific and isolated islands in the Atlantic.

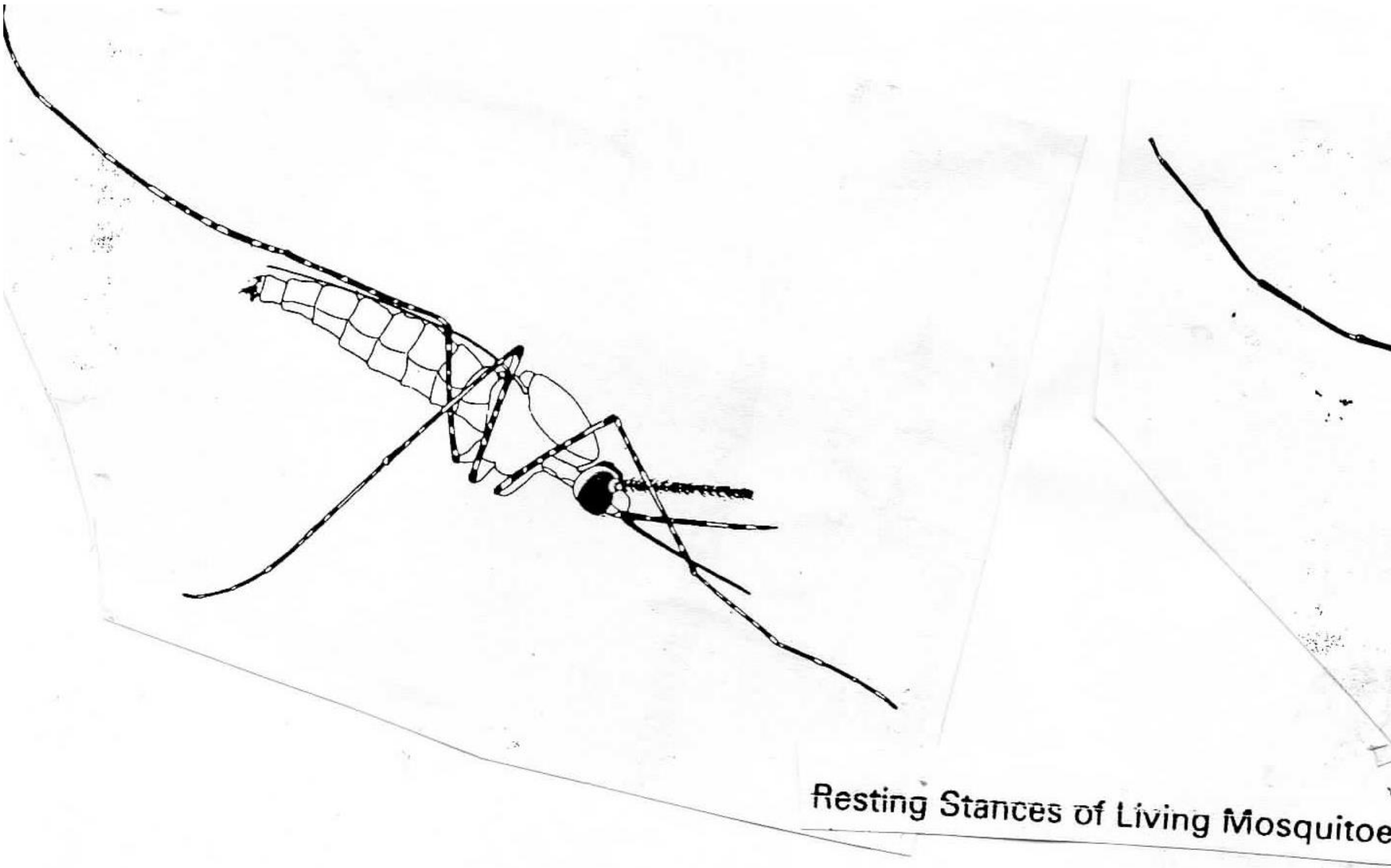
- *Bironella* is confined to New Guinea and tropical Australia.
- *Chagasia* is confined to Neotropical region.

- *Anopheles* are medically important, being the sole vectors of malaria, and they play a substantial role in transmitting lymphatic filariasis due to *Wuchereria bancrofti*.
- *Bironella* and *Chagasia* are medically unimportant.
- Most species of *Anopheles* require large spaces for the mating flights, rendering it difficult to propagate them in captivity.

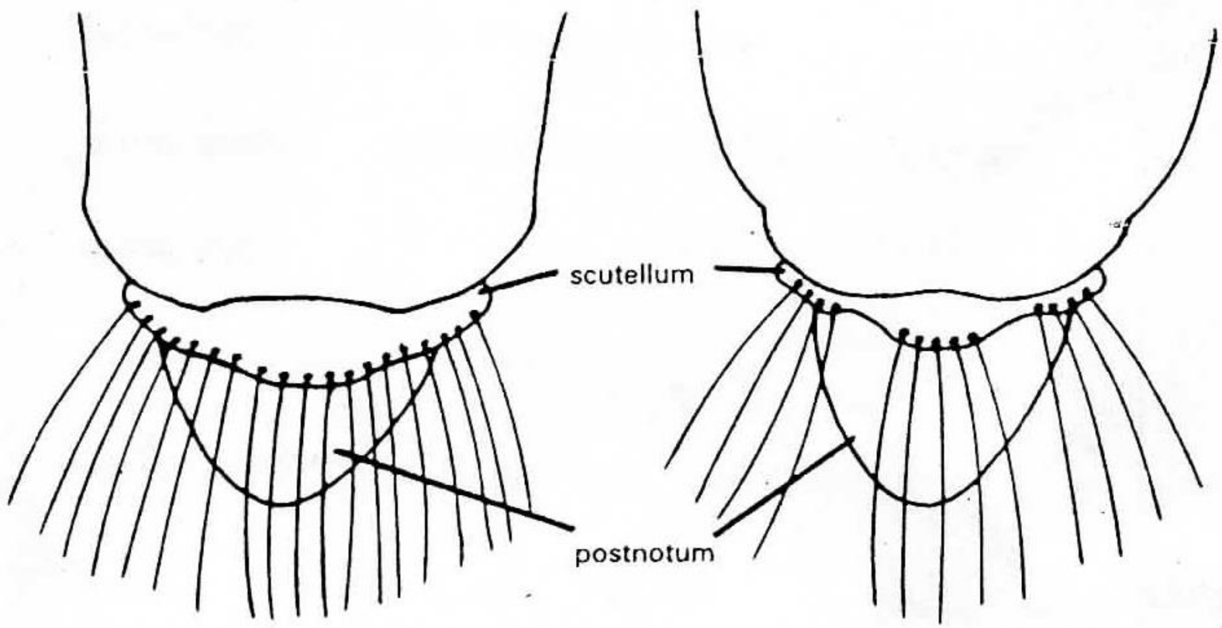
Characteristics

1. Most species stand with proboscis, head and abdomen in almost a straight line, usually resting (on an upright surface) at an angle of about 45° to the surface and have dark and pale spots of scales
2. The maxillary palps of both sexes are about as long as the proboscis (except *Bironella*). The maxillary palps are clubbed in the male.

Resting stance of Anopheles



3. *Anopheles* mosquitoes have discrete blocks of black and white scales on the wings.
4. The scutellum is evenly rounded in *Anopheles* and *Bironella* and trilobed in *Chagasia*.
5. The abdominal sterna, and usually the terga, are completely or nearly devoid of scales.



Scutella of an *Anopheles* (left) and a Culicine (right)

- Anopheline larvae lack a respiratory siphon,
- The head is longer than wide
- Pairs of palmate setae are normally present on some or all of abdominal segment I-VII.

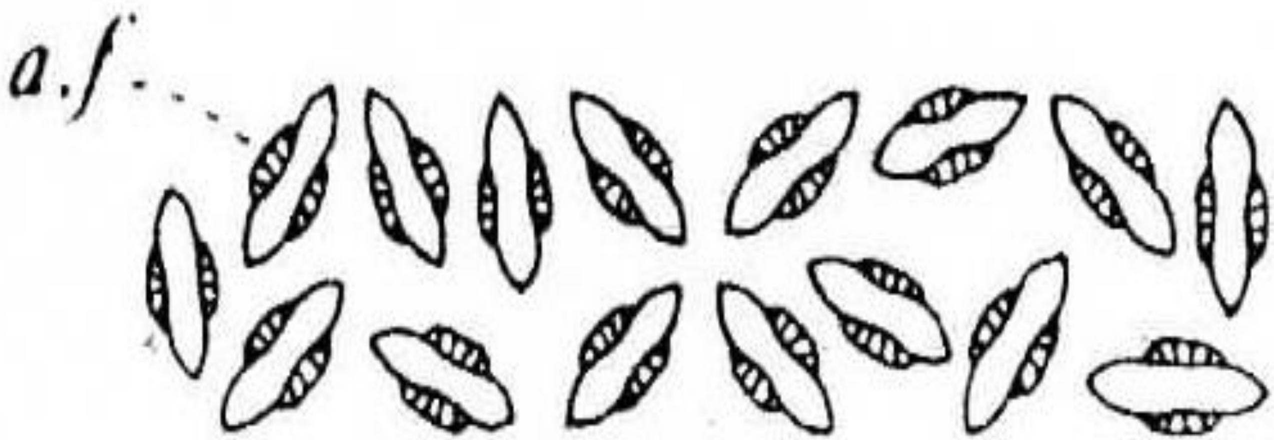
Life Cycle of *Anopheles*

- Adult females lay 50–200 eggs per oviposition.
- Eggs are laid singly and directly on water.
- At a temperature of 25-30˚C, tropical *Anopheles* can be expected to suck blood and lay eggs regularly at intervals of 2 or 3 days.
- The female *Anopheles* mosquito lays a batch of 100 – 150 eggs usually at night on the surface of water.

- They are laid singly but arrange themselves in a distinct pattern on the surface of the water.
- The surface structure of the eggs is such that eggs will attach end to end or side to side but never end to side.
- Anopheline eggs are 1mm in length and bearing paired lateral air-filled floats, which are characteristic of anopheline eggs.

- The floats are air-filled spaces between the exochorion and endochorion of the egg shell to resist submersion

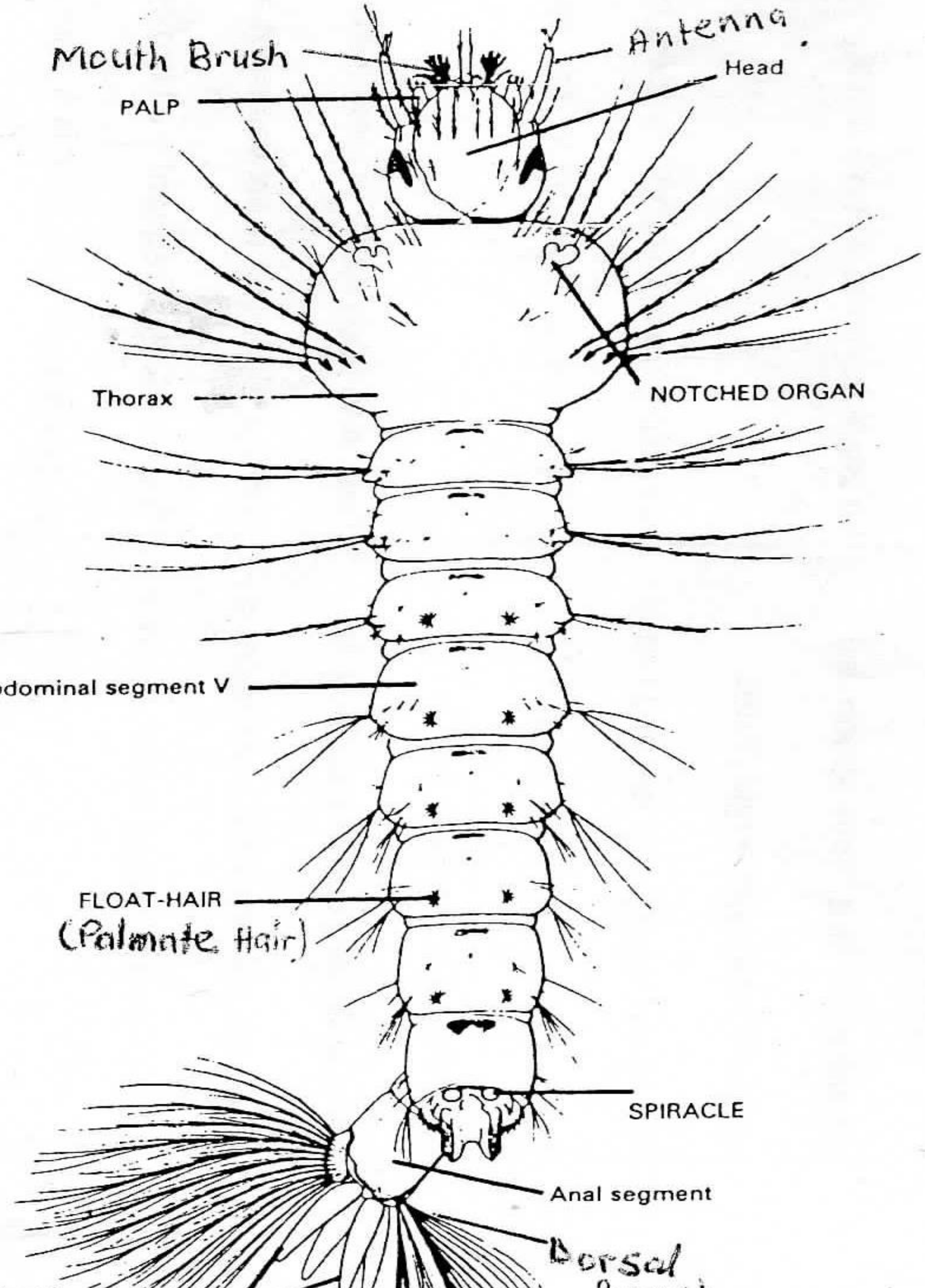
Anopheles



Larva

- The eggs hatch in 2 or 3 days.
- The larva emerges from the egg by using a small egg tooth, placed poster dorsally on its head.
- Three regions can be differentiated in the body of the larva: a well developed sclerotised head, a broad thorax in which the three segments are fused; and a segmented abdomen.
- The larva is apterous and apodous, having neither wings nor legs.

- The larva feeds on small floating particles swept into its mouth by feeding brushes which can be folded under its head.
- Food consists of algae, bacteria protozoa, and other microorganisms
- *Anopheles* larvae lack a respiratory sipho n and for this reason the larva lies paralle l to the water surface supported by the p aired prothoracic notched organ, the post erior spiracular apparatus and paired pal mate hairs (float hairs).


Mouth Brush
Antenna
Head
PALP
Thorax
NOTCHED ORGAN
Abdominal segment V
FLOAT-HAIR
(Palmate Hair)
SPIRACLE
Anal segment
Dorsal

Ve

- Palmate hairs are present on most abdominal segment and occasionally on the thorax.
- They have short, stout basis from which radiate 10-20 leaflets and are unique to anopheline larvae.
- When *Anopheles* larvae lie beneath the surface, the dorsal part of the thorax and abdomen face upward, but the head is rotated 180° so that its ventral surface lies upwards.

- The head has a pair of short antennae, eyes, a pair of feeding brushes and preclypeal and clypeal hairs.
- The respiratory opening is composed of two dorsally placed spiracles located on the 8th abdominal segment and therefore must come to the surface frequently.
- Small glands secrete a waxy substance around the spiracles, which therefore cannot be wetted.

- Atmospheric air is taken through the spiracles.
- The terminal segment is provided with four anal papillae (gills), which have respiratory and excretory functions, but are mainly used to absorb mineral salts.
- Respiration also takes place through the cuticle.

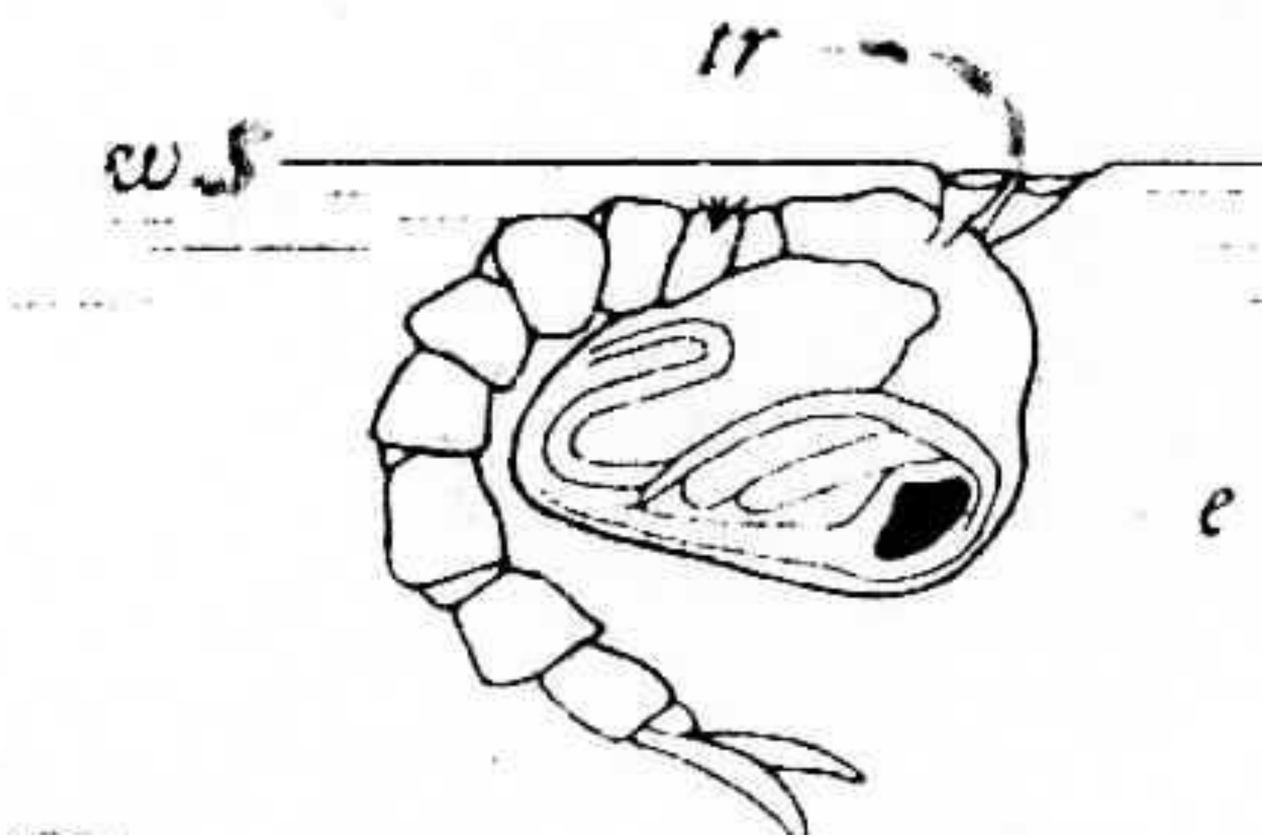
- During the first three instars the head capsule increases in length by the addition of a collar but in the fourth instar the collar remains a narrow band.
- The fully grown fourth instar larva moults into the pupa.

Pupa

- The head and the thorax of the pupae combined into a simple division, the cephalothorax, which is joined posteriorly to a segmented abdomen.
- At rest, the pupa floats at the water surface with the abdomen reflected under the cephalothorax.

- The pupa does not feed but breaths through a pair of broad trumpets dorsally placed on the cephalothorax, i.e it is propneustic, and is susceptible to oil treatment.

- The ninth segment of the abdomen carries a pair of broad, flat plates, the paddles.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w.s
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- Pupa can complete their development out of water; presumably either the pupa itself or enclosed pharate adult has a water proofing wax layer.
- On a dry surface pupae can jump about, which is possibly a defence mechanism against predators.

Adult Emergence

- The pupal skin splits dorsally and the adult emerges gradually from the pupal exuviae.
- The newly emerged adult inflates its wings, separates and grooms its head appendages before flying away.
- The duration from egg to adult varies considerably among species and is strongly influenced by ambient temperature.

- Mosquitoes can develop from egg to adult in as little as 5 days but usually take 10–14 days in tropical conditions.
- Males live for about a week, feeding on nectar and other sources of sugar while the female live longer than 1–2 weeks in nature.
- Their lifespan depends on temperature, humidity, and also their ability to successfully obtain a blood meal

- *Anopheles* mosquitoes can be distinguished from other mosquitoes by the palps, which are as long as the proboscis.
- By the presence of discrete blocks of black and white scales on the wings.
- Adult *Anopheles* can also be identified by their typical resting position

SUBFAMILY CULICINAE

- By far the largest of the two subfamilies, containing almost 90% of the known world spp.
- **Taxonomy of Culicinae**
- Culicinae is the largest and heterogeneous subfamily of mosquitoes containing 3,047 species in 108 gener a.
- The genera are grouped into 11 tribes:

  Aedeomyiini, Aedini, Culicini, Culisetini, Ficalbiini, Hodgesiini, Mansoniini, Orthopodomyiini, Sabethini, Toxorhynchitini, Uranotaeniini

- Species belonging to the subfamily are referred to as “culicines”, however, species of the tribe Aedini are sometimes referred to as “aedines” and species of the tribe Sabethini are known as Sabethines.

3. Genera of Culicinae

- The main genera are *Aedes* and *Culex* *(*768) and the medically important *Ur anotaenia*.

Distribution

- Members of the subfamily are found in all 200 geographic regions of the world, but the majority of species occur in tropical regions.

Characteristics

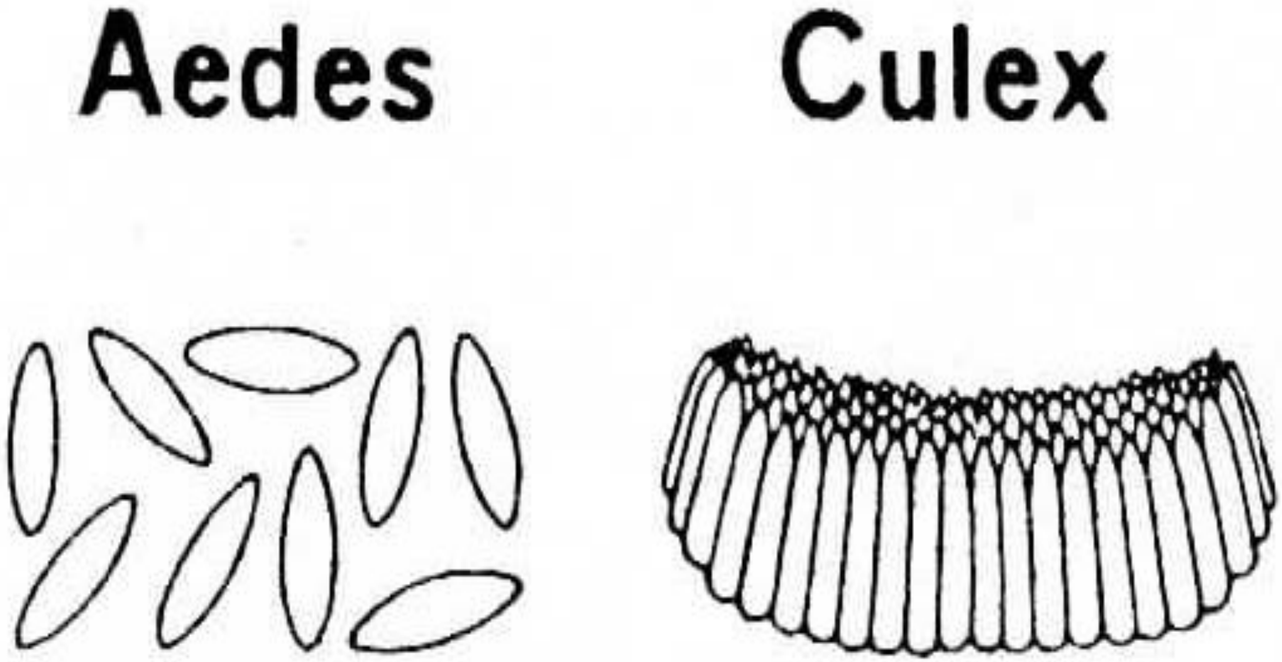
- Adult culicines stand with the body parallel to the surface on which they are resting
- Females have maxillary palps that are usually much shorter than the proboscis. Males have long palps with numerous long setae but they are not swollen apically like those of anophelines.
- The scutellum has three lobes with setae confined to each lobe.

- The wing veins are usually entirely dark-scaled, but speckles or particles of white or yellow scales are present in some species.
- The abdominal terga and sterna are densely covered with scales, which distinguishes them immediately from almost all anophelines.
- The larval spiracles are situated at the tip of the tail-like siphon, projecting dorsally from the eighth abdominal segment.

- The dorsal and ventral abdominal setae arise separately and usually without basal sclerites, and the mouth brushes are composed of numerous, usually slender filaments.

Culicine Eggs

- They are laid either singly (e.g. Aedes) or in the form of egg rafts that float on the water surface (e.g. Culex), or are d eposited as sticky masses glued to the underside of floating vegetation (e.g. Masonia)
- Culicine eggs never have floats.


Aedes
Culex

Culicine Larvae

- All Culicinae larvae possess a siphon which may be long or short.
- They hang upside down at an angle from the water surface.
- There are no abdominal palmate hairs or tergal plates on Culicinae larvae.

Culicine Pupa

- The length of the respiratory trumpets in Culicine pupae is variable, but they are generally longer and more cylindrical.
- Have narrower openings than in Anopheles.
- Abdominal segments 2-7 lack peg-like spines, although they have numerous setae.
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Culicine Adults

- Culicine adults rest with the thorax and abdomen more or less parallel to the surface.
- The scales covering the wing veins are commonly uniformly brown or black.
- Female Culicines have non-plumose antennae; palps are shorter than the proboscis.
- In males the palps are about as long as proboscis but never swollen at ends, palps may be hairy distally.

LIFE CYCLE OF CULICINAE (E.g. *Aedes* sp and *Culex* sp)

- The eggs of *Aedes* are laid in a batch but are not attached to each other.
- They differ from those of *Anopheles* by t he absence of floats.
- Eggs of *Aedes* are laid on the moist surf ace at the water's edge and not on the water itself.

- When the eggs are first laid, they are susceptible to desiccation and collapse and die if dried.
- But when the embryo is fully developed; eggs can withstand desiccation and remain viable in the dried state for many months depending on the species.

Eggs of *Culex* sp.

- The eggs of *Culex* sp are laid in the form of rafts.
- The rafts commonly measure 3-4 m m long and 2-3mm wide.
- The eggs cannot withstand desiccati on and if dried, the eggs collapse an d the embryos die.

Larva

- The Culicine larvae differ from those of *A nopheles* by possessing a siphon on the p enultimate segment of the abdomen.
- The tracheae are continued into the sipho n and the spiracles open at its tip.
- Within the subfamily there is great variet y in the shape and size of siphons.
- In *Aedes*, the siphon is typically short w hile in *Culex,* the siphon is long and slend er.

- Possession of the siphon enables Culicine larvae to hang head down from the surface film and simultaneously respire and feed below the surface.
- Culicine larvae do not possess palmate (float) hairs or prothoracic notched organs.

Pupa

- The Culicine pupa is very similar to that of the Anophelinae.
- The respiratory horn is tubular in Culicine compared with the distally expanded horn in Anophelinae.
- *Aedes aegypti* completes development in ten days at 23.9^{o}C.
- When the progeny of any one egg batch emerge as adults, the males emerge first.

- The male terminalia have to rotate through 180° before the male is ready for mating.
- This process takes about 24 hours so that by the time the females emerge the males are competent for mating.

Genus *Aedes*

- *Aedes* species are typical small mosquito es.
- They usually have black and white stripe markings on their body and legs. *Aedes a egypti* can be distinguished by its silvery white colouration on the thorax.
- In temperate countries, a high proportion of mosquitoes belong to the genus *Aedes* in which there are more than thousand k nown species.

- Many *Aedes* are vectors of arboviruses, inc luding several of the most important mosq uito-borne human diseases such as yellow fever and dengue.
- *Aedes* larvae are characterised by having o nly a single pair of siphonal hairs usually b ranched in addition to pecten teeth.
- Many of the medically important *Aedes* sp ecies are active during daytime, although nocturnal activity is normal for most other species.

- *Aedes* eggs are capable of withstanding desiccation.
- They are laid on damp surfaces such as soil or around a rim of water in a hole, i n situations likely to be flooded causing t he eggs to hatch after adequate rainfall.

- Most species of *Aedes* therefore breed seasonally in swamps and pools, with some groups adapted to smaller containers of water such as rock holes, rot holes in trees, cut bamboo stumps, old snail shells, buckets and other artificial containers.
- It has been demonstrated that arboviruses can be passed transovariably in *Aedes*, i.e. from mother to progeny via the egg. This has been reported for Yellow fever.

- Representatives of three sub genera of *A edes* are natural vectors of *Brugia malayi* and *Wuchereria bancrofti*.
- *Aedes aegypti* is the most widespread an d dangerous species in this sub genus.
- In Africa forest, non anthropophilic popul ations known as *Aedes aegypti formosus* are distinguished by their lack of pale sca les on the abdominal tergites (i.e. the top of the abdomen is entirely dark).

- Presumably from this ancestral stock, man-biting populations have adapted to domestic breeding sites and become sp read throughout the tropics between 35 º North and 35º South.
- Urban Yellow fever is also mainly trans mitted by *Aedes aegypti* in central and South America and in West Africa.

Genus *Culex*

- About 800 species of *Culex* are known, being classified into 21 sub genera with many species acting as the vectors of enzootic arboviruses, protozoa and filariae.
- Generic characteristics are that eggs always form a raft.
- Larvae have several pairs of hair tufts on the siphon and the adult possess tarsal pulvilli and post spiracular bristles.

- The tip of the female abdomen is bluntly rounded and male palps are strongly cur ved upwards.
- General body colouration of the adult is usually brown with wings plain and vein scales dark unlike Aedinae.
- The eggs cannot diapause so *Culex* bree ding is continuous except when fertilized females hibernate.

Subfamily Toxorhynchitinae

- Toxorhynchitinae are very large metallic coloured mosquitoes which do not suck blood.
- They are larger than other mosquitoes.
- The scutellum is rounded and the palps of the female short.
- The basal part of the proboscis stout, the apical part is slender and decurved.
- The proboscis is suited only for imbibing nectar from plants or free fluids.

- Toxorhynchitinae occurs mainly in the tropics and subtropics of the Oriental, Neotropical and Afrotropical.
- About 60 species are known, all classified in a single genus, *Toxorhynchites.*
- Breeding places are flooded tree-holes, rock-holes and artificial containers such as buckets and discarded tyres.
- Female *Toxorhynchites* scatter their rounded buoyant eggs onto water while flying.

- Larvae soon hatch and become predators with mouth brushes composed of six to ten strong recurved teeth on each side for grasping prey.
- Populations of some dangerous container-breeding Culicinae, notably *Aedes aegypti*, can be significantly reduced through predation by *Toxorhynchites*. *Toxorhynchites* adults are diurnally active.

MALARIA

- Malaria is a mosquito-borne infectious disease of humans and other animals caused by parasitic protozoans (sporozoans) of the genus *Plasmodium* (Phylum Apicomplexa).
- It is transmitted via the bite of an infective female *Anopheles* mosquito.
- Malaria affects more people, more persistently throughout the world than any other insect borne disease.

- Anthropophilic *Anopheles* are more likely to transmit the malaria parasites from one person to another.
- Most *Anopheles* mosquitoes are not exclusively anthropophilic or zoophilic.
- The primary malaria vectors in Africa are *A. gambiae* and *A. funestus*.
- They are strongly anthropophilic and, consequently, are two of the most efficient malaria vectors in the world.

Distribution

- It is widespread in Tropical and Subtropical regions, including parts of the Americas, many parts of Asia and much of Africa.
- However it is in Sub-Saharan Africa where 85 - 90% malaria fatalities occur.
- There were an estimated 225 million cases of malaria worldwide in 2009. An estimated 655,000 people died from malaria in 2010.

- A 5% decrease from the 781,000 who died in 2009 according to the World_Health Organization's 2011 World Malaria Report

- Ninety percent of malaria-related deaths occur in sub-Saharan Africa, with ~60% of deaths being young children under the age of five.

- *Plasmodium falciparum*, the most se vere form of malaria, is responsible for the vast majority of deaths asso ciated with the disease.

- Malaria is commonly associated with poverty, and can indeed be a cause of poverty and a major hindrance to economic development.

Human Malaria Parasites (*Plasmodium*)

- More than a hundred species of *Plasmodium* have been described from vertebrates.
- *Plasmodium* is found in RBCs and liver cell in man alimentary canal and salivary glands of female Anopheles mosquito.
- Five species of *Plasmodium* can infect and be transmitted by humans.
- About 20 species in other primates, a similar number in other mammals, and about 40 each in birds and reptiles.

- The vectors of the mammalian species of *Plasmodium* are invariably species of *Anopheles* mosquitoes and those of bird plasmodia are most often Culicine mosquitoes.
- Five species of *Plasmodium* can infect and be transmitted by humans.
- Severe disease is largely caused by *Plasmodium falciparum.*

- The disease caused by *Plasmodium vivax*, *Plasmodium ovale*, and *Plasmodium malariae* is generally a milder disease that is rarely fatal. *Plasmodium knowlesi* is a zoonosis that causes malaria in macaques but can also infect humans.
- *P. knowlesi* (which is the most common cause of malaria in South-east Asia)
- Each of the five malaria parasites provoke different symptoms

Plasmodium falciparum

- Causes malignant tertian malaria fever (malignant = intent to cause harm). It recurs at 48 hours intervals. Tertian – Latin for 'third day' describe the pattern; fever on the first day, normality on day two and fever again on day three.
- Malignant tertian fever is the most severe form of the disease and in the absence of treatment may kill up to 25% of non-immune adults within two weeks.

- Cerebral malaria is the most dangerous and a frequent cause of mortality in children and non-immune adults.
- After the initial series of attacks have passed, malignant tertian fever may recur from the activation of latent erythrocytic forms.
- It also causes renal failure.

- *P. falciparum* is the most common cause of infection and is responsible for about 80% of all malaria cases, and is also responsible for about 90% of the deaths from malaria.
- *P. falciparum* has a higher temperature threshold for development and is most common in warmest areas of the world

Plasmodium vivax

- Causes benign (not inclined to become w orse), tertian malaria; a less serious dise ase that rarely kills but is more persistent than *P. falciparum*.
- It is a more widespread parasite than *P. f alciparum* and has a wider temperature t olerance; extending as far as 16 ^{o}C summ er isotherm and was therefore often the only species present in the cooler temper ate regions.

- Recurrence of fever is every 48 hours.
- The disease may persist for up to 8 years causing relapses at intervals as short as two months.
- It is absent from West Africa because the indigenous people lack the Duffy factor on their erythrocytes, which is essential if *P. vivax* merozoites are to enter erythrocytes.
- The Duffy antigen is located on the surface of red blood cells.

Plasmodium ovale

- *Plasmodium ovale* causes tertian malaria with limited pathenogenicity.
- It is the rarest of the human malaria par asites.
- Has a very long incubation period with r elapse at three monthly intervals.

Plasmodium malariae

- Causes quartan malaria; recurrence of fe ver is at 72 hours (quartan means fourth day).
- It is a widespread parasite but more rare than *P. falciparum* or *P. vivax*.
- It is next to *P. falciparum* in pathogenicit y, with death resulting from kidney failur e.
- It is persistent with relapses up to half a century after initial attack.

Plasmodium knowlesi

- Is the fifth major human malaria parasite .
- The parasite is transmitted by the bite of an *Anopheles* mosquito
- It may cause severe malaria as indicated by its asexual erythrocytic cycle of about 24 hours, with an associated fever that typically occurs at the same frequency (i.e. the fever is quotidian).

- It is a primate malaria parasite commonly found in Southeast Asia.
- It causes malaria in long-tailed macaques (*Macaca fascicularis*), but it may also infect humans, either naturally or artificially.

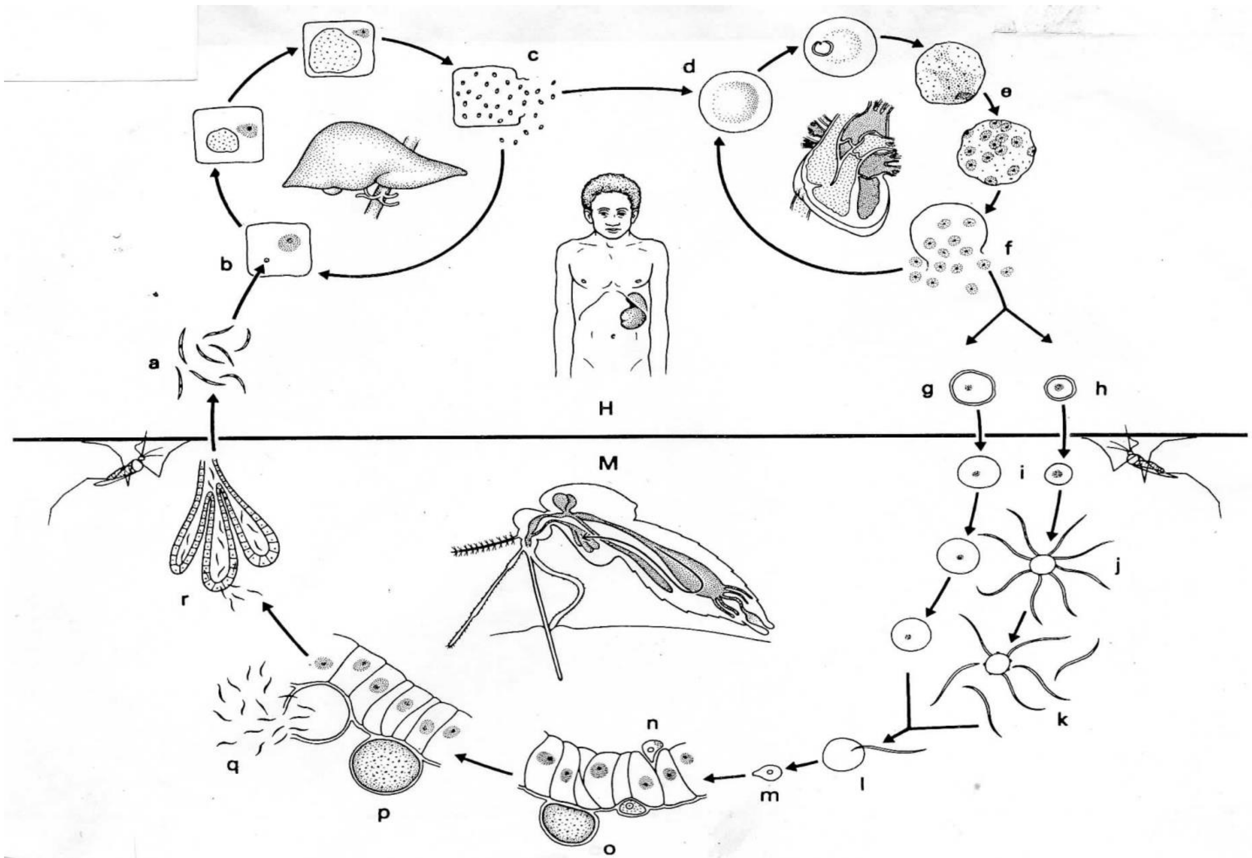
THE LIFE CYCLE OF PLASMODIUM

- The malaria parasite exhibits a complex life cycle involving an insect vector (mosquito) and a vertebrate host (human).
- Female mosquitoes of the *Anopheles* genus are the primary, i.e. definitive hosts and act as transmission vectors.
- Primary host is the host of the *Plasmodium* in which it completes its sexual lifecycle.

- The parasite's secondary hosts are humans and other vertebrates.
- Female *Anopheles* mosquito is called infective when the Sporozoites are present in the alimentary canal or salivary gland.
- Five *Plasmodium* species infect humans.

Anopheles mosquito feeding on human arm

- Infection in humans begins with an infected female *Anopheles* mosquito taking a blood meal from a human host.
- As it feeds, it injects saliva contaminated with the sporozoite stage of the *Plasmodium* into the bloodstream of the host during feeding.
- The sporozoites are carried by the circulatory system to the liver which quickly invade the liver cells (hepatocytes).



The life cycle of a *Plasmodium*, the malaria pathogen, in human (H) and mosquito (M): (a) injection of sporozoites into human host by feeding mosquito; (b) sporozoite enters liver parenchyma cell; (c) rupture of schizont to release merozoites; (d) merozoites enter erythrocyte; (e) trophozoite becoming schizont; (f) schizont releasing merozoites; (g) female macrogamete formation; (h) male gametocyte formation; (i) gametes lacking erythrocyte coat; (j) flagellate microgamete; (k) exflagellation; (l) zygote formation; (m) ookinete; (n) oocyst forming on mosquito inner midgut wall; (o), (p) oocyst maturation and sporogeny; (q) release of sporozoites; (r) sporozoites entering salivary gland. (Modified after Kettle, 1984; Katz *et al.*, 1989.)

- Sporozoites are cleared from the circulation within 30 minutes

- During the next 14 days in the case of *P. falciparum*, the liver-stage parasites differentiate and undergo asexual multiplication resulting in tens of thousands of **merozoites** which burst from the hepatocyte

- **Merozoite**
- The third stage in the asexual cycle of a malaria parasite derived from division of the schizont

- **Merozoites** are cryptozoites and Metacryptozoites formed after Pre-erythrocytic and Exo-erythrocytic schizogony.

- The prepatent period of infection that started with an infective bite ends when the merozoites are released and either infects further liver cells or enters the bloodstream and invades the erythrocytes.
- Invasion occurs when the erythrocyte invaginates to engulf the merozoite, which subsequently feeds as a trophozoite within a vacuole.

- In the red blood cells, they develop into ring forms, trophozoites and schizonts which in turn produce further merozoites.
- **Trophozoite**

  Is the first stage in the asexual cycle of a malaria parasite derived from a merozoite
- **Schizont**

  The second stage in the asexual cycle of a malaria parasite produced by pre-erythrocytic schizogonous cycle or by

division of a trophozoite

- Trophozoite enlargement is accompanied by an active metabolism including the in gestion of host cytoplasm and the prote olysis of haemoglobin into amino acids.

- The end of the trophozoite period is man ifested by multiple rounds of nuclear divi sion resulting in a schizont.

- The schizont releases from 6 to 16 merozoites which commence the repetition of the erythrocytic cycle.
- This synchronous release of merozoites from the erythrocytes liberates parasite products that stimulate the host's cells to release cytokines (a class of immunological mediators) which provoke the fever and illness of malaria attack.

- The length of this erythrocytic stage of the parasite life cycle depends on the parasite species: 48 hours for *P. falciparum, P. vivax*, and *P. ovale* (tertian malaria) and 72 hours for *P. malariae* (quartan malaria).

Exogenous Sexual phase and Sporogony

- After several erythrocyte cycles (asexual phases), some trophozoites do not under go division but differentiate to the sexual forms, male and female gametocytes (ma cro- or microgametocytes), a process that takes 8 days for *P. falciparum* but only 4 days for *P. vivax*.
- The gametocytes are large parasites whic h fill up the erythrocyte, but contain only one nucleus.

- These gametocytes are taken up by a fe male *Anopheles* mosquito during a blood meal.
- Within the mosquito midgut, the male ga metocyte undergoes a rapid nuclear divisi on, producing 8 flagellated microgamtes which fertilize the female macrogamete .
- The resulting ookinete traverses the mos quito gut wall and encysts on the exterior of the gut wall as a oocyst.

- The oocyst undergoes multiple rounds of as
exual replication (sporogony) resulting in th
e production of sporozoites.
- Sporogony does not occur below 16 ^{o}C or ab
ove 33 ^{o}C which explains the temperature li
mitations for *Plasmodium* development.
- When the oocyst ruptures, it releases hundr
eds of sporozoites that migrate through the
mosquito's body to the salivary glands, whe
re they are then ready to infect a new hum
an host

- The asexual reproduction from ookinete (m) to the stage where the sporozoites enter the salivary gland is known as **sporogony**
- This type of transmission is occasionally referred to as anterior station transfer.

- The time required for development in the mosquito (the extrinsic incubation_period) ranges from 10–21 days, depending on the parasite species and the temperature.
- If a mosquito does not survive longer than the extrinsic incubation period, then she will not be able to transmit any malaria parasites.

Summary

- In summary, malaria parasites undergo three distinct asexual replicative stages
  1. Exoerythrocytic schizogony
  2. Blood stage schizogony
  3. Sporogony

  resulting in the production of merozoites and sporozoites.
- When schizogony produces merozoites, it is called merogony.

Signs and Symptoms of Malaria

- Malaria symptoms usually refer to various symptoms known to patient.
- Malaria signs may refer to those signs only noticeable by a doctor.
- Clinical symptoms of malaria are associated with the bursting of infected erythrocytes releasing merozoites, malaria pigment and other debris into the blood stream.

- People with malaria typically have fever, chills, muscle aches, arthralgia (joint pain) headache, which turn within an hour into profuse sweating with headache, vomiting, dizziness and high temperature lasting for 2 to 6 hours, after which the temperature falls rapidly to normal and patient may feel well.
- Symptoms recur at intervals of 48 hours to 72 hours.
- Symptoms usually appear between 10 and 15 days after the mosquito bite.

- The result of an attack of malaria is anaemi a with the possibility of oxygen deprivation to the tissues.
- Attack of the malaria parasites on the perso n’s red blood cells makes the person’s temp erature rise.
- Bursting of red blood cells makes the perso n feel cold and have hard, shaking chills.
- The destruction of red blood cells can also c ause jaundice (yellowing of the skin or whit es of the eyes).

- Patients with severe *P. falciparum* malaria may develop liver and kidney failure, convulsions, and coma.
- Infections with *P. vivax* and *P. ovale* may cause less serious illness, parasites may remain dormant in the liver for many months, causing a reappearance of symptoms months or even years later.

Malaria Epidemiology and Pathogenesis

- Malaria is said to be endemic in an area when it occurs at a relatively constant incidence by natural transmission over successive years.
- An epidemic occurs when the incidence in area rises or a number of cases of the disease occur in a new area.
- Malaria is said to be in a stable state when there is little seasonal or annual variation in the disease incidence.

- Stable malaria is found in warmer areas of the world where conditions encourage rapid sporogeny- usually associated with *P. falciparum* pathogen.
- Most of the pathologic findings of malaria are due to the destruction of RBC; the en larged spleen is due to congestion of sinu soids with erythrocytes.

Treatment of Malaria

1. Chemotherapy (use of antimalarial drugs)

   The antimalarial drugs are classified by their selective actions on different phases of the parasite's life cycle.

   (a) Tissue schizonticides-eliminate developing tissue schizonts in the liver e.g. Primaquine

(b) Blood schizonticides (suppressive agents)-these drugs kill blood schizonts e.g. Chloroquine (prognanil), pyrimethamine, mefloquine, amodiaquine (amoquine), quinine, artesunate.

(c) Gametocytocides- prevent infection in mosquitoes by destroying gametocytes in the blood e.g. Primaquine for *P. falciparum* and chloroquine for *P. vivax*, *P. malariae* and *P. ovale*

(d) Sporontocidal agents- these are drugs that render gametocytes non-infective in the mosquito e.g. pyrimethamine.

2. Chemoprophylaxis- Prevent attack of all forms of malaria. Pyrimethamine and proguant prevent maturation of the early *P. falciparum* hepatic schizonts.

Vector control

- Efforts to eradicate malaria by eliminating mosquitoes have been successful in some areas.
- Malaria was once common in the United States and southern Europe, but vector control programs, in conjunction with the monitoring and treatment of infected humans, eliminated it from those regions.
- In some areas, the draining of wetland breeding grounds and better sanitation were adequate.

- Depending on the situation, source reductio
n, biocontrol, larviciding (control of larvae),
or adulticiding (control of adults) may be us
ed to manage mosquito populations.
- These techniques are accomplished using h
abitat modification, pesticide, biological-con
trol agents, and trapping.
- Since many mosquitoes breed in standing w
ater, source reduction can be as simple as e
mptying water from containers around the
home

Biological Control

- Biological control or "biocontrol" is the use of natural enemies to manage mos quito populations.
- There are several types of biological co ntrol including the direct introduction of parasites, pathogens and predators to t arget mosquitoes.

- Effective biocontrol agents include predatory fish that feed on mosquito larvae such as mosquitofish (*Gambusia affinis*) and some cyprinids (carps and minnows) and killifish.
- Tilapia will also consume mosquito larvae.
- Other predators include dragonfly naiads, which consume mosquito larvae in the breeding waters, and adult dragonflies, which eat adult mosquitoes.

- Like all animals, mosquitoes have their own set of diseases.
- Microbial pathogens of mosquitoes include viruses, bacteria, fungi, protozoa, nematodes, and microsproidia
- Also used as biological control agent are the dead spores of varieties of the natural soil bacterium *Bacillus thuringiensis*, especially *Bt israelensis* (BTI).

- BTI is used to interfere in the digestion systems of larvae.
- It can be dispersed by hand or dropped by helicopter in large areas.
- BTI is no longer effective after the larvae turn into pupae, because they stop eating.

Larviciding

- Control of larvae can be accomplished through use of contact poisons, growth regulators, surface films, stomach poisons (including bacterial agents), and biological agents such as fungi, nematodes, copepods, and fish.

Adulticiding

- Control of adult mosquitoes is the most familiar aspect of mosquito control to most of the public.
- It is accomplished by ground-based applications or via aerial application of chemical pesticides.
- Generally modern mosquito-control programs use low-volume applications of pesticides.

YELLOW FEVER

- Yellow fever is an acute, viral haemorrhagic disease which is transmitted to humans by infected female mosquito, *Aedes* (Stegomyia) *aegypti.*
- Yellow fever is common in West and Central Africa and parts of South America.
- Mosquitoes that spread yellow fever usually bite during the day.


Western Sahara
Algeria
Libya
Egypt
Saudi Arabia
Cape Verde
Mauritania
Mali
Niger
Chad
Oman
Yemen
Eritrea
Senegal
The Gambia
Guinea-Bissau
Guinea
Burkina Faso
Benin
Nigeria
Sudan
Djibouti
Somalia
Sierra Leone
Côte d'Ivoire
Ghana
Central African Republic
Ethiopia
Liberia
Cameroon
Togo
Equatorial Guinea
Uganda
Kenya
São Tomé and Principe
Gabon
Rwanda
Democratic Republic of the Congo
Burundi
Indian Ocean
Republic of the Congo
Tanzania
Atlantic Ocean
Angola
Malawi
Zambia
Areas at Risk for Yellow Fever Transmission
Areas of No Risk
Zimbabwe
Madagascar
Mozambique
Namibia
Botswana

Atlantic Ocean
Panama Canal Zone
Panama
Caracas
Trinidad and Tobago
Maturin
Panama
Guyana
Venezuela
Suriname
French Guiana
Colombia
Ecuador
Quito
Puyo
Riobamba
Iquitos
Manaus
Fortaleza
Chachapoyas
Recife
Peru
Brazil
Huánuco
Aracaju
Lima
Salvador
Cuzco
Bolivia
Brasilia
La Paz
Santa Cruz
Sucre
Belo Horizonte
Pacific Ocean
Tarija
Paraguay
Iguassu Falls
Sao Paulo
Rio de Janeiro
Asuncion
Salta
Chile
Posadas
Resistencia
Argentina
Uruguay
Areas at Risk for Yellow Fever Transmission
Areas of No Risk
Falkland Islands

Cause

- The disease is caused by *Flavivirus* of the family Flaviviridae.
- In Africa there are two distinct genetic types (called topotypes) associated with East and West Africa.
- South America has two different types, but since 1974 only one has been identified as the cause of disease outbreaks.

Signs and symptoms

- Once contracted, the virus incubates in the body for 3 to 6 days, followed by infection that can occur in one or two phases.
- The first, "acute", phase usually causes fever, muscle pain with prominent backache, headache, shivers, loss of appetite, and nausea or vomiting.
- Most patients improve and their symptoms disappear after 3 to 4 days.
- Often, the high fever is paradoxically associated with a slow pulse.

- However, 15% enter a "toxic phase" within 24 hours.
- Fever reappears and several body systems are affected.
- The patient rapidly develops jaundice (yellow of the skin and whites of the eyes) and complains of abdominal pain with vomiting.
- Bleeding can occur from the mouth, nose, eyes and/or stomach.
- Blood appears in the vomit and faeces.

- Kidney function deteriorates; this can range from abnormal protein levels in the urine (albuminuria) to complete kidney failure with no urine production (anuria).
- Half of the patients in the "toxic phase" die within 10-14 days.
- The remainder recover without significant organ damage.

- Yellow fever is difficult to recognize, espec
ially during the early stages.
- It can easily be confused with malaria, typ
hoid, rickettsial diseases, haemorrhagic vi
ral fevers (e.g. Lassa), arboviral infections
(e.g. dengue), leptospirosis, viral hepatitis
and poisoning (e.g. carbon tetrachloride).
- Blood tests (serology assays) can detect y
ellow fever antibodies that are produced i
n response to the infection.

Transmission

- The yellow fever virus is an arbovirus of the *flavivirus* genus, and the mosquito is the primary vector.
- It carries the virus from one host to another, primarily between monkeys, from monkeys to humans, and from person to person.
- Humans and monkeys are the principal animals to be infected.

- The virus is carried from one animal to an other (horizontal transmission) by a biting mosquito (the vector).
- The mosquito can also pass the virus via i nfected eggs to its offspring (vertical trans mission).
- The eggs produced are resistant to drying and lie dormant through dry conditions, h atching when the rainy season begins.
- The mosquito is the true reservoir of the v irus

- The viral cycle in the mosquito is 12 days, after which the yellow fever virus reaches the mosquito's salivary glands and remains there for the rest of the mosquito's life.
- With every blood meal the female mosquito transmits virus contaminated saliva
- Several different species of the *Aedes* and *Haemogogus* mosquitoes transmit the virus.

- The mosquitoes either breed around houses (domestic), in the jungle (wild) or in both habitats (semi-domestic).
- There are three types of transmission cycles.

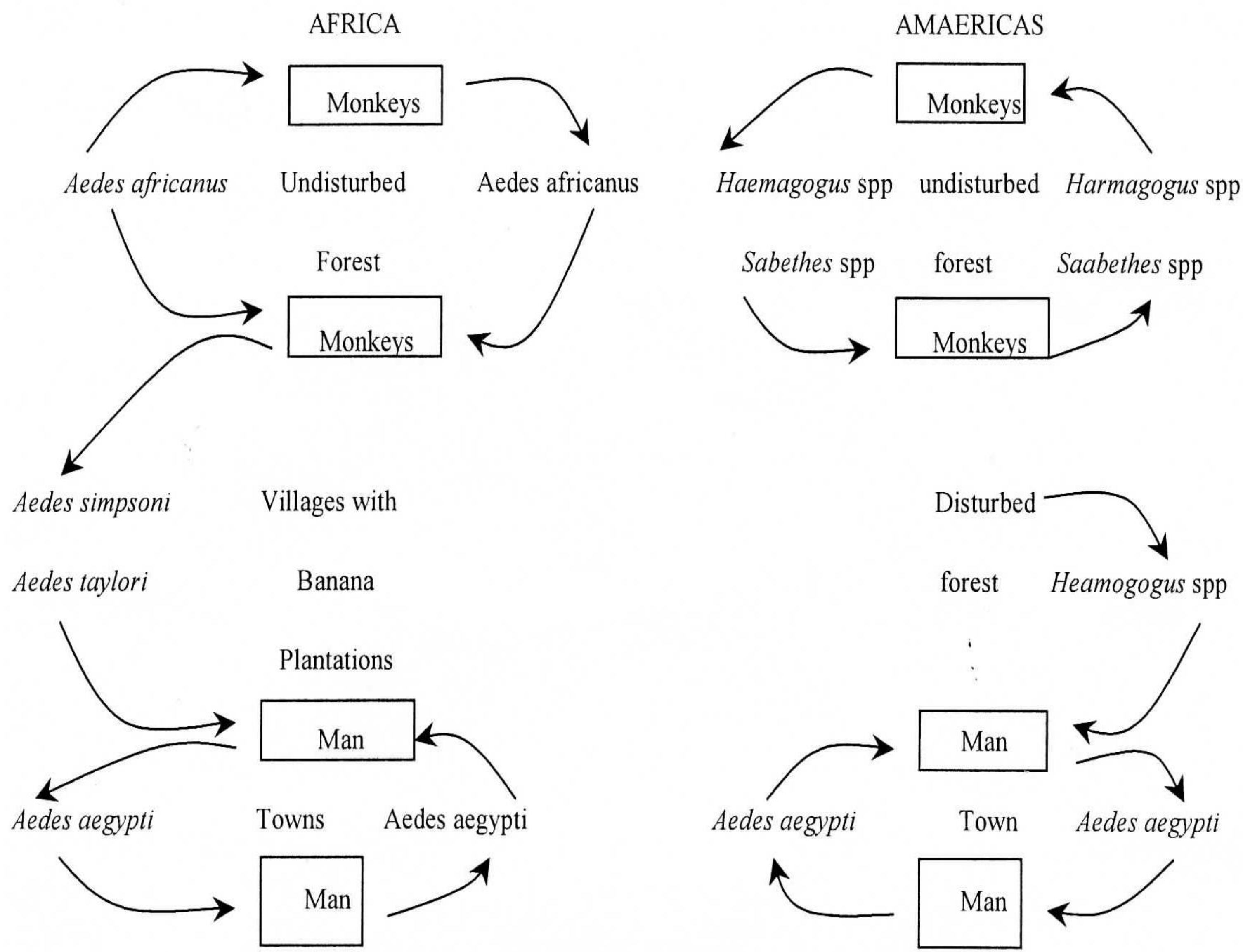
  1. Sylvatic
  2. Intermediate
  3. urban.
- All three cycles exist in Africa, but in South America, only sylvatic and urban yellow fever occur.

Sylvatic (Jungle) Yellow Fever

- Jungle yellow fever is mainly a disease of monkeys.
- It is spread from infected mosquitoes (by *Aedes africanus* in Africa) to monkeys in the tropical rain forest.
- The infected monkeys then pass the virus to other mosquitoes that feed on them.

- At the forest edge, monkeys are likely to b
e bitten by *Aedes* (*Stegomyia*) *simpsoni* w
hich breeds in water-filled axils of certain s
trains of banana plants, or rot holes in ste
ms of pawpaw.
- The infected mosquitoes bite humans enter
ing the forest, resulting in occasional cases
of yellow fever.

- People working and living among such plantations in Africa are likely to become infected with yellow fever and other viruses transmitted from monkeys via *Ae. simpsoni*.
- Majority of the cases are young men working in the forest on plantations, or involved in logging, etc.
- Man to man transmission may then be continued by *Ae*. *aegypti*.



Yellow fever ecosystems in Africa and the Americas

Intermediate yellow fever

- In humid or semi-humid savannahs of Afri
  ca, small-scale epidemics occur.
- These behave differently from urban epide
  mics; many separate villages in an area su
  ffer cases simultaneously, but fewer peopl
  e die from infection.
- Semi-domestic mosquitoes (that breed in t
  he wild and around households) infect bot
  h monkeys and humans.

- This area is often called the "zone of emergence", where increased contact between man and infected mosquito leads to disease
- This is the most common type of outbreak seen in recent decades in Africa.
- It can shift to a more severe urban-type epidemic if the infection is carried into a suitable environment (with the presence of domestic mosquitoes and unvaccinated humans).

Urban Yellow Fever

- Urban yellow fever is a disease of humans .
- It is spread by mosquitoes that have been infected by other people.
- *Aedes aegypti* is the type of mosquito that usually carries yellow fever from human to human.
- These mosquitoes have adapted to living among humans in cities, towns and villages.

- They breed in discarded tires, flower pots , oil drums, and water storage containers close to human dwellings.
- Large epidemics can occur when migrant s introduce the virus into areas with high human population density.
- Domestic mosquitoes (of one species, *Ae des aegypti*) carry the virus from person to person.

- These outbreaks tend to spread outwards from one source to cover a wide area.
- Urban yellow fever is the cause of most y ellow fever outbreaks and epidemics.

TREATMENT

- There is no specific treatment for yellow fever.
- Dehydration and fever can be corrected with oral rehydration salts and paracetamol.
- Any superimposed bacterial infection should be treated with an appropriate antibiotic.
- Intensive supportive care may improve the outcome for seriously ill patients, but is rarely available in poorer, developing countries

Prevention

- Vaccination is the single most important measure for preventing yellow fever.
- In populations where vaccination coverag e is low, vigilant surveillance is critical for prompt recognition and rapid control of o utbreaks.
- Mosquito control measures can be used t o prevent virus transmission until vaccina tion has taken effect.

- In high risk areas where vaccination coverage is low, prompt recognition and control of outbreaks through immunization is critical to prevent epidemics.
- WHO strongly recommends routine yellow fever vaccination for children in areas at risk for the disease.

DENGUE FEVER (BREAKBONE FEVER)

- Is an infectious tropical disease caused by the dengue virus that is spread by mosquitoes.
- Dengue fever virus (DENV) is an RNA virus of the family *Flaviviridae*; genus *Flavivirus*.
- There are four strains of the virus, which are called serotypes, and these are referred to as DENV-1, DENV-2, DENV-3 and DENV-4

Cause

- Dengue fever is caused by one of the f our different but related viruses.
- It is spread by the bite of mosquitoes, most commonly the mosquito *Aedes a egypti*, which is found in tropic and su btropic regions.

Transmission

- Dengue virus is primarily transmitted by *Aedes* mosquitoes, particularly *A. aegypti* .
- These mosquitoes usually live between the latitudes of 35° North and 35° South below an elevation of 1,000 metres.
- Other *Aedes* species that transmit the disease include *A. albopictus*, *A. polynesiensis* and *A. scutellaris*.

- Humans are the primary host of the virus, but it also circulates in nonhuman primat es.
- An infection can be acquired via a single b ite.

- A female mosquito that takes a blood meal from a person infected with dengue fever becomes itself infected with the virus in the cells lining its gut.
- About 8–10 days later, the virus spreads to other tissues including the mosquito's salivary glands and is subsequently released into its saliva.
- The virus seems to have no detrimental effect on the mosquito, which remains infected for life

- Dengue can also be transmitted via infected blood products and through organ donation

Symptoms

- Dengue fever begins with a sudden high fever 4 to 7 days after the infection.
- A flat, red rash may appear over most of the body 2 - 5 days after the fever starts.
- A second rash, which looks like the measles, appears later in the disease.
- Infected people may have increased skin sensitivity and are very uncomfortable.

- Other symptoms include:
- Fatigue
- Headache (especially behind the eyes)
- Joint aches
- Muscle aches
- Nausea
- Swollen lymph nodes
- Vomiting

Signs and tests

- Tests that may be done to diagnose this condition include:
- Antibody titer for dengue virus type s
- Complete blood count (CBC)
- Polymerase chain reaction (PCR) tes t for dengue virus types

Treatment

- There is no specific treatment for deng ue fever.
- You will need fluids if there are signs o f dehydration.

Prevention

- There are no approved vaccines for the dengue virus.
- Prevention thus depends on control of and protection from the bites of the mosquito that transmits it.

FAMILY: SIMULIIDAE (BLACKFLY)

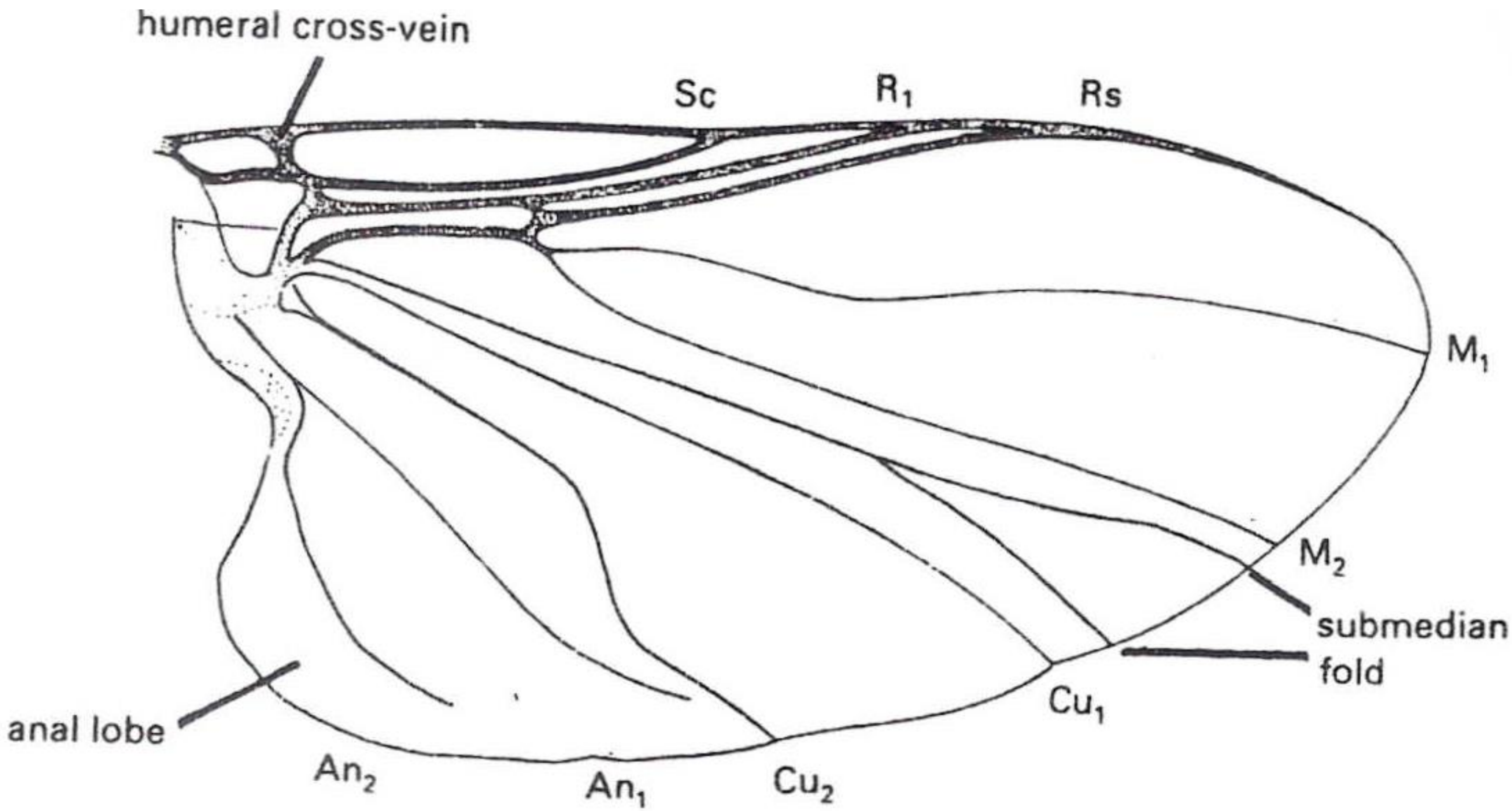
- They are small, dark, stout-bodied, hump-back Nematocera.
- Simuliids are generally 1 – 5mm lon g and are diurnal.
- The females suck blood and have bl ade-like mouth parts

Distribution

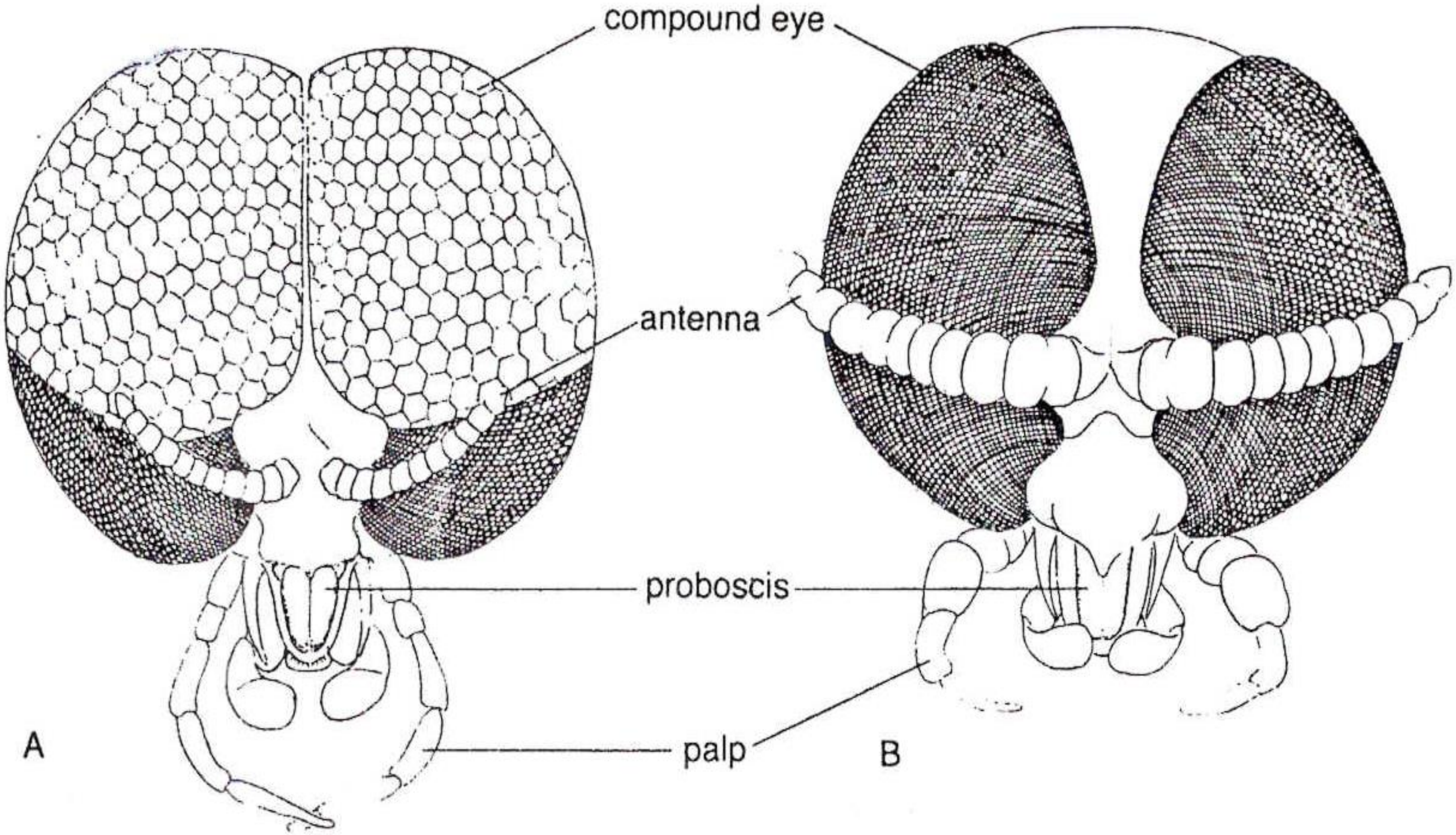
- Black flies are widely distributed.
- They are abundant in the tropics.
- These insects serve as the vectors of Onchocerciasis.

Characteristics of of Simuliidae

- Have a characteristic **humped thorax** due to the strong development of the scutum
- The **anterior veins are thickened** (heavy) and remaining veins are weak.
- The wings are short and broad with a **large anal lobe.**
- The antennae are short and similar in both sexes. The commonest number of antennal segments is 11; occasionally there are 10 (*Austosimulim*).


humeral cross-vein
Sc
R1
Rs
M1
M2
submedian
fold
Cu1
Cu2
An1
An2
anal lobe

- In the female the eyes are well separated above the antennae, i.e. the female is **di choptic**, whiles the male eyes are larger and broadly contiguous above the antenn ae, i.e. the male is **holoptic**.
- The lower ommatidia of male are similar to those of the female but the upper ones are greatly enlarged.
- In males and in a few species in which th e females do not bite, the mandibles and maxillae are not toothed.



compound eye
antenna
proboscis
palp
A
B

- Breed in fast running water.
- Larvae have a complete head an
d are attached to substratum.

Genus *Simulium*

- The largest genus is *Simulium* with nearl y 1200 species arranged in 43 subgenera .
- *Simulium* occurs in all zoogeographical r egion with the greatest number (410) be ing found in the Palaearctic region.
- In *Simulium* and *Austrosimulium* the radi al sector (Rs) on the wing is unbranched.

- *Simulium* is abundant in the tropics
- Man-biting species transmit *Onchocerca v olvulus*.
- They also act as intermediate hosts of ot her filariae and blood-borne protozoa of b irds and mammals.
- The females are vicious biters in the open during the day but do not enter houses.
-

- Biting activity is influenced by weather conditions and older (infected) flies may differ in their behaviour from newly emerged, unfed flies.

Life cycle

- Females lay their triangular eggs in swiftly, running water (and therefore oxygenated) water.
- The eggs are commonly laid in batches of 300 – 500, which are attached to rocks, grass and other objects in or near running water by a gelatinous fluid.
- The gelatinous substance in which the eggs are embedded is formed by adherent outer membranes of the individual eggs, i.e. their exochorions.

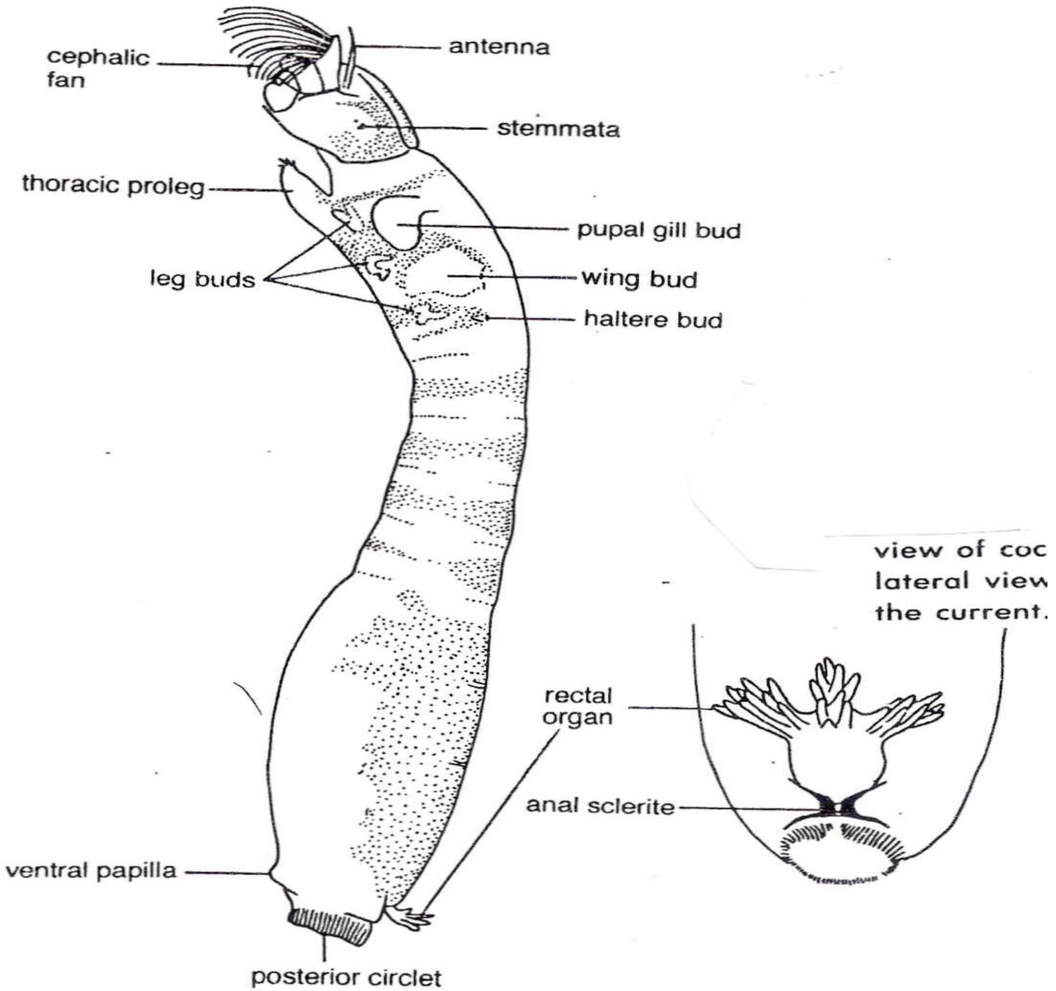
- Some species tolerate sluggish streams and will not require much oxygen.
- *Simulium damnosum* requires much oxygen and therefore breeds in fast flowing sreams.
- *S. damnosum* females oviposit communally in the short period between tropical sunset and darkness.
- The eggs hatch in one or two days

Larva

- The emerging larva spins a web of silk on the substrate, which is continued into a silken thread on which the larva drifts down stream with the current in search of a suitable object on which to settle.
- When this has been found, the larva spins a patch of silk to which it anchors itself by its posterior circlet of hooks.
- Larvae also produce copious amounts of protein glue which is used to attach them to substrate

- The larva can change its location by drifting down stream on silken thread
- Or by looping over the surface using the po terior circlet and the hooks on the anterior roleg to retain a hold on secreted silk.

- The larva has a distinct, sclerotized head with paired, simple eyes (stemmata), and an elongated hour-glass shaped body, in which the thorax and posterior part of the abdomen are broader than the anterior segments of the abdomen.
- The head bears a pair of cephalic (labral) fans, homologous structures to the lateral palatal brushes of the Culicidae.



cephalic fan
antenna
stemmata
thoracic proleg
pupal gill bud
leg buds
wing bud
haltere bud
view of coc
lateral view
the current.
rectal organ
anal sclerite
ventral papilla
posterior circlet

- They do not create a current but filter water passing over the larva.
- Larvae are anchored posteriorly and extend in the direction of the current with the head leading.
- The body is twisted through 90 – 180 ^{o} so that the fans and mouthparts face towards the surface of the water.
- The water current is divided by the proleg and directed towards the fans.

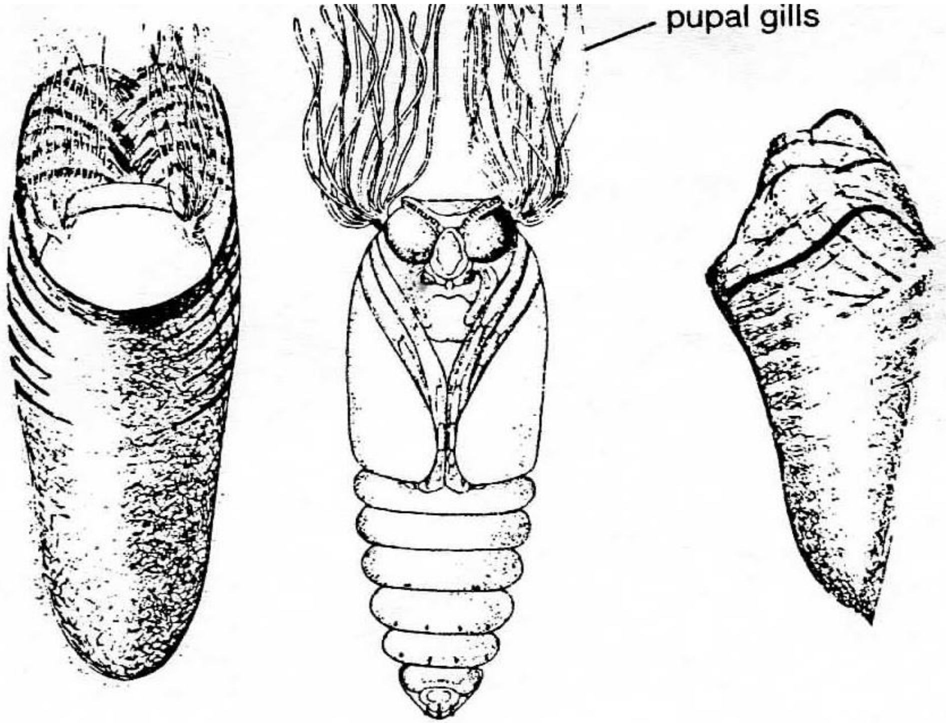
- A sticky secretion produced by the cibarial glands enables the fans to capture fine par icles, which are transferred to the cibarium by the mandibular brushes.
- The larva has a single anterior proleg, surr ounted by a circlet of hooks and the abdom en ends in a posterior circlet.
- The anus opens dorsally of the posterior ci clet, and from it may be extruded the recta organ, which is concerned with chloride ext raction from the water.

- Movement of water over the body surface provides the larva with adequate dissolve d oxygen for respiration.
- Larvae pass through six to nine instars a nd the number is not constant even withi n a species.
- Simuliid larvae reach a length of 4-12 m m.
- The mature larva is actually a pharate pu pa within the larval skin, and may move t o a different site before pupating.

Pupa

- In most species the pharate pupa spins a cocoon, often slipper-shaped with the closed end directed upstream and the open end downstream.
- The head and thorax of the pupa are combined into a single cephalothorax, and there is a segmented abdomen.
- The cephalothorax bears a pair of elongate, branched pupal gills, which trail downstream of the cocoon.

pupa



Pupa and cocoon of *Simulium simile*. From left to right – dorsal view of cocoon containing a pupa; ventral view of pupa, removed from cocoon; lateral view of cocoon. The cocoon is arranged with its closed end directed into the current.

- The pupa, which does not feed, becomes progressively darker as the adult develop s within, but the mature pupa takes on a silvery appearance as a film of air is secr eted between the pharate adult and the p upal cuticle.
- When the pupal exuviae splits, the adult f loats up to the surface in a bubble of air and immediately takes to flight.

- The pupal period is 2–10 days.
- The length of the life cycle varies with the species and environmental conditions.
- The larval stage of *S. damnosum* can be completed in as little as 8 days.
- The life cycle from egg to adult can be completed in less than 2 weeks.

- Adult emergence occurs predominantly in the daytime, depending on light and tem perature.
- In *S. damnosum* 60-90% of the day’s em ergence has occurred by midday and ther e is no emergence at night.
- Mating occurs in close association with th e breeding site, and in a few species occu rs on the ground but in the majority of sp ecies it occurs on the wing when males fo rm small swarms in association with visu al markers.

Feeding

- Simuliids are exophilic, exophagic and largely diurnal.
- As in other blood sucking Nematocera both males and females feed on nectar, which is stored in the crop, and only the females are haematophagous with blood passing directly to the midgut.

- Female simuliids can be classified reproductively as showing obligate autogeny, i.e. females maturing all eggs without a blood meal; primiparous autogeny, i.e. females maturing the first egg batch without a blood meal but needing blood for each subsequent ovarian cycle: and obligate anautogeny when females need blood to mature every egg batch.

Medical Importance

- The most serious human disease associated with simuliids is onchocerciasis or river blindness, due to infection with the filarial worm *Onchocerca volvulus*.
- This disease exists in the Afrotropical and Neotropical regions.
- In Africa *Simulium damnosum* and *S. neavei* are actual or potential vectors of *Onchocerca volvulus* in man.

- These species differ in their ecology and feeding preference which affect their importance as vectors of human onchocerciasis.
- The *S. damnosum* complex contains at least 40 sibling species including forms that are found in the forest zone or in the savannah which are vectors only of the *O. volvulus* strain endemic to their own zones.

- *S. neavei* complex is confined to small streams in hilly forest; its flight range is limited.
- The larvae and pupae are found attached to crabs of the genus *Potamonautes*.
- The chief vector species are *S. ethiopiense* in Ethiopia, *S. neavei* in Zaire and *S. woodi* in Tanzania.

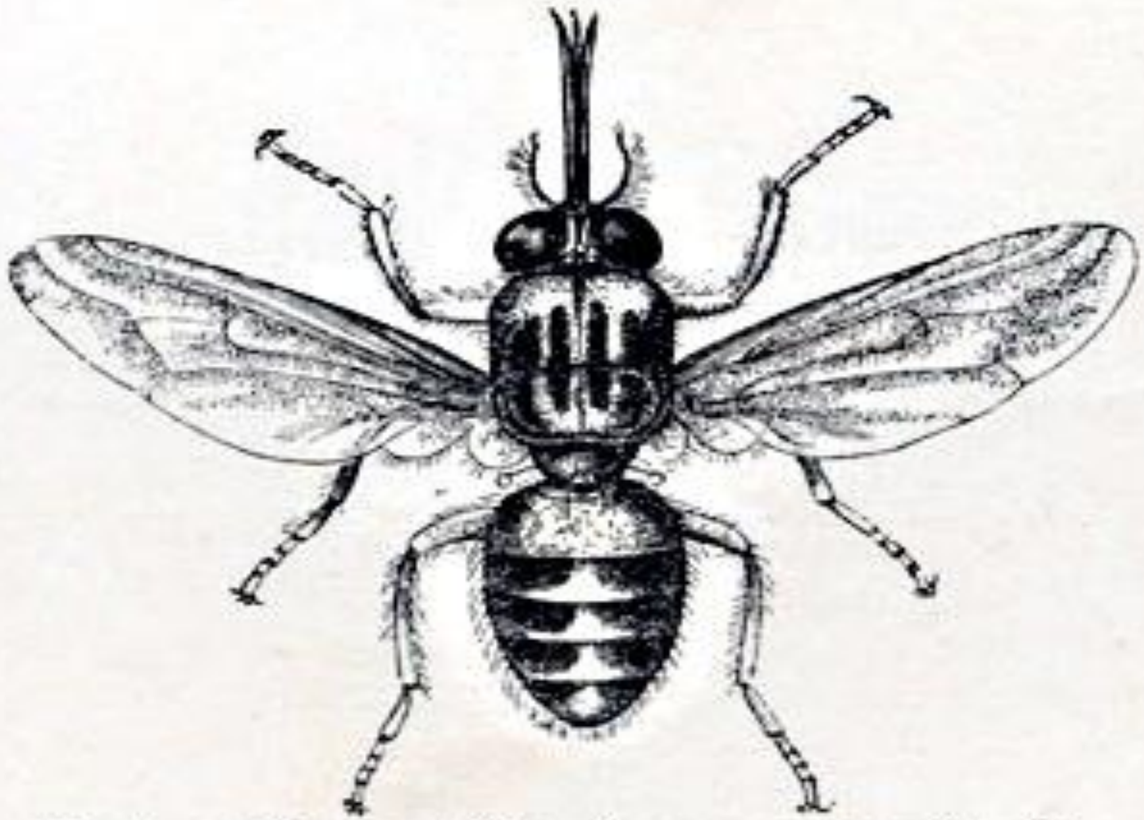
Control of *Simulium*

- Like mosquitoes, the larvae and pupae of *S*
  imulium are aquatic.
- Most of the methods which have been used
  to destroy the larvae and pupae of mosquit
  oes are not applicable to the control of *Sim*
  ulium.
- Further more the fly bites during the day a
  nd not by night as in the case of *Anopheles*
  .

- Methods of preventing people from being b
itten are limited to the wearing of protectiv
e clothing.
- Also applying repellent chemicals on the sk
in to ward off the insects.
- Larval stages of the fly can be killed by rel
easing insecticides (like DDT) into streams
and rivers.
- Other insecticides include organophosphor
us insecticides like temephos, phoxin etc.

FAMILY GLOSSINIDAE (Tsetse flies)

- Tsetse flies are large, brown to greyish flie
  s, 6-15mm long.
- They are robust, sparsely bristled and usua
  lly larger than a housefly.
- The mouthparts consist of a horny labrum,
  a slender hypopharynx (through which ant
  coagulant saliva is injected into the bite wo
  und) and a stout ventral labium.
- The unique viviparous genus *Glossina* cont
  ains some 30 species and sub species.



Tsetsefliege (Glossina morsitans). 3/1.
(Art. *Tsetsefliege.*)

- Proboscis is stout and projects well in front of the head.
- These three parts enclose a food canal through which blood is sucked by muscular action.
- There are some 10 species concerned with the transmission of African Trypanosomiasis.
- Of these species 4 are important: *G. palpalis, G. morsitans, G. tachinoides and G. Swynnertonis.*

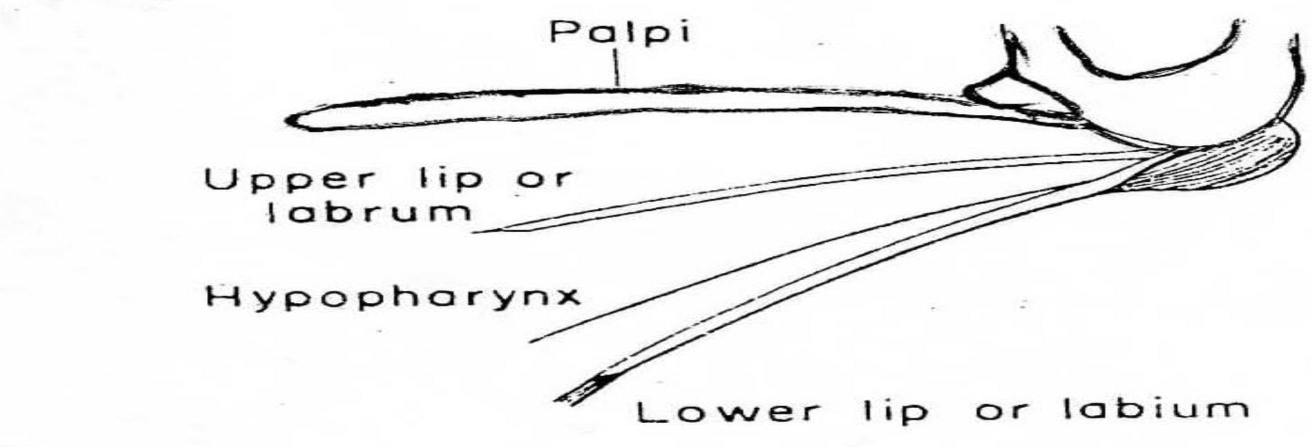
Distribution

- They are confined to tropical Africa between latitudes 15^0 N and 30^0 S.
- They are mainly found in vegetation by rivers and lakes, in gallery-forests and in vast stretches of wooded savannah.
- They occupy roughly half of the surface of the continent of Africa.

Characteristics

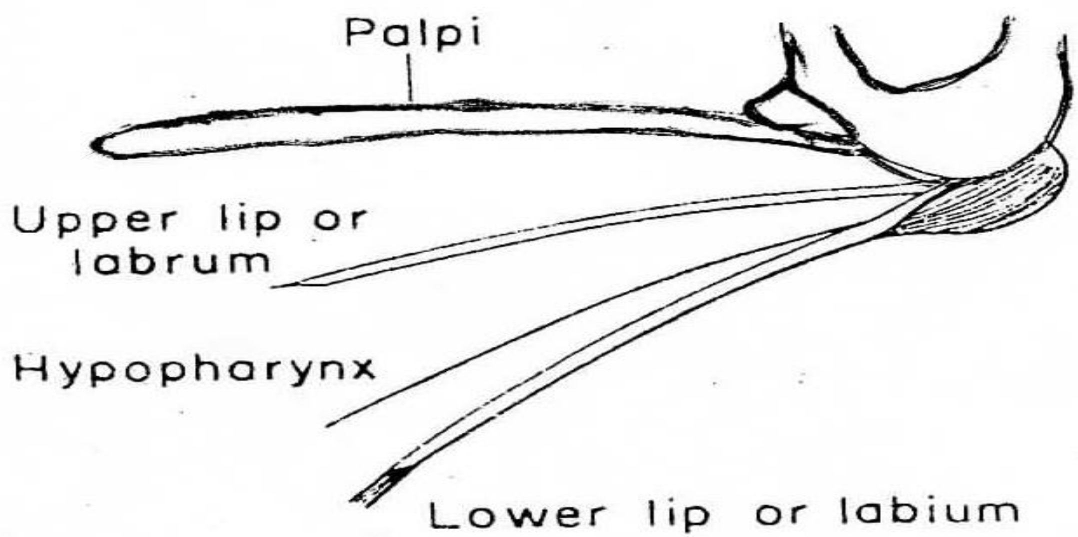
- Features which distinguish *Glossina* specie s from other biting flies such as *Tabanus, Chrysops*, *Stomoxys*, etc., are:

1. *Glossina* possess a long straight proboscis with a basal bulb.



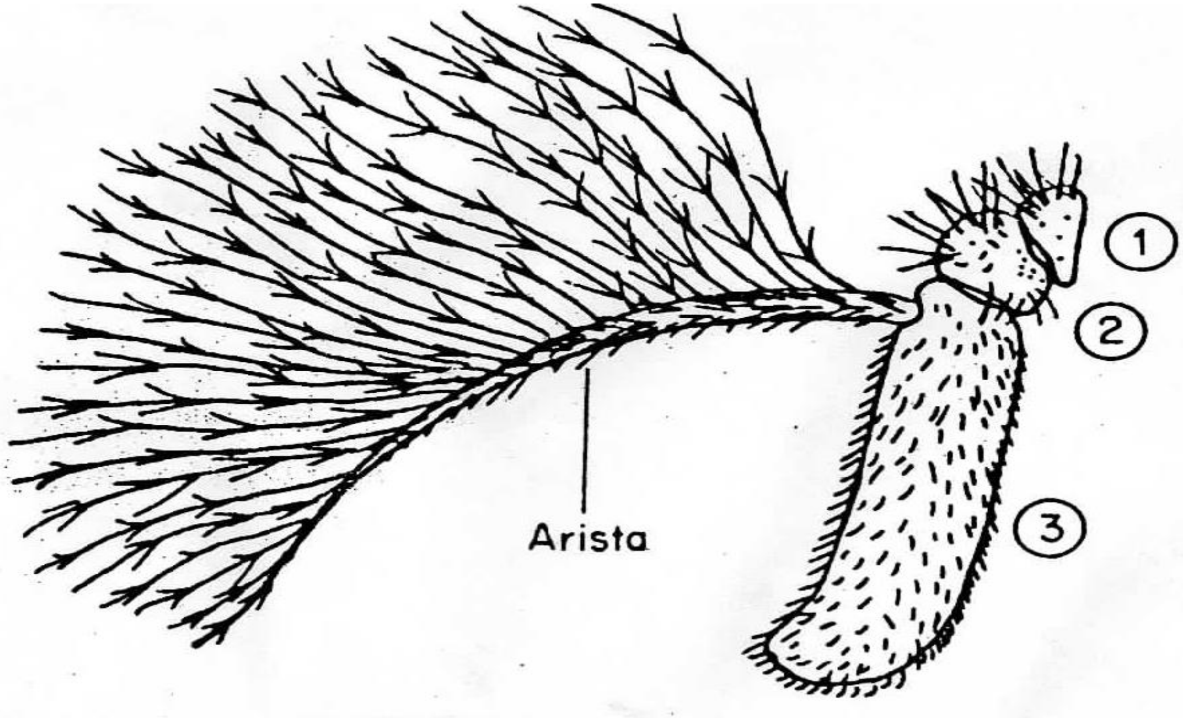
Mouthparts of *Glossina*.

2. The labial palps are as long as the proboscis in *Glossina*.



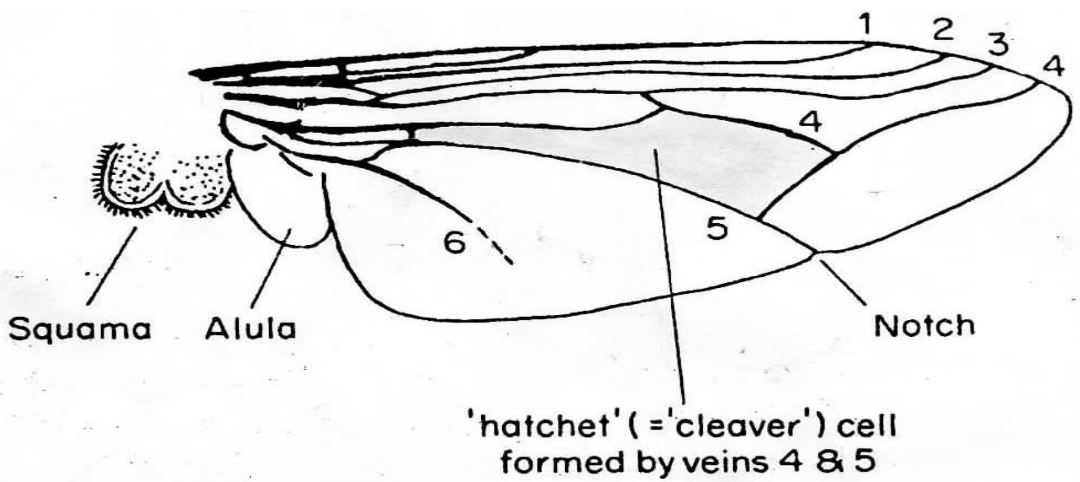
Mouthparts of *Glossina*.

3. The presence of branched hairs on the arista

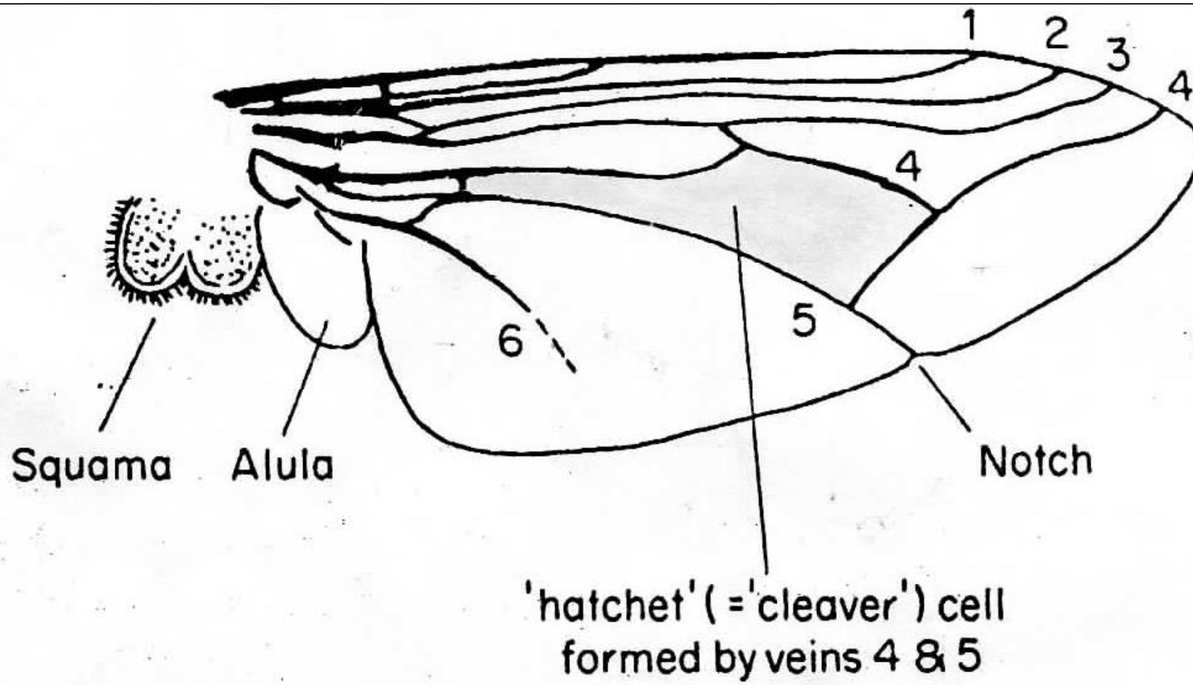


Antenna of Glossina showing the dorsal arista with branched hairs, which arises from the third antennal segment. In other flies the hairs of the arista are unbranched.

4. The presence of the ‘hatchet’ or ‘cleaver’ cell, enclosed between the fourth and fifth longitudinal wing veins is diagnostic of *Glossina*.



Wing of *Glossina* showing venation and the ‘hatchet’ (= ‘cleaver’) cell enclosed between veins 4 and 5. The shape of the ‘hatchet’ cell is unique to *Glossina*; in all other flies the corresponding cell is triangular. *Glossina* is also unusual among higher flies in that the wings are held scissor-



Wing of *Glossina* showing venation and the 'hatchet' (= 'cleaver') cell enclosed between veins 4 and 5. The shape of the 'hatchet' cell is unique to *Glossina*; in all other flies the corresponding cell is triangular. *Glossina* is also unusual among higher flies in that the wings are held scissor-like over the back at rest.

5. The wings are folded, scissors-like over the back of the resting fly.

- Male and female tsetse flies feed exclusivel y on the blood of vertebrates.
- The genus *Glossina* is usually divided into t hree species groups.
  1. The fusca group e.g *G. longipennis*
  2. Palpalis group e.g *G. palpalis*, *G. fucipes*
  3. Morsitans group e.g *G. morsitans*.
- This separation is based on a combination of ecological requirements, distributional, b ehavioral, molecular and morphological cha racteristics of the species.

- *G. longipennis* and *G. brevipalpis* are members of the fusca group.
- Flies of the group include important vectors of trypanosomes pathogenic to livestock, especially species of the *Trypanosoma vivax* group and *T. congolense* group.
- They have never been associated with transmission of trypanosomiasis to man

- The flies of the Fusca group are associated with dense, humid, tropical forests or forest edges.
- The Palpalis group is found mostly in West Africa and the Congo basin.
- The Palpalis group are basically dependent on dense riverine or lacustrine vegetation.
- However their distribution extends into the savannah zone; crocodiles and other reptiles are important hosts

- The Morsitan group (Eastern & Central Africa) are the least hygrophylic and occupy vast areas of bush land and thicket vegetation, often far from rivers and lakes – that is open forest land where mammalian game is plentiful.

Palpalis and Morsitan groups

- Species of these groups are active only during daylight hours.
- Tsetse flies hunt their prey partly by sight; scent however becomes important at close range.
- When not actively seeking food, flies normally rest on woody part of vegetations.

Life Cycle

- Tsetse flies have viviparous reproduction.
- A single larva is produced at a time and is retained and nourished within the body of the female fly.
- The female rears one larva at a time to the third instar larva.
- After moulting twice within the female it is deposited in a carefully selected spot so that it may pupate – this takes place once every 10-12 days during the breeding period of the fly.

- Female flies are normally fertilized only o nce shortly after emergence.
- The female has enough sperms from this single mating throughout life.
- During favourable conditions a female pr oduces 20 larvae at intervals of about 11 days.

- Each successive fertilized egg passes from the oviduct into the uterus.
- In the oviduct it hatches into a small white larva.
- The young larva obtains nutrients from the secretion of the uterine glands of the mother.
- The larva grows and moults twice during the intra-uterine development.

- The mature larva, now in the third instar is extruded by the mother while she is pe rched on the ground or on vegetation.
- The newly deposited larva then burrows i nto the soil to a depth of a few millimetre s, using peristaltic movements.
- Having reached a point below the surface where conditions are suitable, it becomes immobile and begins to pupariate (pupat e) still within the third larval skin.

- The skin darkens and hardens.
- During emergence from the puparium, it uses a structure known as ptilinum.
- This is an eversible bladder extruded from the front of the head during the first few days of adult life; this bladder can still be everted while the body is still soft and soapy in texture.
- Flies in this stage, so far are referred to as teneral flies.

- Older flies are non-teneral flies – in which the head and the body are hardened and ptilinum can no longer be everted.
- After the quiescent period, the young ten eral flies seek for their first blood meal.
- Flies normally feed at intervals of three t o four days.
- They die of starvation if deprived of blood meal for 10-12 days.

- The average life span of female *Glossina* is 2-3 months: exceptionally for 6-7 months.
- Male flies have a much shorter life span.

Control of Tsetse flies

- Horizontally or inclined branches, 2-5 cm thick and 1-3 mm from the ground are fa voured resting sites during the day (for most species).
- Resting flies are most numerous where s uch perches provide good field of view e. g. along the edge of the thickets or margi ns of leaves and streams.

AFRICAN TRYPANOSOMIASIS

- Trypanosomiasis are diseases of humans an
  d livestock.
- Sleeping sickness occurs only in 36 sub-Sah
  aran Africa countries where there are tsetse
  flies that transmit the disease.
- Rural populations living in regions where tra
  nsmission occurs and which depend on agri
  culture, fishing, animal husbandry or huntin
  g are the most exposed to the tsetse fly an
  d therefore to the disease

- They are mainly found in vegetation by rivers and lakes, in gallery-forests and in vast stretches of wooded savannah.

Cause

- They are caused by parasitic flagellate Protozoa of the order Kinetoplastida (Phylum Sarcomastigophora).
- The parasites concerned are protozoa belonging to the Genus *Trypanosoma*.
- The disease is a vector-borne parasitic disease spread by the bite of an infected tsetse fly (Genus *Glossina*)

- Tsetse fly (*Glossina* Genus) are biological vectors of trypanosomes meaning that tsetse, in the process of feeding, acquire and then transmit small, single-celled organisms called trypanosomes from infected vertebrate hosts to uninfected animals.
- In humans, tsetse transmitted Trypanosomiasis is called sleeping sickness.

- In animals, tsetse vectored trypanosomiasis include nagana, souma, and surra according to the animal infected and the trypanosome species involved

Human Trypanosomiasis

- Human African Trypanosomiasis is caused by trypanosomes of the *Trypanosoma brucei* species.
- This disease is invariably fatal unless treated but can almost always be cured with current medicines, if the disease is diagnosed early enough.

Trypanosomiasis

- Trypanosomiasis is transmitted to humans by tsetse fly (*Glossina* Genus) bites which have acquired their infection from human beings or from animals harbouring the human pathogenic parasites.

- The *Trypanosoma brucei* species, which causes the disease, has often been subdivided into three sub-genera which were identified based either on the vertebrate hosts which the strain could infect or on the virulence of the disease in humans.
- The trypanosome infectious to animals and not to humans was named *Trypanosoma brucei brucei.*

- The strains which infect humans were divided into two sub-species based on their different virulences:

  1. *Trypanosoma brucei gambiense* has a slower onset.
  2. *Trypanosoma brucei rhodesiense* refers to strains with a more rapid, virulent onset.

Trypanosoma brucei gambiense

- *Trypanosoma brucei gambiense (T.b.g.)* is found in 24 countries in West and Central Africa.

- This form represents more than 98% of reported cases of sleeping sickness and causes a chronic infection.

- A person can be infected for months or even years without major signs or symptoms of the disease.
- When symptoms emerge, the patient is often already in an advanced disease stage where the central nervous system is affected.

- *Trypanosoma brucei rhodesiense (T.b.r.)* is found in 13 countries found in Eastern and Southern Africa.
- This form represents less than 10% of reported cases and causes an acute infection.
- First signs and symptoms are observed after a few months or weeks after infection.
- The disease develops rapidly and invades the central nervous system.

- Another form of trypanosomiasis occurs mainly in 21 Latin American countries.
- The causal organism is a different species from those causing the African form of th e disease and are not transmitted by tset se fly.
- The most notable is American Trypanoso miasis known as Chagas disease which oc curs in South America.

American Trypanosomiasis (Chagas)

- Chagas is caused by *Trypanosoma cruzi*.
- Transmitted by certain species of Reduviidae, members of the Hemiptera.

Animal Trypanosomiasis

- Other parasite species and sub-species of the *Trypanosoma genus* are pathogenic to animals and cause animal trypanosomiasis in wild and domestic animal species.
- When it occurs in bovine cattle or horses is called **nagana**
- It is known as **sura** when it occurs in domestic pigs.

- These diseases reduce the growth rate, milk productivity, and strength of farm animals, generally leading to enventual death of the infected animals.

- Certain species of cattle are called **trypanotolerant** because they can survive and grow even when infected with trypanosomes although they also have lower productivity rates when infected.
- *Trypanosoma congolense* and *Trypanosoma vivax* are the two most important species infecting bovine cattle in sub-saharan Africa. *Trypanosoma simiae* causes a virulent disease in swine.

- Animals can host the human pathogen parasites, especially *T.b. rhodesiense*. *T. brucei* multiplies in the blood of a range of animals including domestic animals and wild game as well humans.
- Domestic and wild animals are an important parasite reservoir.
- Examples of domestic animals that serve as reservoir are cattle, sheep, dogs, pigs, and goats and wild game – bushbuck (*Tragelaphus scriptus)*.

Genus Trypanosoma

- The genus *Trypanosoma* is divided into two types.
  1. Salivaria
  2. Stercoraria
- They differ in their modes of transmission.
- Salivarian trypanosomes either undergo cyclic development in the insect before being transmitted with saliva, or are transmitted mechanically.

- Stercorarian trypanosomes also undergo development in the insect but, with the e xception of *T. rangelin* the infective forms are deposited in the faeces of the vector.
- Species of salivarian trypanosomes that a re pathologic to man are *Trypanosoma br ucei gambiense* and *T. b. rhodesiense* (in Africa).
- The main Stercorarian Trypanosome is *T. cruzi* in (America)
-

Mode of transmission

- Humans are reservoir for *T.b. gambiense*, whereas *T.b. rhodesiense* has reservoirs i n both humans and domestic animals-(es pecially cattle), wild animals e.g antelope s
- Riverine species of *Glossina palpalis*, *G. t achinoides* and *G. fascipes* transmit *T.b. gambiense;* whereas woodland species of *G. morsitans*, *G. pallidipes* and *G. swynn ertorni* transmit *T.b. rhodesience*

- The tsetse fly does not become infective until 20-40 days after sucking infected blood meal.
- Both male and female tsetse flies take blood meals and can transmit the disease.
- The fly is infectious throughout its 2-3 months lifetime.
- Tsetse transmit trypanosomes in two ways, **mechanical** and **biological** transmission.

Mechanical Transmission

- Mechanical transmission involves the direct transmission of the same individual trypanosomes taken from an infected host into an uninfected host.

- Mechanical transmission requires that tsetse feed on an infected host and acquire trypanosomes in the blood meal, and then, within a relatively short period, for tsetse to feed on an uninfected host and regurgitate some of the infected blood from the first blood meal into the tissue of the uninfected animal.

- This type of transmission occurs most freq uently when tsetse are interrupted during a bloodmeal and attempt to satiate thems elves with another meal.
- Other flies, such as horse-flies(family Taba nidae) carry infective Trypanosomes on th e proboscis where the organisms are capa ble of remaining alive for up to 24hrs.
- This can be transmitted to man during fee ding.

Biological Transmission

- Biological transmission requires a period of incubation of the trypanosomes within the tsetse host.
- The term **biological** is used because tryp anosomes must reproduce through sever al generations inside the tsetse host duri ng the period of incubation, which requir es extreme adaptation of the trypanosom es to their tsetse host.

- In this mode of transmission, trypanosomes reproduce through several generations, changing in morphology at certain periods.
- This mode of transmission also includes the sexual phase of the trypanosomes.
- Tsetse are believed to be more likely to become infected by trypanosomes during their first few bloodmeals.

- Tsetse infected by trypanosomes are thought to remain infected for the remainder of their lives.
- Because of the adaptations required for biological transmission, trypanosomes transmitted biologically by tsetse cannot be transmitted in this manner by other insects.

Cycle of Biological Transmission

- The cycle of biological transmission of try panosomiasis involves two phases
    1. One inside the tsetse host and the
    2. Other inside the vertebrate host.
- Trypanosomes are not passed between a pregnant tsetse and her offspring so all n ewly emerged tsetse adults are free of inf ection.
- An uninfected fly that feeds on an infecte d vertebrate animal may acquire trypano somes in its proboscis or gut.

- These trypanosomes, depending on the species, may remain in place, move to a different part of the digestive tract, or migrate through the tsetse body into the salivary glands.
- When an infected tsetse bites a susceptible host, the fly may regurgitate part of a previous blood meal that contains trypanosomes, or may inject trypanosomes in its saliva.

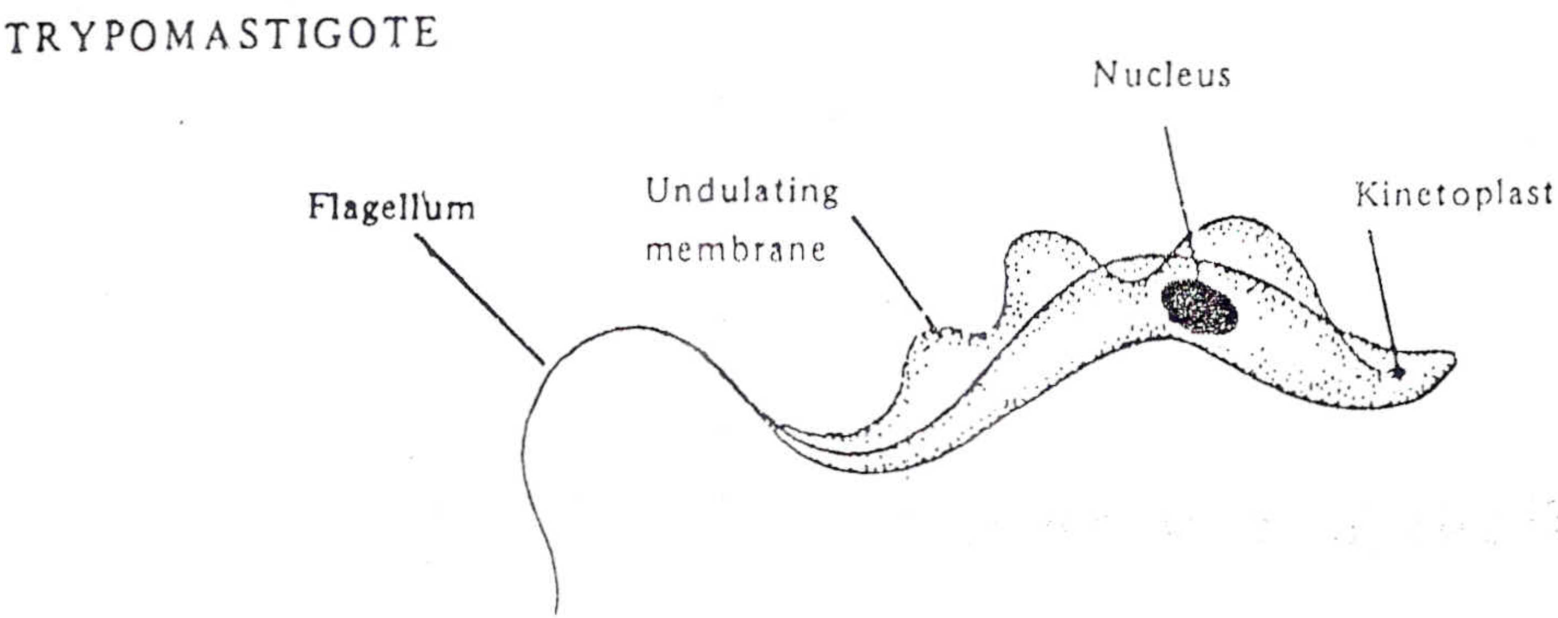
- It is believed the inoculation must contain a minimum of 300 to 450 individual trypanosomes to be successful, and may contain up to 40,000 individuals.
- The trypanosomes are injected into vertebrate muscle tissue but make their way, first into the lymphatic system, then into the bloodstream, and eventually into the brain.

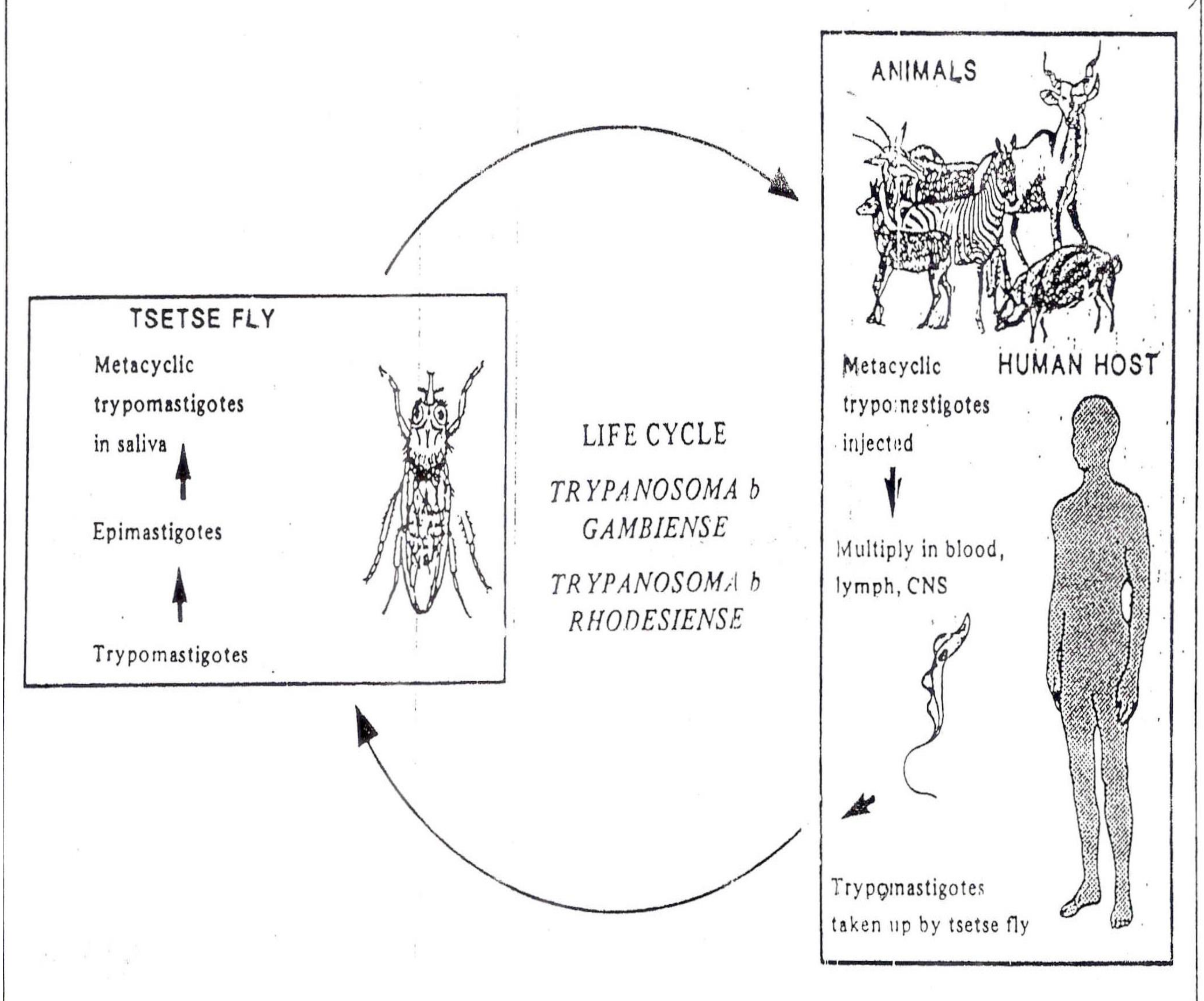
- The disease causes the swelling of the ly mph glands, emaciation of the body, and eventually leads to death.
- Uninfected tsetse may bite the infected a nimal prior to its death and acquire the di sease, thereby closing the transmission c ycle.
- These diseases are caused by several diff erent trypanosome species

Life cycle of *T.b gambiense* and *T.b rhodesiense*

- The 3 week life-cycle in the tsetse fly begins with the ingestion of Trypomastigote in the blood meal from the reservoir host.
- They multiply in the insect's gut and form the procyclic stage and then migrate to the salivary glands.
- Here they are transformed into epimastigote.

TRYPOMASTIGOTE




TSETSE FLY
Metacyclic trypomastigotes in saliva
Epimastigotes
Trypomastigotes
LIFE CYCLE
TRYPANOSOMA b GAMBIENSE
TRYPANOSOMA b RHODESIENSE
ANIMALS
HUMAN HOST
Metacyclic trypomastigotes injected
Multiply in blood, lymph, CNS
Trypomastigotes taken up by tsetse fly

- They multiply further and form metacyclic Trypomastigotes, which are transmitted by the tsetse fly bite.
- The metacyclic Trypomastigote in the saliva is injected into vertebrate muscle tissue when the fly feeds.
- They make their way, first into the lymphatic system, then into the bloodstream, and eventually into the brain.

- A firm tender red nodule is formed at the site of inoculation, within a few days
- At the site of inoculation in man, Trypomastigote undergoes longitudinal division.
- They then enter the blood stream, differentiate into the blood stream forms and multiply to form Trypomastigote to complete the cycle.

Polymorphism in trypanosomes

- Development of *T. b gambiense* and *T.b. rhodesiense* is characterized by the occur rence of 3 main types of blood form:
  1. slender forms-long, thin and have free flagellum
  2. stumpy blood stream form-thick and short with no flagellum; a short one may be present

3. intermediate forms: long , with moderately thick body and free flagellum of medium length

- Distinction between stumpy and intermed iate forms may not be clear

ClinicalSymptons

- Symptoms of East and West African trypa nosomiasis are similar.
- Both forms of the disease begin with rela tively minor signs, but they become incre asingly severe if the infection persists an d progresses throughout the body.
- The first sign of the disease is a painful s ore from a tsetse fly bite that becomes re d and otherwise visibly infected after 1-2 weeks.

Symptoms

- Fever, severe headache, rash.
- Irriitability, swelling around the the eye and hands, extreme fatigue.
- Swollen lymph nodes (especially at the back of the neck), aching muscles and joints.
- Mood changes
- Weight loss occurs as the illness progress.

- If left untreated, the parasite infects CNS tissues.
- Indeed, personality changes, confusion, slurred speech, inability to concentrate, difficulty walking and talking, and seizures may occur in late stages of infection.
- Patients with advanced African trypanosomiasis often sleep during the day, while suffering insomnia at night.

Treatment

- The type of treatment depends on the stage of the dis ease.
- The drugs used in the first stage of the disease are of lower toxicity and easier to administer

1. **Pentamidine:** used for the treatment of the first stage of *T.b. gambiense* sleeping sickness.

- This should be done during the early stages of the dis ease before the parasite has penetrated into the centra l nervous system – has poor penetration of the CNS

2. **Suramin:** used for the treatment of the first stage of *T.b. rhodesiense*.

- It provokes certain undesirable effects, in the urinary tract and allergic reactions. These include nausea, vomiting, fever, anaemia, jaundice, nephrotoxicity etc

3. **Melarsoprol:** used to treat the late stage of the disease when the CNS is involved.

4. **Eflornithine:** less toxic than melarsoprol, It is only effective against *T.b. gambiense*. The regimen is strict and difficult to apply.

Vector control

- Current vector control interventions involve the use of insecticides massive aerial and ground based campaigns with organochlorine insecticides such as DDT applied as aerosol sprays at Ultra-Low Volume rates.

1. Sequential aerosol spraying technique (SAT) involve aerial application of low dosage, non-residual aerosols from fixed-wing air craft.

2. Ground spraying.
3. Insecticide-treated targets or insecticide-treated animals – live baits.
4. Tsetse trap

These often use electric blue cloth, since this color attracts the flies. The traps can kill by channeling the flies into a collection chamber or by exposing the flies to insecticide sprayed on the cloth.

- The use other-baited traps or scree
ns,

Releases of Irradiated Males (Sterile Insect Technique)

- This technique involves the rearing of large numbers of tsetse, separation of the males.
- Irradiation of these flies (males) with large doses of gamma rays to make them sterile and then release into the wild.
- Since females only mate a few times in their life, generally only once, any mating with a sterile male prevents that female from giving birth to any offspring.

FILARIASIS

- **Filariasis** is a parasitic and infectious tropical disease, that is caused by thread-like filarial nematode worms.
- There are 9 known filarial nematodes which use humans as the definitive host.
- These are divided into 3 groups according to the niche within the body that they occupy:
  1. Lymphatic Filariasis
  2. Subcutaneous Filariasis, and
  3. Serous Cavity Filariasis.

Lymphatic Filariasis

- Is caused by the worms *Wuchereria bancrofti*, *Brugia malayi*, and *Brugia timori*.
- These worms occupy the lymphatic system, including the lymph nodes, and in chronic cases these worms lead to the disease Elephantiasis.

Subcutaneous Filariasis

- Is caused by *Loa loa* (the African eye worm), *Mansonella streptocerca*, *Onchocerca volvulus*, and *Dracunculus medinensis* (the guinea worm).
- These worms occupy the subcutaneous layer of our skin and our fat layer.

Serous Cavity Filariasis

- Serous Cavity Filariasis is caused by the worms *Mansonella perstans* and *Mansonel la ozzardi*, which occupy the serous cavity of the abdomen.

- In all cases, the transmitting vectors are either blood sucking insects (fly or mosqu ito) or Copepod crustaceans in the case of *Dracunculus medinensis*.

Human Filarial Nematode worms

- Human filarial nematode worms have a complicated life cycle, which primarily consists of five stages.
- After the male and female worm mate, the female gives birth to thousands of live microfilariae.
- The microfilariae are taken up by the vector insect (intermediate host) during a blood meal.

- In the intermediate host, the microfilariae molt and develop into 3rd stage (infective) larvae in one to two weeks.
- Upon taking another blood meal the vector insect injects the infectious larvae into the dermis layer of our skin.
- After approximately one year the larvae molt through 2 more stages, maturing into to the adult worm.

ONCHOCERCIASIS (RIVER BLINDNESS)

- Onchocerciasis is a parasitic disease caused by the filarial worm *Onchocerca volvulus*.
- It is transmitted through the bites of infected blackflies of *Simulium* species, which carry immature larval forms of the parasite from human to human.
- In the human body, the larvae form nodules in the subcutaneous tissue, where they mature to adult worms

- After mating, the female adult worm can release 1000-3000 microfilariae a day. These move through the body, and when they die they cause a variety of conditions, including blindness, skin rashes, lesions, intense itching and skin depigmentation.

- Onchocerciasis is often called “river blindness” because the blackfly, *Simulium damnosum*, which transmits the disease, abounds in fertile riverside areas that frequently remain uninhabited for fear of infection.
- *O. volvulus* is almost exclusively a parasite of man.
- Onchocerciasis is the world's second leading infectious cause of blindness.

Distribution

- Onchocerciasis tends to be localized in distribution within its endemic areas.
- It occurs in 35 countries worldwide**:**
- 28 in tropical Africa, where 99% of infected people live.
- Isolated foci in Latin America (6 countries) and
- Yemen.

Causes

- Onchocerciasis is caused by nematodes (roundworms) that inhabit subcutaneous t issues.
- Onchocerciasis is transmitted by the bite of black flies of the genus *Simulium*.
- Females require a blood meal for ovulatio n, and they can transmit infective-stage l arvae as well as receive microfilariae duri ng the blood meal.

- During the blood meal, the black fly can transmit infective-stage larvae to the host.
- Fly saliva acts as a chemoattractant for microfilariae in the surrounding subcutaneous tissues.
- Large quantities of microfilariae may be ingested during the blood meal.

- Microfilariae then migrate to the fly's flight muscles, where they emerge as infective-stage larvae after 6-18 days and travel to the proboscisis

Causative agent

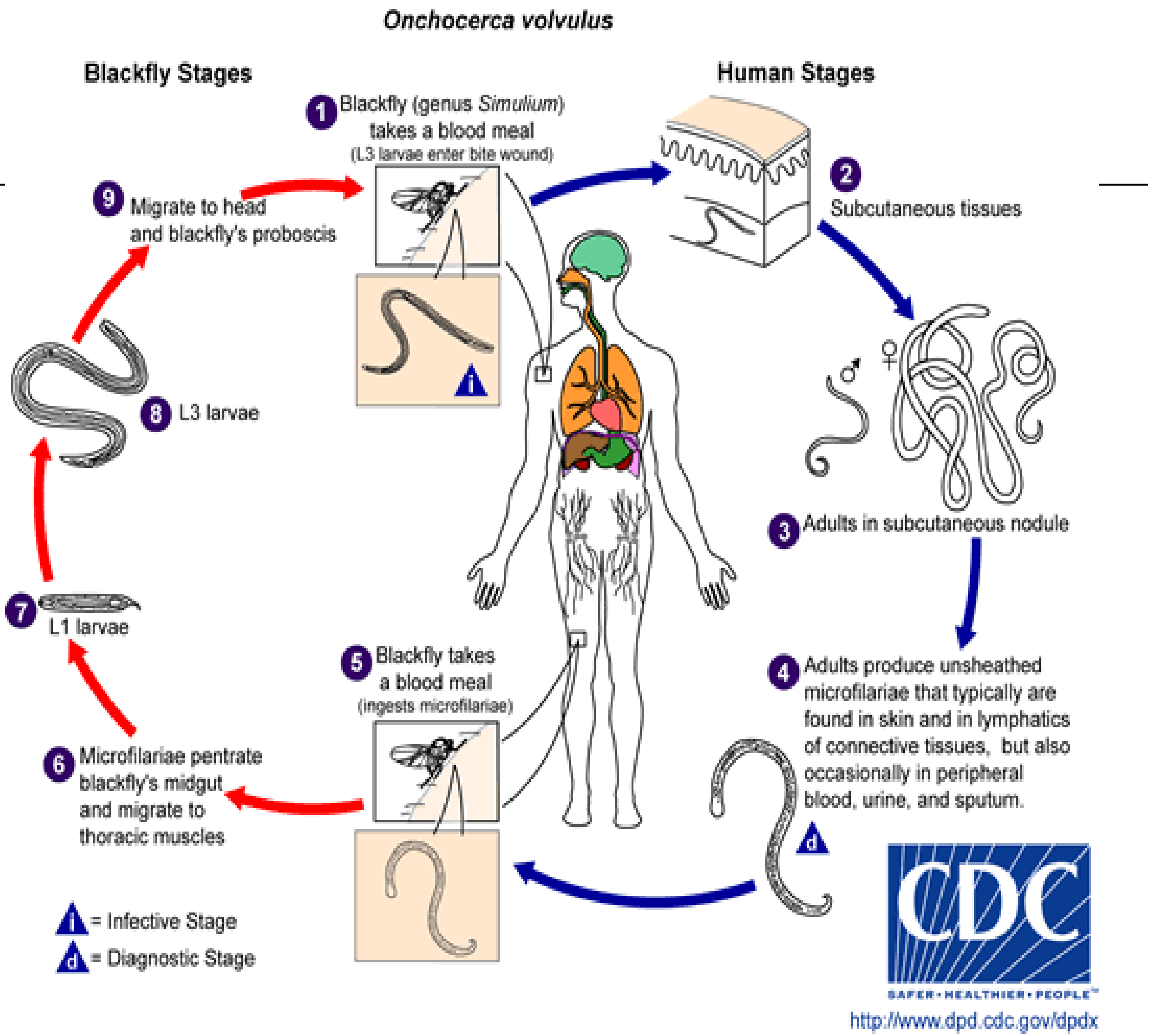
- Onchocerciasis is caused by a parasitic worm, *Onchocerca volvulus*, of the family filariidae that inhabit subcutaneous tissues.
- *Onchocerca volvulus,* a nematode can inhabit subcutaneous tissues in the human body for up to 14 years.

Onchocerca volvulus (adult worms)

- *Onchocerca volvolus* is a helminthic worm
- male: 2-3 cm long
- female: 60 cm long
- Adults occur in the subcutaneous tissues and in nodules
- microfilariae: 300 x 8 micrometer, 1000-3000 produced per day per adult female worm
- Adult worms have a longevity of 10-15 years

Life Cycle of *Onchocerca volvulus*

- *O volvulus* has a 5-stage life cycle, and humans are the only definitive hosts and *Simulium* black flies are obligate intermediate hosts.
- During a blood meal, an infected blackfly (genus *Simulium*) introduces third-stage filarial larvae (L3) into the skin of the human host, where they penetrate into the bite wound.


Onchocerca volvulus
Blackfly Stages
Human Stages
1 Blackfly (genus Simulium) takes a blood meal
(L3 larvae enter bite wound)
2 Subcutaneous tissues
3 Adults in subcutaneous nodule
4 Adults produce unsheathed microfilariae that typically are found in skin and in lymphatics of connective tissues, but also occasionally in peripheral blood, urine, and sputum.
5 Blackfly takes a blood meal
(ingests microfilariae)
6 Microfilariae pentrate blackfly's midgut and migrate to thoracic muscles
7 L1 larvae
8 L3 larvae
9 Migrate to head and blackfly's proboscis
i = Infective Stage
d = Diagnostic Stage
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- The larvae migrate to the subcutaneous ti ssue and undergo two more molts into ad ult filariae.
- They form nodules as they mature into ad ult worms over six to twelve months.
- Adults can live in the nodules for approxi mately 15 years.
- Some nodules may contain numerous ma le and female worms.

Nodules caused by the adult worms

Onchocerca volvulus: nodules (removed from under the skin of infected people) contain the adult worms.

- After maturing, adult male worms mate with female worms in the subcutaneous tissue to produce between 700 and 1,500 microfilaria per day.
- In the subcutaneous nodules known as onchocercomata, the female worms are capable of producing microfilariae after 6-12 months for approximately 9 years.

- The microfilariae, measuring 220 to 360 µm by 5 to 9 µm and unsheathed, have a life span that may reach 2 years.
- They are occasionally found in peripheral blood, urine, and sputum but are typicall y found in the skin and in the lymphatics of connective tissue

- The microfilaria migrate to the skin during the day, and the black flies only feed in the day, so the parasite is in a prime position for the female fly to ingest it.
- A blackfly ingests the microfilariae during a blood meal.

- After ingestion, the microfilariae migrate from the blackfly's midgut through the h emocoel to thoracic flight muscles of the black fly.
- There the microfilariae develop into first-stage larvae (L1), into the second larval stage (L2.) and subsequently into the thi rd-stage infective larvae (L3) .

- The third-stage infective larvae (L3) migrate to the blackfly's proboscis and into the saliva and can infect another human when the fly takes a blood meal.
- The black fly takes another blood meal, passing the larvae into the next human host's blood.
- Maturation in the black fly takes about 7 days.

Symptoms

- Adult worms lodge in nodules under the skin, releasing large numbers of microfilariae into surrounding tissues.
- Immature worms move through the body and after dying, cause a variety of conditions including:

1. Serious visual impairment and blindness caused by destruction of cornea.

Eye infections by the microfilaria larvae

2. Skin rashes,

3. Lesions,

4. Intense itching and depigmentation of the skin.

This woman has leopard skin and onchocercal skin lesions on both legs.

5. Lymphadenitis (resulting in hanging groins and elephantiasis of the genitals).
6. General debilitation.

Prevention and control

- In a number of countries, onchocerciasis has been controlled through spraying of b lackfly breeding sites with insecticides.

1. Use of larvicide: Temephos (abate) as larvicide is effective but resistance develops
2. Biological manipulation: Use of biocide like Bacillus thuringensis to kill the insect vector.

3. Physical manipulation: Involves the wearing of protective clothing to prevent vector-human contact.

Chemotherapy/ Drug treatment

- Treatment may involve the use of the drug ivermectin.
- For best effect, entire communities are treated at the same time.
- A single dose may kill first-stage larvae (microfilariae) in infected people, and it prevents transmission for many months in the remaining population.

- Other drugs are also available, including the tetracycline-class antibiotic doxycycline, which kills the *Wolbachia* and renders the female nematodes sterile.
- Both albendazole and Diethylcarbamazine (DEC) have been shown to be effective in killing the adult-stage filarial parasites (necessary for complete cure of infection), but ideal treatment regimens still need to be defined.

- Suramin kills adults worms but has l ittle effect on microfilaria

Onchocerciasis Control Programme (OCP)

- The OCP, is a joint effort of the UN Food and Agriculture Organization, UNDP,WHO and World Bank.
- The control programme is aimed at:

1. Preventing infected and uninfected people in endemic areas from going blind.
2. Freeing endemic areas of the blackfly to make available fertile riverine lands for agricultural purposes.

3. Resettlement of the indigenous people and rehabilitation of healthy blind people.
4. Treatment of infected people.
5. Training of health personnel such as epidemiologist, vector biologist, hydrobiologist, and ophthalmologist in the participating countries to take over when the WHO mandate has expired.

OCP Programme in West Africa

- Launched in 1974 in an area encompassi ng originally 7 countries in West Africa.
- In 1986, the programme was extended to include a further 4 countries,
- A total operational area of 1.23 million sq . km,
- A combined human population of 30 milli on.

- OCP's principal method for controlling onchocerciasis involved interrupting transmission by eliminating the blackfly vector.
- Simulium larvae are killed through the use of larvicide aerial spraying over breeding sites in fast-flowing rivers.
- Temephos as larvicide is effective but resistance develops

OCP, a major control initiative

- Following interruption of transmission, the reservoir of adult worms dies out in humans after 14 years.
- To complement vector control activities, OCP also distributes ivermectin.

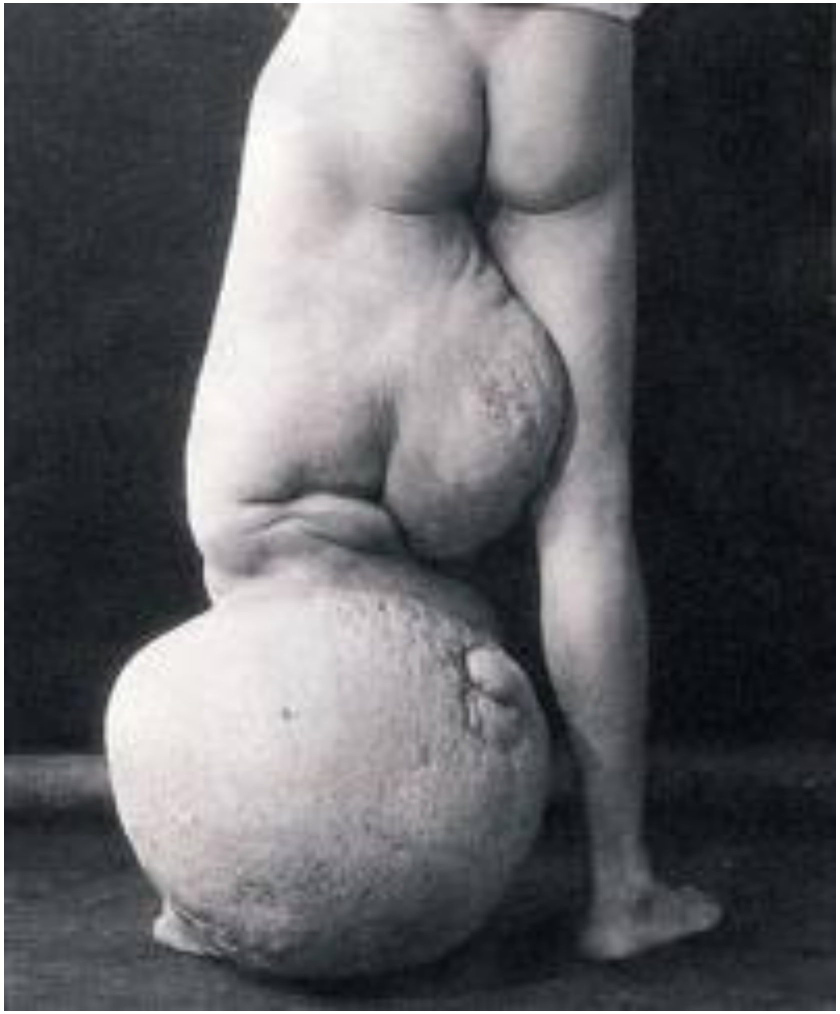
LYMPHATIC FILARIASIS

- Lymphatic Filariasis, known as Elephantiasis is caused by a nematode parasite of the order Filariidae.
- The parasites are transmitted to humans through the bite of an infected mosquito.
- The parasites develop into adult worms in the lymphatic vessels.

- The adult thread-like, white worms inhabit the lymphatic vessels and nodes of the hu man host causing inflammation of lymphat ic vessels (lymphangitis) and swelling of th e lymphatic nodes (Lymphadenitis).
- Lymphatic filariasis causes enlargement of the entire leg or arm, the genitals, vulva a nd breasts.
- In endemic communities, 10-50% of men and up to 10% of women can be affected.

Enlargement of the entire leg(s)

Enlargement of the entire leg

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- Over 120 million have already been affected by it; over 40 million of them are seriously incapacitated and disfigured by the disease.
- One-third of the people infected with the disease live in India, another one third are in Africa and most of the remainder in South Asia, the Pacific and the Americas.


- In tropical and subtropical areas where lymphatic filariasis is well-established, the prevalence of infection is continuing to increase.
- A primary cause of this increase is the rapid and unplanned growth of cities, which creates numerous breeding sites for the mosquitoes that transmit the disease.

Cause

- Lymphatic filariasis is caused by infection w ith nematodes (roundworms) of the family Filariodidea.
- There are three types of these thread-like f larial worms:

1. *Wuchereria bancrofti*, which is responsible for 90% of the cases
2. *Brugia malayi*, which causes most of the remainder of the cases
3. *B. timori*, which also causes the diseases.

- These worms live almost exclusively in humans, lodge in the lymphatic system, the network of nodes and vessels that maintain the delicate fluid balance between the tissues and blood.
- They live for 4-6 years, producing millions of immature microfilariae (minute larvae) that circulate in the blood.

TRANSMISSION

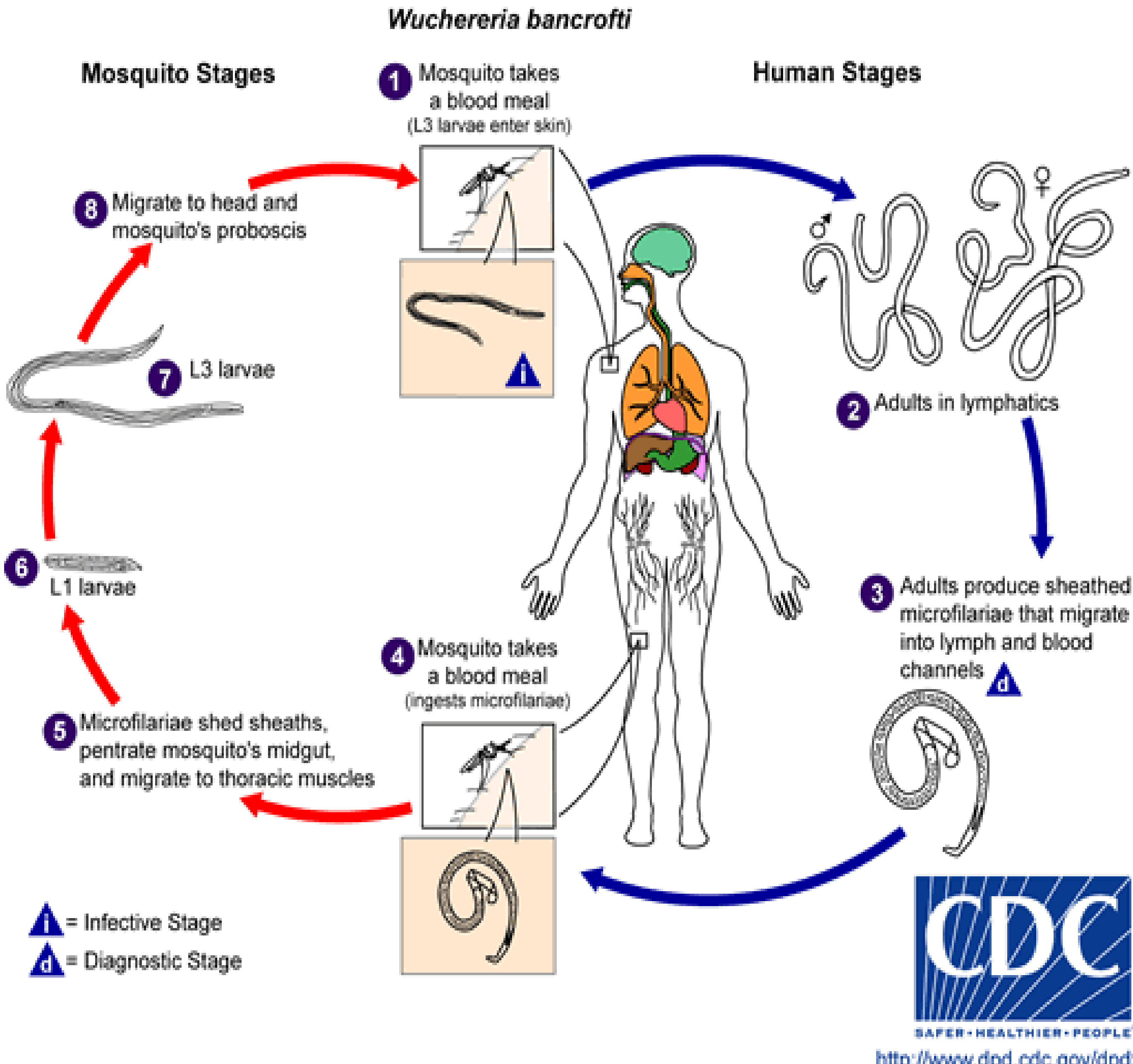
- The disease is transmitted by mosquitoes that bite infected humans and pick up the microfilaria.
- The microfilaria develop inside the mosquito into the infective stage in a process that usually takes 7-21 days.
- The larvae then migrate to the mosquitoes' biting mouth-parts, ready to enter the punctured skin following the mosquito bite, thus completing the cycle.

- In West Africa, only *Anopheles gambiae* and *An. funestus* are found to be important natural vectors of *Wuchereria bancrofti*.

- Different species of the following genera of mosquitoes are vectors of *W. bancrofti* filariasis depending on geographical distribution.

1. *Culex* (*C. annulirostris*, *C. bitaeniorhynchus*, *C. quinquefasciatus*, and *C. pipiens*)
2. *Anopheles* (*A. arabinensis*, *A. bancroftii*, *A. farauti*, *A. funestus*, *A. gambiae*, *A. koliensis*, *A. melas*, *A. merus*, *A. punctulatus* and *A. wellcomei*).

3. *Aedes* (*A. aegypti*, *A. aquasalis*, *A. bellator*, *A. cooki*, *A. darlingi*, *A. kochi*, *A. polynesiensis*, *A. pseudoscutellaris*, *A. rotumae*, *A. scapularis*, and *A. vigilax*)
4. *Mansonia* (*M. pseudotitillans*, *M. uniformis*).
5. *Coquillettidia* (*C. juxtamansonia*).


Wuchereria bancrofti
Mosquito Stages
Human Stages
1 Mosquito takes a blood meal (L3 larvae enter skin)
2 Adults in lymphatics
3 Adults produce sheathed microfilariae that migrate into lymph and blood channels
4 Mosquito takes a blood meal (ingests microfilariae)
5 Microfilariae shed sheaths, pentrate mosquito's midgut, and migrate to thoracic muscles
6 L1 larvae
7 L3 larvae
8 Migrate to head and mosquito's proboscis
i = Infective Stage
d = Diagnostic Stage
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- During a blood meal, an infected mosquito introduces third-stage filarial larvae (L3) onto the skin of the human host, where they penetrate into the bite wound .
- They develop into adults between three months to one year and commonly reside in the lymphatics .

- The female worms measure 80 to 100 mm in length and 0.24 to 0.30 mm in diameter.
- The males measure about 40 mm by .1 mm.
- Adults produce microfilariae measuring 244 to 296 μm by 7.5 to 10 μm, which are sheathed and have nocturnal periodicity (maximum concentration is from 22.00 to 02.00hrs).

- South Pacific microfilaria have the absence of marked periodicity. It appears that
- The nocturnal periodicity is an adaptation to the habits of night biting. *E.g. C. quinquefasciatus*, and *C. pipiens* and certain *Anopheles*.
- The microfilariae migrate into lymph and blood channels moving actively through lymph and blood

- A mosquito ingests the microfilariae during a blood meal.
- After ingestion, within one hour, the microfilariae lose their sheaths.
- Some of them work their way through the wall of the proventriculus and cardiac portion of the mosquito's midgut and reach the thoracic muscles.

- There the microfilariae develop into first-stage larvae (L1) and subsequently into third-stage infective larvae (L3).
- The third-stage infective larvae migrate through the hemocoel to the mosquito's prosbocis after about ten days.
- These can infect another human when the mosquito takes a blood meal .
- At high temperature and in moisture the cycle is completed in 10 – 14 days.
- Retarded to six weeks by cold.

SIGNS AND SYMPTOMS

- Many people never acquire outward clinical manifestations of their infections.
- The asymptomatic form of infection is most often characterized by the presence in the blood of thousands or millions of larval parasites (microfilariae) and adult worms located in the lymphatic system.
- The worst symptoms of the chronic disease generally appear in adults and in men more often than in women.

Clinical manifestation:

- Characterized by the gross enlargement of a limb or areas of the trunk or head – The severe swelling is caused by abnorm al accumulation of watery fluid in the tiss ues (edema).
- The skin usually becomes thickened and pebbly appearance.
- In few parts, it may become ulcerated an d darkened.

- Other possible features are fever, chills and a general feeling of ill health (malaise).
- This disease may also involve the male and female genital organs.
- In a male, it will result with enlarge scrotum with retracted penis.
- The skin will becomes thickened, non elastic, warm and tender.
- The spermatic cords also may be thickened as well.

- As for female, the vulva (external parts of the female genital organ) may also be affected by elephantiasis.
- The disease may manifest itself as a long, tumorous mass covered by thickened and ulcerated skin may develop between the thighs.
- The lymph nodes will later be enlarged.

- Acute episodes of local inflammation invo lving skin, lymph nodes and lymphatic ve ssels often accompany the chronic lymph oedema or elephantiasis.
- Some of these are caused by the body's i mmune response to the parasite, but mo st are the result of bacterial infection of s kin where normal defences have been pa rtially lost due to underlying lymphatic da mage.

- With pressure of swellings, the skin bursts open causing epithelial exfoliation.
- Careful cleansing can be extremely helpful in healing the infected surface areas and in both slowing and, even more remarkably, reversing much of the overt damage that has occurred already.

- In endemic communities, some 10-50% of men suffer from genital damage, especially hydrocoele (fluid-filled balloon-like enlargement of the sacs around the testes) and elephantiasis of the penis and scrotum.

DIAGNOSIS

- Until very recently, diagnosing lymphatic filariasis had been extremely difficult, since parasites had to be detected microscopically in the blood, and in most parts of the world, the parasites have a "nocturnal periodicity" that restricts their appearance in the blood to only the hours around midnight.
- The use of "card test" to detect circulating parasite antigens

Prevention and control

- Prevention and control requires coordinated efforts of 3 basic areas:
- 1. Vector control
- 2. Chemotherapy
- 3. Miscellaneous (education and community participation.

1. Vector control

- Insecticides (Chemical control)
- Biological control

2. Chemoterapy

- **Communities where filariasis is endemic.**
- The primary goal of treating the affected community is to eliminate microfilariae from the blood of infected individuals so that transmission of the infection by the mosquito can be interrupted

- Single doses of diethylcarbamazine (DEC) have the same long-term (1-year) effect in decreasing microfilaraemia as the formerly-recommended 12-day regimens of DEC and, even more importantly.
- The use of single doses of 2 drugs administered concurrently (optimally albendazole with DEC or ivermectin) is 99% effective in removing microfilariae from the blood for a full year after treatment.

Treating the individual.

- Both albendazole and DEC have been shown to be effective in killing the adult-stage filarial parasites (necessary for complete cure of infection).

METHODS OF PEST CONTROL

- **Pest control** refers to the regulation or management of a species defined as a pest, usually because it is perceived to be detrimental to a person's health, the ecology or the economy. A practitioner of pest control is called an **exterminator**.

PESTS

- **What is a Pest?**

- The planning group for Science and Technology of the Organization for Economic Co-operation and Development (OECD) in 1977 defined a pest as ‘any form of plant or animal life or any pathogenic agent injurious or potentially injurious to plants or plant products, livestock or man.’

Pests contd.

- In another definition, a pest is any animal or plant which does economic damage to crops and domesticated animals or is harmful to human health or land fertility constitutes a pest.
- Pests include some vertebrates such as certain birds and rodents; many species of insects, ticks, molluscs, crustaceans, mites and other arachnids; nematodes and other parasitic worms; weeds and other undesired plants; fungi, bacteria, viruses and other harmful micro-organisms.

Methods of Pest Control

- Various methods are available for the cont rol of different pest infestations.

1. These methods vary in their levels of sophistication and different pest situations may demand different control methods.
2. Chemical control
3. Biological Control (Biocontrol)

Methods of Pest Control contd.

4. Cultural Control
5. Use of Resistant Varieties
6. Mechanical and Physical Control
7. Regulatory Control
8. Use of Pheromones
9. Use of Antifeedants

Chemical control

- Chemical controls include the use of insectic ides, horticultural oils or the application of herbicides to reduce insect population or to prevent insect injury.
- The chemicals used may poison the insect, a ttract them to other devices or repel them f rom specified areas.
- It is the best known and most commonly use d pest control method.

Chemical control contd.

- The appealof chemical pesticides/insecticides for use in pest control can be attributed to a n umber of factors;

1. Many modern pesticides are relatively cheap in the developed countries.
2. Pesticides can be applied easily.
3. Of greatest importance perhaps, pesticides often afford the only practicable and quick control method where pest populations are approaching economic thresholds

Disadvantages of Pesticide Use

1. A major disadvantage is that most pesticides though relatively cheap are often expensive to the poor developing nations who need them most.

   The problem is more acute with the frequent need for repeated pesticide applications.

2. Pesticides may leave toxic residues on food and fodder (food grown for livestock) when they are applied close to the harvesting of the crop.

Disadvantages of Pesticide Use contd.

- Residues may have adverse effects on ecosystems by creating disequilibrium of food chains, scavengers, insect-host relationships, insect-plant relationships.

3. There is always the danger that pesticides may kill organisms other than the pests.

Disadvantages of Pesticide Use contd.

The destruction of these non-target organisms may cause serious disruptions in the ecosystem thus upsetting the balance of nature.

For example, the destruction of natural enemies of pests may lead to pest resurgence and outbreak of secondary pests into major pests.

Disadvantages of Pesticide Use contd.

4. Pests themselves may develop resistance to pesticides. In this case, the pests become unaffected by pesticides which formerly were effective in killing them.

   The problem of resistance causes a changeover to new pesticides which further adds to the expense of chemical control.

Disadvantages of Pesticide Use contd.

5. Pesticides have the grave disadvantage of posing a hazard to humans.

   As surely as pesticides will kill pests, they will also as well kill people who handle them carelessly. There are, in fact, many examples from different countries of human deaths resulting from careless handling of pesticides.

6. Pesticides may encourage increased densities of bacteria and fungi that feed on pesticide residues in the field, robbing them of their potency.

Biological Control (Biocontrol)

- Biological control refers to the deliberate introduction of predators, parasites and pathogens designed to reduce the pest population to a level at which it is no longer considered a pest.
- Usually entomophagous insects and disease causing organisms are used as biological control agents but some vertebrate predators have also been used, e.g. *Gambusia* fish have been used against mosquito larvae.
- Entomophagous insects can be subdivided into predators and parasites.

Biological Control Agents

- Biological Control Agents may be classified as follows:
- Parasites (parasitoids)
- Predators
- Phytophagous insects
- Insect pathogens such as viruses, fungi, bacteria, protozoa and nematodes.

Techniques of Biological Control.

- Classical biological control/ importation.
- Inoculation
- Inundation

Augmentation

- Conservation of natural enemy

Classical Biological Control

- Classical biological control is the introduction of natural enemies to a new locality where they did not originate or do not occur naturally.
- It involves the introduction of suitable natural enemies of a pest (which itself might have been introduced accidentally into the area without its natural enemies)

Classical Biological Control cont'd.

- The idea is to lower permanently the equilibrium position of the pest to a non-economic level.
- Beneficial species released in sufficient number will successfully colonize and become an integral part of the ecosystem.
- This technique has yielded by far the best results and has been largely directed against exotic insect pests.

Examples of successful biological control

1. The mealy bug was accidentally introduced and spread to 30 countries in Africa.

- A search in the presumed area of origin of the mealy bug, South America, led to the specific parasite *Epidinocarsis lopezi* being introduced to Nigeria in 1981. By 1986, it was established in 13 countries.

2. Cottony cushion scale in California – The introduction of the vedalia beetle, *Rodolia cardinali*, from Australia into California to control the cottony cushion scale, *Icerya purchasi* on citrus.

Augmentation control

- Involves the periodic introduction of pred ators
- Consist of
  1. Inoculation
  2. Inundation
- Inoculative release and inundative release are different methods of biological contro l that affect the target pest in different w ays.

Augmentation - Inoculation

I. **Inoculation:** The repeated release of relatively small numbers of a natural enemy for the purpose of building-up a population over generations for the control of future generations of pests.

This approach has been used particularly, though not exclusively, for the control of imported pests.

It has proved especially useful on perennials, against sedentary pests and in 'ecological islands'.

Augmentation - Inundation

With inundative release, natural enemy (predators) are collected, mass-reared in the laboratory and periodically released in large numbers into the pest area to effect immediate high mortality in the pest population.

Inundation

- Inundative release anticipates only control of the population and generation on which it is applied, with no expectation of long-term regulation.
- Habitat or environmental manipulation is another form of augmentation. This tactic involves altering the cropping system to augment or enhance the effectiveness of a natural enemy.

Conservation of Natural Enemy

- This involves creating situations favourable t o colonization of crops by resident natural en emies.
- A variety of management activities can be us ed to optimize the survival and/or effectiven ess of natural enemies.

Conservation of Natural Enemy cont,d.

- Conservation activities might include reducing or eliminating insecticide a pplications to avoid killing natural e nemies, staggering harvest dates in adjacent fields or rows to ensure a c onstant supply of hosts (prey) or pro viding shelter or alternative food sou rces to improve survival of beneficia l species.

Advantages of Biological Control

1. The main benefit of natural pest control methods is that it does not harm the environment. The technique is selective with no side effects. Biological control agents tend to be fairly prey-specific and do not carry the kind of environmental dangers associated with insecticides.

Advantages of Biological Control cont'd.

2. Biological control is cheap - If successful, biological control is a very economical method.

   In classical biological control the only cost incurred is the initial one. This cost is, however, repaid many times over by the resulting benefits (Dough, 1967).

Advantages of Biological Control cont'd.

3. Biological control agents are self-propagating and self-perpetuating. Once introduced, biological control agents will persist in time, and may spread over large areas from the points of release and reach targets that chemicals cannot .This makes them sufficient and cost-effective
4. The development of resistance of pests to biological control is unlikely.

Advantages of Biological Control cont'd

5. Compared to DDT pesticides, it will not emit harmful toxins which could damage the ozone layer or harm the other organisms living within the agricultural area

6. Might reduce pest population below the level that causes economic damage.

Disadvantages of Biological Control

1. Biological control limits the subsequent use of pesticides. Where biological control agents are being used against one pest, it is clearly difficult to continue using insecticides against other pests on the same crop.
2. Biological control takes a long time to produce results. It takes some time for biological control agents to spread from their point of release, to build up in numbers and to make their impact on the pest population.

Disadvantages of Biological Control cont'd.

3. Not an exterminant: a biological control system, if intended to be self-perpetuating, involves the presence of the prey even if only at low levels. There may be several types of pests which, even at low levels will still cause economic damage.
4. Biological control can be very expensive.
5. Biological control may be unpredictable: certainty of control is not always assured.

Disadvantages of Biological Control cont'd.

6. In some cases, biological control can have unforeseen negative results that could outweigh all benefits. For example, when the mongoose was introduced to Hawaii in order to control the rat population, it predated on the endemic birds of Hawaii, especially their eggs, more often than it ate the rats.
7. Biocontrol can't meet the control of rapid growing weeds, particularly those competing with short-term crops. It is more suitable for perennial weeds (both terrestrial and aquatic).

Cultural Control

- Cultural control is the use of farming techniques or cultural practices associated with crop production, designed to make the environment difficult for the survival of pests. i.e. it involves manipulation of the environment to the disadvantage of the pest.
- The environment is changed by altering farming practices at the correct time so as to kill the pests or slow down their multiplication; or alternatively, they may provide a more favourable environment for the natural enemies of the pest.

Crop Rotation

- This method prevents continuous breeding of pests and therefore prevents build-up of pest populations and may hold them below numbers that will cause economic damage.
- Pests that are reduced (in numbers) effectively by rotation usually have a long life cycle, a limited host range and are relatively immobile in some stages of their development.

Crop Rotation cont'd

- Changing crops in a rotation system i solates such pests from their food su pply.
- It is perhaps most useful in preventi ng build-up of soil pests such as plan t parasitic nematodes.

Planting Date (Time):

- Variation of sowing date can control pests , most of which show seasonal predictabili ty, either by avoiding the egg-laying perio d of the pest or by allowing the plants to r each an age where they are resistant by t he time the pest appears.

Time of Harvesting

- Prompt harvesting of maize and beans may prevent these crops from being infested by maize weevil (*Sitophilus zeamaise*) and *Acanthoscelides obtectus*) respectively. Both infest the field crops from nearby stores.

Soil Tillage

- Many insects live or hibernate in suitable temp erature and humidity conditions relatively near the soil surface.
- These conditions can be desturbed by ploughin g, which creates temporary drought conditions in the upper soil layers.
- The use of tillage operations to reduce populati ons of soil-inhabiting pests may work in several ways:
- It may change physical conditions of soil
- Bury a stage of a pest

Soil Tillage cont’d

- May expose larvae and pupae to the full r
  adiation of the sun.
- Mechanically damage some stage of the p
  est.
- Eliminate host plants of pest, or hasten th
  e growth or increase the vigor of the crop
  .

Residue Disposal/Sanitation

- Farm hygiene often has a pest control pur pose.
- The destruction of crop residues removes residual pest populations (e.g. stem-borin g larvae in maize) and eliminates plant de bris on the soil surface in which many pes ts (e.g. flea beetles and whiteflies of bras sicas) find shelter for hibernation.

Residue Disposal/Sanitation cont'd

- In South Africa removal of fallen ora
nges depletes the larval pool of the
African false codling moth *Cryptophl
ebia leucotreta* making it easier for
the parasitic natural enemy, *Trichogr
ammatoidea lutea*, to contain the re
maining moth populations.

Trap Crops

- Small plantings of a susceptible or preferred crop may be established near a major crop to act as a "trap".
- After the pest insect has been attracted to the trap crop, it is usually treated with insecticides ploughed under or both e.g. in Uganda it has been shown that *Cissus sp*. is a very attractive trap plant.

Alternative Hosts

- Many crop pests may develop on plants ot her than the crops.
- The destruction of these alternative host plants will also reduce the numbers of the pests concerned.

Use of Resistant Varieties

- Plant resistance represents the inherent ability of a crop variety to restrict, retard or overcome pest infestations.
- For our purposes resistant varieties of plants are less damaged or less infested by the pest than other varieties in the field under comparable environmental conditions and stage of growth.
- Plant resistance is one of the most effective and reliable methods of pest control.

Use of Resistant Varieties cont'd

- Its use involves no extra expense to the farmer. However, this method cannot be used against weed pests.
- Plant resistance may consists of three major types:
- (a)Non-preference(Antixenosis), (b)Antibiosis and
- (c)Tolerance.

Non-Preference

- The presence of hairs, thorns, etc, by a plant may discourage oviposition (egg-laying) and/or feeding by an insect.
- Physical characteristics of plants such as height, colour, odour (smell) and leaf size may influence the attraction of insects to plants.
- After the insect arrives at the plant, factors like hairiness, leaf age, succulence (freshness), leaf size and stem diameter may influence feeding and egg-laying.

Non-Preference cont'd

- High silica content in plants has been shown to discourage feeding in insects as the silica abrades the mandibles of the insects.

Antibiosis

- The tendency of a plant to resist insect injury often by injuring or destroying the insect.
- Antibiosis in plants interferes with the insect's life history, causing reduced life-span,fecundity or size, growth, development rate or increased mortality.

Antibiosis cont'd

- It is usually a function of the nitrogen or amino acid concentration of plant tissues.
- Some plants actually produce ecdysones that act as insect anti-hormones, interfering with juvenile production and so preventing successful metamorphosis.

Antibiosis cont'd

- For example, in antibiosis, eggs of the insect pests may not hatch; or when they hatch, larvae or nymphs may not develop or may take abnormally long periods to develop; or pupae may not become adults. When adults are produced, they may lay few or no eggs.

Tolerance

- Tolerance is the term used when the resistant plant is capable of supporting a population of insects without loss of vigour.
- Tolerance is usually shown towards specific pests only. Pathak and Saxene, (1979) believe that the ability of tolerant plants to survive infestations for a longer period permits a longer exposure of the insects to their natural enemies.

Disadvantages of Plant Resistance

- This method is that usually a long period of time is required to breed, multiply and distribute the resistant varieties, especial ly with tree crops.
- Another disadvantage is that it is possible for resistance to break down. Biotypes of pests may evolve which can damage previ ously resistant crop varieties.

Mechanical and Physical Control

- Mechanical control is the reduction of pest populations by using devices which affect them physically or alter their physical environment.
- Physical and mechanical methods of pest control differ from cultural techniques in that they are applied directly to the pest. For example, tomato hornworms may be picked directly from tomatoes.

Mechanical and Physical control cont'd

- Temperature and humidity control – temperature and humidity variations are best used against pests of stored products, such as grain, where 3 – 4 hours at 52 – 55^{o}C in a high frequency electrostatic field kills most pests.
- On living grain, pest destruction is more difficult since the grain must not also be destroyed.

Regulatory Control

- The objective of regulatory control is to prevent the entry and establishment of new pests in a country or area and to de stroy or prevent further spread of those already present.
- Quarantine stations are established by la w at a country's entry ports, and at time s within the country, to inspect incoming plants, animals and commodities for the presence of new pests.

Regulatory control cont'd

- If such pests are found, they are destroyed together with the commodity in which they are found.
- Laws are passed to prohibit the importation of plants and animals from countries or areas which are suspected to contain pests of quarantine significance.

Use of Pheromones

- A pheromone is defined as a chemical or a mixture of chemicals that is released to the exterior by an organism and that causes one or more specific reactions in a receiving organism of the same species (Shorey, 1978b).
- Pheromones have particular advantages for pest control because they are usually highly species-specific, leave no undesirable residues in the environment and are effective in very minute quantities.

Use of Pheromones cont'd

- Synthetic analogues of many major pests are now available and are often used to b ait traps. The pheromones most used in p est control are the sex attractant pherom ones usually produced by the female of th e species.

Use of Antifeedants

- Antifeedants are defined as substances which when tasted, can induce cessation of feeding either temporarily or permanently, depending upon the potency (Nakanishi, 1977).
- Antifeedants may not directly kill the pest; they prohibit feeding so that the pest starves to death.

Use of Antifeedants cont'd

- Substances which interfere with the feeding activity of a pest on the treated plant offer yet another novel approach to insect pest control.
- The use of antifeedants in pest control is not applicable to non-animal pests such as weeds and fungi.

Advantages and Disadvantages of Antifeedants

- Antifeedants have the advantage of not h arming beneficial insects. They act only a gainst insects which attack the crops, and even these are not necessarily killed.
- Antifeedants, however, have the disadvan tage that only surface-feeding pests are a ffected; insects with piercing-sucking mou thparts are unaffected.

Genetic Control Methods

- Genetic control involves the use of geneti cally impaired pests to limit reproduction and survival of their own species in natura l populations.
- The male of such pests are mass reared in the laboratory and released among wild p opulations in the field so that mating with normal insect will either not result in an o ffspring or lead to reduced fitness of the progeny.

Genetic Control methods cont'd

- These methods may be discussed under the fo llowing:
- Radiation sterilization release method
- Radiation-inducedtranslocation/Chromosomal translocations.
- Chemosterilants
- Hybrid sterility
- Cytoplasmic incompatibility

Integrated Pest Management (IPM)?

- Integrated pest management is an effective and environmentally sensitive approach to pest management which **utilizes all suitable control methods in combination** either to reduce pest populations and maintain them at levels below those causing economic injury or to so manipulate the populations that they are prevented from causing such injury
- The purpose IPM is to greatly reduce use of pesticides which in turn avoid the problems identified as effect on toxic agents

IPM

- IPM is an ecologically based approach to pest control that uses biological controls, sex attractants, crop rotation, selected planting times and limited application of pesticides
- The purpose is to greatly reduce use of pesticides which in turn avoid the problems identified as effect on toxic agents

Goal of IPM

- The goal of an IPM system is to manage pes ts effectively as well as the environment to balance benefits of control costs, public he alth and environmental quality.
- IPM takes advantage of all appropriate pest management options.
- IPM aims to suppress pest populations belo w the economic injury level (EIL).

Applications

- IPM is used in:
  1. Agriculture
  2. Horticulture
  3. Human habitations
  4. Preventive conservation

How does IPM Work?

- IPM is a continuous system of controlling pests (weeds, diseases, insects and others) in which pests are identified, action thresholds are considered, all possible control options are evaluated and selected control(s) are implemented.

Fundamental Principles that define IPM

1. **Monitor** the site for presence of pests and numbers as well as natural controls.

   Use standardized, tested monitoring methods rather than basing decisions on haphazard observation.

1. Monitoring

- Regular observation is critically important .
- Visual inspection, insect and spore traps, and other methods are used to monitor pe st levels.
- Record-keeping is essential, as is a thorou gh knowledge of target pest behavior and reproductive cycles

2. Identify the pest(s)

- That are the source of the problem and the level of infestation. Correct pest identification is required to identify optimum solutions.

- Mistaken identification of a pest may result in ineffective actions. E.g., plant damage due to over-watering could be mistaken for fungal infection, since many fungal and viral infections arise under moist conditions.

2. **Identify the pest(s)**

- **NB**: Monitoring and identification removes the possibility that pesticides will be used when they are not really needed or that t he wrong kind of pesticide will be used.

3. Understand the biology and economics of the pest

- Learning the biology of the pest tells you h ow fast it reproduces, where it likes to live , what it likes to eat, and special things it can do.
- You also know what naturally eats/kills the pest (natural enemies and climatic conditi ons)
- You will use this information to choose the best ways to manage the pest.

4. Action Thresholds

- Sighting a single pest does not always mean control is needed.
- Action thresholds are determined by factors such as severity of the problem caused by the pest, health or property concerns related to the pest, and user needs for the site where the pest is found.
- Actions are taken only when the potential damage is sufficient to justify action.

5. Select an appropriate strategy or curative action

- To avoid the pest surpassing the established threshold, select the appropriate cultural, mechanical/physical, biological, sex attractants, crop rotation, selected planting times and/or chemical prevention or control techniques.

- The selected control method(s) of protection must balance considerations of safety, and potential hazards to property and the environment.

6. Evaluate and implement control strategy

- **Implement control tactics** that will be most effective, economical and have least impact on non-target species and the environment.
- Selected methods should be beneficial organisms.

7. Evaluation

- Evaluate the effectiveness and overall success of the pest management programme and identify potential areas for improvement when possible.
- This requires keeping records and reviewing them on a regular basis.

Advantages of Integrated Pest Management

1. There is less harm to the environment due to the use of little or no chemical
2. There is less toxic residues in crops/food.
3. It is economical when used properly. It is less expensive than chemical method of pest control.

Advantages of IPM

4. It is more effective and reliable against a wide variety of pests than other (single) methods

5. Quick acting when a problem reaches economically proportions

Disadvantages of IPM

1. It is very costly compared to the traditional method of spraying with insecticides.

2. It is also very time consuming