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Study Materials

Programme: B.Sc.General with Zoology
(CBCS System)

Course Code: **DSE-2 (SEM-VI)**

Course Name: **INSECT VECTOR AND DISEASES**

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1.1 Types of hosts, types of relationships (Parasitism, Symbiosis, Commensalism)

Symbiosis: Symbiotic relationships, or symbioses (plural), are close interactions between individuals of different species over an extended period of time which impact the abundance and distribution of the associating populations. Any association between two species populations that live together is symbiotic, whether the species benefit, harm, or have no effect on one another. Both positive (beneficial) and negative (unfavourable to harmful) associations are therefore included, and the members are called symbionts. Symbiosis, is any of several living arrangements between members of two different species, including mutualism, commensalism, and parasitism.

Mutualism: In past it was termed symbiosis. Mutualism, is association between organisms of two different species in which each benefits. Mutualistic arrangements are most likely to develop between organisms with widely different living requirements. In this case both of the species derive benefits and there exists a close and often permanent and obligatory relationship which is more or less essential for survival of each..

For example, termites have a mutualistic relationship with protozoa that live in the insect's gut. The termite benefits from the ability of bacterial symbionts within the protozoa to digest cellulose. The termite itself cannot do this, and without the protozoa, it would not be able to obtain energy from its food (cellulose from the wood it chews and eats). The protozoa and the bacterial symbionts benefit by having a protective environment and a constant supply of food from the wood chewing actions of the termite.

Lichens have a mutualistic relationship between fungus and photosynthetic algae or bacteria. As these symbionts grow together, the glucose produced by the algae provides nourishment for both organisms, whereas the physical structure of the lichen protects the algae from the elements and makes certain nutrients in the atmosphere more available to the algae.

Commensalism: Commensalism, in biology, is a relationship between individuals of two species in which one species obtains food or other benefits from the other without either harming or benefiting the latter. The commensal—the species that benefits from the association—may obtain nutrients, shelter, support, or locomotion from the host species, which is unaffected. The commensal relation is often between a larger host and a smaller commensal. The host organism is essentially unchanged by the interaction, whereas the commensal species may show great morphological adaptation. This relationship can be contrasted with mutualism, in which both species benefit.

One of the best-known examples of a commensal is the remora (fish) that rides attached to sharks and other fishes. Remoras have evolved on the top of their heads a flat oval sucking disk structure that adheres to the bodies of their hosts. Both remoras and pilot fishes feed on the leftovers of their hosts' meals.

Other examples of commensals include bird species, such as the great egret (*Ardea alba*), that feed on insects turned up by grazing mammals or on soil organisms stirred up by plowing. Various biting lice, fleas, and louse flies are commensals in that they feed harmlessly on the feathers of birds and on sloughed-off flakes of skin from mammals.

Parasitism:- Parasitism is a kind of relationship between species, where one organism lives on or in another organism, causing some harm to host, and the parasite is adapted structurally to this way of life. A parasite is an organism that lives in or on another living organism and derives nutrients from it. In this relationship, the parasite benefits, but the organism being fed upon, the host is harmed. The host is usually weakened by the parasite as it siphons resources the host would normally use to maintain itself. The parasite, however, is unlikely to kill the host, especially not quickly, because this would allow no time for the organism to complete its reproductive cycle by spreading to another host. Parasitism is a kind of symbiosis, a close and persistent long-term biological interaction between the parasite and its host. Unlike commensalism and mutualism, the parasitic relationship harms the host, either feeding on it or, as in the case of intestinal parasites, consuming some of its food. Within that scope are many possible ways of life. Parasites are classified in a variety of different but overlapping schemes, based on their interactions with their hosts and on their life cycles, which are sometimes very complex.

Ecto-parasite (Ectozoa): Lives outside on the surface of the body of the host. E.g ticks and mites
Endo-parasite (Entozoa): Lives inside the body of the host: in the blood, tissues, body cavities, digestive tract and other organs. E.g *Ascaris*, *Plasmodium* etc
Temporary Parasite: Visits its host for a short period. E.g mosquito
Permanent Parasite: Leads a parasitic life throughout the whole period of its life. E.g *Ascaris*
Facultative Parasite: Lives a parasitic life when opportunity arises.
Obligatory Parasite: Cannot exist without a parasitic life. E.g *Plasmodium*
Occasional or Accidental Parasite: Attacks an unusual host.
Wandering or Aberrant Parasite: Happens to reach a place where it cannot live.
Epiparasite: It is a parasite whose host, often an insect, is also a parasite and their association is called hyperparasitism

Types of Hosts

Host is the organism upon or inside which the parasite lives or the organism which lodges the parasite.

Before discussing the various types of hosts let us take an example of the malaria causing protozoan parasite *Plasmodium.* For this parasite there are two hosts, man and female *Anopheles* mosquito. In mosquito the parasite undergoes sexual reproduction to produce infective stages. When this mosquito bites the man, infective stages get transmitted to man. Here in second host the parsite undergoes asexual reproduction and produces large no of parasites. Some of the parasites get matured into gamete producing parasites. So when mosquito bites the infected man, gamete producing parasites get transmitted to mosquito where sexual reproduction takes place and the cycle continues.

The various types of hosts are as.

1. PRIMARY HOST (Definitive host): It is the host that harbours the adult stage or sexually mature stage of a parasite or the host in which the parasite undergoes sexual reproduction. e.g., Man is the primary host for *Wuchereria bancrofti* (Filarial Worm), Female *anopheles* mosquito is the primary host for malaria causing protozoan *Plasmodium vivax.*

2.**SECONDARY HOST (Intermediate host)**: Is the host that harbours the developing larval or immature or asexual stages of a parasite or the host in which the parasite undergoes asexual reproduction. e.g, Man is the secondary host for *plasmodium vivax*, Female culex mosquito is the secondary host for *Wuchereria bancrofti.*

3.Paratenic Host (A carrier or transport host): An intermediate host which is not needed for the development of the parasite, but nonetheless serves to maintain the life cycle of the parasite . It is a host, where the parasite remains viable without further development. A paratenic host is similar to an intermediate host, except that it is not needed for the parasite's development cycle to progress. Paratenic hosts serve as "dumps" for non-mature stages of a parasite in which they can accumulate in high numbers.

4. Reservoir Host: Also known as temporary host. It is the host that lodges the infective stages of a parasite in its body when the main host is not available. In the reservoir host , the parasite neither undergoes development nor causes any disease. In the absence of regular host some parasites survive in the reservoir hosts. Reservoir hosts become the source of infection for regular hosts. Reservoir hosts are not essential for the parasite to complete its life cycle. e.g, Monkey is the reservoir host for *Plasmodium*

5. Vector Host: Vector is an organism which transfers the infective stages of a parasite from one main host to another. It is host in which part of life cycle of host takes place and is instrumental in transmission of infective stages of parasite from one host to another.

Vectors are of two types , namely;

A) MECHANICAL VECTOR: It is the vector , which merely transfers the infective stages of a parasite but no part of the parasitic development takes place in it. e.g., Houseflies and Cockroaches in the case of *Entamoeba.*

B) BIOLOGICAL VECTOR: It is the vector in which the parasite undergoes a part of the development before it gets transferred to another host. e.g., Female *anopheles* mosquito in the case of *Plasmodium* and Female *culex* mosquioto in the case of *Wuchereria.*

1.2 Zoonosis Transmission, Prevention and control of diseases (Tuberculosis, typhoid)

Zoonosis: Zoonosis refers to diseases that can be passed from animals to humans. They are sometimes called zoonotic diseases. Animals can carry harmful germs, such as bacteria, fungi, parasites, and viruses. These are then shared with humans and cause illness. Zoonotic diseases range from mild to severe, and some can even be fatal.

Tuberclousis:

Tuberculosis (TB; short for tubercle bacillus) is a common, and in many cases lethal, infectious disease caused by various strains of mycobacteria, usually *Mycobacterium tuberculosis* . Tuberculosis typically attacks the lungs, but can also affect other parts of the body. It is spread through the air when people who have an active TB infection cough, sneeze, or otherwise transmit their saliva through the air. Most infections are asymptomatic and latent, but about one in 10 latent infections eventually progresses to active disease which, if left untreated, kills more than 50% of those infected. One third of the world's population is thought to have been infected with M. tuberculosis with new infections occurring at a rate of about one per second.

Zoonotic tuberculosis (TB) is a form of tuberculosis in people caused by *Mycobacterium bovis*, which belongs to the *M. tuberculosis* complex. Cattles are most important animal reservoir for *M. bovis* in relation to zoonotic exposure of humans. But the disease can affect many other species snd become established in wildlife reservoirs. It often affects sites other than the lungs (extrapulmonary), but in many cases is clinically indistinguishable from TB caused by *M. tuberculosis.*

Transmission: When people with active pulmonary TB cough, sneeze, speak, sing, or spit, they expel infectious aerosol droplets 0.5 to 5.0 μm in diameter. A single sneeze can release up to 40,000 droplets. Each one of these droplets may transmit the disease, since the infectious dose of tuberculosis is very small (the inhalation of fewer than 10 bacteria may cause an infection).

While the most common route of transmission of *M. bovis* to humans is through food (mainly untreated dairy products or, less commonly, untreated meat products), airborne transmission also poses an occupational risk to people in contact with infected animals or animal products, including farmers, veterinarians, slaughterhouse workers and butchers. Zoonotic TB can also get transmitted to humans through close contact with wild animals like elephants etc.

Prevention And control:

IMPROVE THE SCIENTIFIC EVIDENCE BASE

1. Systematically survey, collect, analyse and report better quality data on the incidence of zoonotic TB in people, and improve surveillance and reporting of bovine TB in livestock and wildlife.

2. Expand the availability of appropriate diagnostic tools and capacity for testing to identify and characterize zoonotic TB in people.

3. Identify and address research gaps in zoonotic and bovine TB, including epidemiology, diagnostic tools, vaccines, effective patient treatment regimens, health systems and interventions coordinated with veterinary services.

REDUCE TRANSMISSION AT THE ANIMAL-HUMAN INTERFACE

4. Develop strategies to improve food safety.

5. Develop capacity of the animal health sector to reduce the prevalence of TB in livestock.

6. Identify key populations and risk pathways for transmission of zoonotic TB.

STRENGTHEN INTERSECTORAL AND COLLABORATIVE APPROACHES

7. Increase awareness of zoonotic TB, engage key public and private stakeholders and establish effective intersectoral collaboration.

8. Develop and implement policies and guidelines for the prevention, surveillance, diagnosis, and treatment of zoonotic TB, in line with intergovernmental standards where relevant.

9. Identify opportunities for community-tailored interventions that jointly address human and animal health.

10. Develop an investment case to advocate for political commitment and funding to address zoonotic TB across sectors at the global, regional and national levels

ZOONOTIC TB MUST BE PRIORITIZED IN THE GLOBAL HEALTH AGENDA

The UN Sustainable Development Goals (SDGs) emphasise the importance of multidisciplinary approaches to improving health. In the context of the SDGs, WHO's End TB strategy calls for diagnosis and treatment of every TB case. This must include people affected by zoonotic TB. Zoonotic TB in people cannot be fully addressed without controlling bovine TB in animals and improving food safety. Through a One Health approach, together we can save lives and secure livehoods.

1.3 Life history and pathogenicity of *Entamoeba histolytica, Plasmodium vivax, Trypanosoma gambiense*

Entamoeba Histolytica

Entamoeba Histolytica is a parasitic protozoan and lives as an endo-parasite in the upper part of the large intestine, i.e., colon of man. It inhabits the mucous and sub-mucous layers of the large intestine. It feeds mainly on the tissues of the intestinal wall and often produces severe ulcers and abscesses. The parasite is worldwide in distribution and more common in most countries of trop-ics and subtropics rather than temperate zones. E. histolytica is scarcely pathogenic found in human beings of temperate zones.

Life Cycle of Entamoeba Histolytica:

The life cycle of E. histolytica is completed through a single host-man. Hence it is called monogenetic. Trophozoite and cyst stages of the parasite are concerned with the life cycle.

Encystment: Entamoeba histolytica multi-plies by binary fission in the trophozoite stage. They have the capacity to encyst. Unfavourable conditions in the habitat such as lack of nutrients, temperature deviations from the optimum range, decreased O2 ten-sions, lowered pH and accumulation of meta-bolic wastes may be the causes for encyst-ment.

Precystic form: Prior to encystment the trophozoite of each parasite loses its pseu-dopodium, eliminates food vacuoles and becomes spherical, called a precystic form. The diameter of this stage varies 10-20 μm and the structure of the nucleus is like the trophozoite stage of the parasite.

Mature cyst form: The precystic form secrets a thin, tough and transparent mem-brane around it, called the cyst wall. The animal having a cyst is called a cyst. The process of enclosing in a cyst is called encystment or encystation. At the early stage the cyst contains a single nucleus. The single nucleus is divided mitotically forming two nuclei. This is called binucleate cystic stage. Then the two nuclei are divided by mitosis and four nuclei occur. The nuclear divisions take place without cytoplasmic division and this tetra-nucleate cyst is called mature cyst. The whole process of encystment takes a few hours and the mature cyst lives in the lumen of the intestine of host only two days.

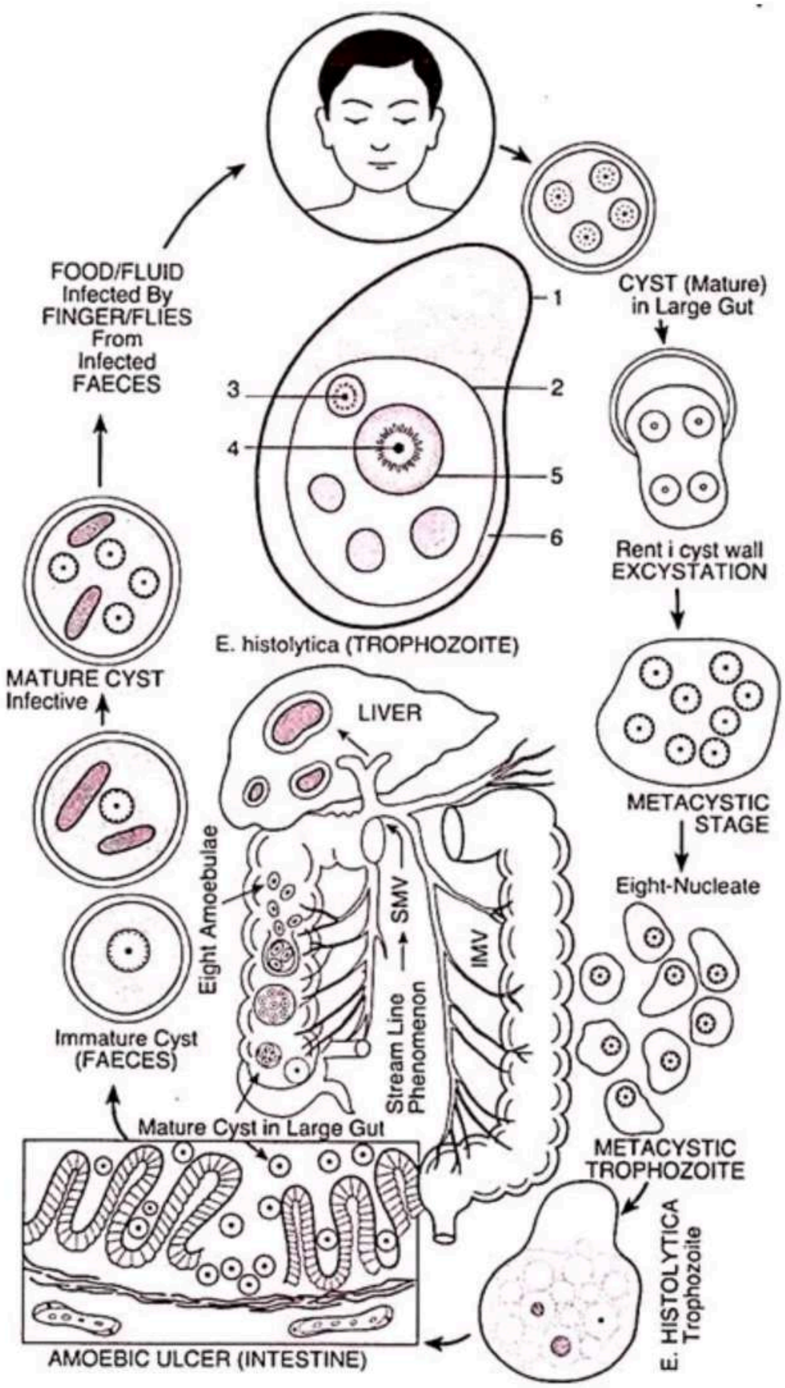
Tolerance of the cyst: The cysts of E. histolytica can survive about one month in water and about 12 days on dry land. They can tolerate the temperature up to 50° Celsius and 4 hours in formaldehyde solution.

Infection: At the tetranucleate stage the cyst is infective to a new host. The infective cysts pass out through the host's faeces and are introduced into the gut lumen of a new host through the contaminated drink, food and vegetables.

Excystment: Then the infective cysts pass into the lower portion of the small intestine (colon) of the new host. Here the process of excystment occurs. The excystment is the process by which the cysts are transformed into the trophozoites. The cyst wall in the colon becomes permeable by the action of intestinal enzymes, the trypsin of the intes-tine. The cyst wall ruptures and 4-nucleate amoeba emerges out from the cyst.

Factors for excystment: Temperature, pH, chemical composition of the medium and the flora of the bacteria may be the reasons for excystment.

Metacystic form: After the emergence of quadrinucleate amoeba, the division of cyto-plasm immediately ensues and produces four small metacystic trophozoites.



Trophozoites: Both the nucleus and cytoplasm of each metacystic trophozoite divide and as a result 8 small amoebulae are produced. These are called young uninucleate trophozoites. They are motile and penetrate the mucous membrane.

The young trophozoites feed on host tissues, blood, bacteria and yeast and gradually in-crease in size to attain maturity. Inside the tissues the trophozoites multiply and start the procystic form of the life cycle. Transformation of a quadrinucleate metacystic stage of entamoeba histolytica to eight uninucleate trophozoites

Transmission: Cysts of Entamoeba are transmitted from one individual to another in a variety of ways:

1. The cysts are generally transmitted with food or drink.

2. House flies and cockroaches may trans-mit cysts mechanically.

3. Raw vegetable is also another source of infection.

4. In many countries human faeces are used as fertilizer and thus roots and leaves of plants remain contaminated with viable cysts. Food handlers are also sometimes responsible for the spread of infection owing to imperfect personal sanitary measures.

Pathogenicity (Pathogenic Effects) of Entamoeba Histolytica:

Entamoeba histolytica causes amoebic dysentery, abscesses in liver, lungs and brain and non-dysenteric infections.

1. Amoebic Dysentery: Entamoeba histolytica secretes a tissue dissolving enzyme (probably of histolysin nature) that destroys the epithelial lining of the colon and causes its necrosis and forms the abscesses (small wounds) which later become flask- shaped bleeding ulcers. The cavity of these ulcers is generally filled with mucus, bacteria, amoeba and cell debris. The abscesses pour their contents into the lumen of the intestine. The ulcers vary greatly in number and size; in severe cases almost the entire colon is undermined. The ulceration of colon may produce severe dysentery. In amoebic dysentery, the stools are acidic and contain pure blood and mucus, in which swarms of amoeba and blood corpuscles, are usually present. The patient feels discomforted due to the rectal straining and intense gripping pains with the passage of blood and mucus stools every few minutes.

2. Abscesses in Liver, Lungs and Brain: Sometimes Entamoeba histolytica may be drawn into the portal circulation and carried to the liver. In liver the parasites settle, attack the liver tissue and form abscesses. The patient has pain in liver region, fever and high leucocyte number, a condition referred to as amoebic hepatitis. Lung abscesses are fairly frequent; these are usually caused by direct extension from a liver abscess through the diaphragm. The lung abscesses usually rupture into a bronchial tube and discharge a brown mucoid material which is coughed out with the sputum. Sometimes the parasite also forms abscesses in the brain. Abscesses elsewhere are rare.

3. Non-Dysenteric Infections: Although amoebiasis is usually thought of as the cause of dysentery with blood and mucus containing stools or of liver abscesses, these conditions are actually the exception rather than rule and some workers have reported that as many as 90% of dysentery cases in temperate climates are apparently symptomless. Even in tropics, dysentery is exceptional. Although about 10% of the general population is infected with Entamoeba histolytica, yet most of them are carriers or passers. The symptoms commonly associated with chronic amoebiasis are abdominal pain, nausea, and bowel irregularity, with headaches, fatigability and nervousness in minority of cases.

Treatment (Therapy) of Entamoeba Histolytica:

For prompt relief of acute or sub-acute dysentery the injections of Emetin are given. But certain antibiotics, such as Fumagillin, Terramycin, Erythromycin and Aureomycin are more effective and may be given orally. For eradication of intestinal infections or in chronic cases, certain arsenic compounds (Carbarsone, Thiocarbarsone and Vioform) and a number of iodine compounds (Yatren, Diodoquin and Vioform) are effective. For amoebiasis of liver or lungs, Chloroquine is quite effective. The most significant advancement in the treatment of amoebiasis is the use of Metronidazole and Tinidazole as both luminal and tissue amoebicide.

Prevention (Prophylaxis) of Infection Caused by Entamoeba Histolytica:

Following measures are essential in the prevention of the disease:

1. Sanitary disposal of faecal matter.

2. Perfect sanitation and protection of water and vegetables from pollution.

3. Washing of hands with antiseptic soap and water before touching the food.

4. Cleanliness in preparing the food.

5. Protection of foods and drinks from houseflies, cockroaches, etc.

6. Raw and improperly washed and cooked vegetables should be avoided.

Plasmodium vivax

Members of the genus Plasmodium are collec-tively known as malarial parasites because they cause a febrile disease by the bite of the malarial parasite infected female anopheles mosquitoes called malaria. Plasmodium vivax lives as an intracellular parasite in the red blood corpuscles (R.B.Cs) of man in the form of its mature adult condition, called trophozoite. The species of Plasmodium are reported from reptiles, birds and various mammals. However, Plasmodium is widely distributed in tropical and temperate countries of the world but they are no longer a problem in the colder countries of the world. Countries like India, Sri Lanka, Bangladesh, Nepal, Pakistan, etc., are worst affected. Plasmodium vivax has two hosts; man and female Anopheles mosquito. Man is considered to be the primary host and female Anopheles mosquito, the secondary or intermediate host.

Life Cycle and Plasmodium Vivax:

The life cycle of Plasmodium vivax is digenetic involving two hosts as mentioned earlier. Its life cycle is completed both by asexual and sexual phases. Asexual phase of its life cycle is completed in man by schizogony (differentiated into exoerythrocytic schizogony involving pre- and post-erythrocytic schizogonic cycles, and erythrocytic schizogony) and sexual phase of its life cycle is completed in female Anopheles mosquito by gametogony, syngamy and sporogony.

(a) Part of Life-Cycle of P. Vivax in Man (Asexual Cycle):

It is completed in the following way:

Inoculation: When an infected female Anopheles bites a man to suck his blood, then along with its saliva it injects the sporozoite stage of Plasmodium into the human blood. The parasite remains always in the body of one of the two hosts, hence, the sporozoites do not possess any protective covering. The sporozoite, infective stage, is minute measuring about 11 to 12 microns in length and 0.5 to 1 micron in width, sickle-shaped cell with an oval nucleus; mosquito inoculates sporozoites in thousands. The sporozoites are capable of slight gliding movement. In about half an hour the sporozoites disappear from the blood stream, and they enter the parenchymatous cells of the liver where they undergo at least two schizogonic cycles.

Schizogony in Liver Cells: In the liver cells, the sporozoite grows to form a large, round schizont. The schizont divides by multiple fission to form about one thousand to several thousand small spindle-shaped cells called merozoites; this multiple fission is called schizogony. The schizont ruptures and merozoites are liberated into the sinusoids or venous passages of the liver.nThis phase of asexual multiplication is pre-erythrocytic schizogony and the merozoites produced by it are also called cryptozoites or cyptomerozoites; these cryptozoites are immune to medicines and the resistance of the host.

A second phase of asexual multiplication known as an exo-erythrocytic schizogony occurs in the liver cells in which the cryptozoites enter into new liver cells and grow into schizonts, the schizont divides to form merozoites; the merozoites of the second generation are termed metacryptozoites or phanerozoites. The exo-erythrocytic schizogony may continue in more liver cells to form a reservoir of merozoites, or some merozoites after at least two cycles of schizogony may re-enter the blood stream when they invade erythrocytes. It is supposed that the merozoites of second generation, i.e., metacryptozoites are of two types; the more numerous and smaller are micro-metacryptozoites, while larger and less in number are macro-metacryptozoites. In fact, the micro-metacryptozoites invade the R.B.Cs and start erythrocytic schizogony, while the macro-metacryptozoites enter fresh liver cells to continue the exo-erythrocytic schizogony. The merozoites attack only the young and immature corpuscles, (the merozoites of P. malariae attack only old corpuscles, while those of P. falciparum attack all kinds of corpuscles indiscriminately).

Pre-patent and Incubation Periods:The pre-patent period is the duration between the initial sporozoite infection and the first appearance of parasite in the blood. In case of P. vivax, it is about 8 days on an average. The incubation period is the time taken from the infection of man by sporozoites till the appearance of first malarial symptom. In case of P. vivax, it is about 14 days on an average ranging from 10 to 17 days. Of course, during the incubation period the host shows no symptoms of malaria.

Schizogony in Erythrocytes: In the erythrocytes, a third multiplication phase of schizogony occurs which is known as erythrocytic schizogony. The micro-metacryptozoite feeds on erythrocytes, a vacuole appears in it, the nucleus is pushed to one side, and the micro-metacryptozoite is changed into what is called as the ring-shaped trophozoite, the signet ring stage, which is 1/3 to 1/2 the size of the erythrocyte. The signet ring stage is not found in P. falciparum. The trophozoite grows to become rounded and amoeboid, this is the full grown trophozoite and is known as a schizont. The large schizont makes the erythrocyte to become very large. The schizont shows yellowish-brown pigment granules of haemozoin derived from the iron of haemoglobin of erythrocyte; the enlarged erythrocyte acquires granules called Schuffner's dots. The schizont now undergoes multiple fission to form 12 to 24 oval-shaped merozoites; this phase of asexual multiplication is erythrocytic schizogony. The much weakened erythrocyte bursts and the merozoites are liberated into the plasma from where they enter new erythrocytes, then they repeat the erythrocytic schizogony once every 48 hours. However, the merozoites may again go from the blood to the liver cells and invade them to undergo another phase of asexual multiplication which is called post-erythrocytic schizogony.

Formation of Gametocytes: After many generations of schizogony in the blood, some of the merozoites slowly grow large producing much haemozoin, these are inside erythrocytes and do not change in schizonts but they grow and are transformed into two types of gametocytes called macro gametocytes and microgametocytes. The condition which brings about the formation of gametocytes is not known. Gametocytes appear in the peripheral blood at various intervals after the onset of fever, they remain inactive while in the human blood. The macro gametocytes are female, they are round with the food laden cytoplasm and a small eccentric nucleus. The microgametocytes are male, they have a clear cytoplasm and a large central nucleus. Both gametocytes contain large amounts of haemozoin; they enlarge the erythrocytes. Gametocytes remain in the human blood for several weeks, but are unable to develop any further, it is necessary for them to be taken into the body of an Anopheles', if this does not happen they degenerate and die.

(b) Part of Life-Cycle of P. Vivax in Mosquito (Sexual Cycle):

Many species of Anopheles, but not all species, act as intermediate hosts. If the gametocytes are sucked up along with human blood by a female Anopheles then they reach the stomach where corpuscles are dissolved and the gametocytes are set free.

Gametogony: The microgametocytes, after release in the stomach of mosquito, undergo the process of ex-flagellation. The cold-bloodedness of the mosquito is said to stimulate this process. However, the nucleus of microgametocytes divides into 6-8 haploid daughter nuclei. These nuclei migrate towards the periphery of microgametocyte. The cytoplasm pushes out forming long flagellum like structures having one daughter nuclei in each. Thus, 6-8 flagellum like male gametes or microgametes measuring from 20-25 microns in length are formed. Soon these gametes separate and start moving actively in the stomach of mosquito.

On the other hand, the macro gametocytes undergo maturation process, thereby two polar bodies are pushed out and a female gamete or macrogamete is formed. The female gamete is non-motile and develops a cytoplasmic or receptive cone. Stomach of an infected female anopheles with oocysts of Plasmodim

Fertilisation: If microgamete happens to reach the macrogamete, then it enters into the female gamete at the point of cytoplasmic cone and finally complete fusion of nucleus and cytoplasm of the two gametes occurs. This results in the formation of rounded zygote. Several microgametes may approach a macrogamete but only one of them enters the macrogamete and others shed off. The fusion of male and female gametes is called syngamy. Here, the gametes are dissimilar (anisogametes), hence, their fusion is called anisogamy.

Ookinete and Encystment: The zygotes, thus, formed remain rounded and motionless for 24 hours but soon they elongate to become worm-like having pointed ends and motile. The zygotes are now called ookinetes or vermicules. An ookinete measures about 15 to 22 microns in length and 3 microns in width. The ookinete moves and bores through the wall of the stomach of mosquito and comes to lie beneath the outer epithelial layer. (The ultrastructure of ookinete shows the presence of a central, irregular nucleus, dense cytoplasm, brown pigment granules, many mitochondria and ribosomes in it. It also shows the presence of contractile fibrils, the microtubules). However, here they become spherical and secrete a thin elastic membranous cyst. The cyst is also partly secreted by the surrounding tissues of the stomach. Thus, the ookinetes become encysted and in this condition it is referred to as the oocyst. The oocyst grows in size and sometimes called sporont. As many as 50 such oocysts can be seen on the stomach of the host mosquito. Howard (1906) has observed that the ookinetes which do not succeed in boring the stomach wall pass out from mosquito's body with faecal matter.

Sporogony: The nucleus of oocyst first divides by meiosis and then by mitosis several times (Bano, 1959) and its cytoplasm develops vacuoles forming faintly-outlined cells called sporoblasts. Particles of chromatin arrange themselves around the periphery of each sporoblast. Then the cytoplasm forms slender spindle-shaped haploid cells known as sporozoites. Each oocyst may have ten thousand sporozoites, and group of sporozoites gets arranged around the vacuoles. This phase of asexual multiplication in which sporozoites are formed is called sporogony which is completed in 10-20 days from the time the gametocytes are taken in by the mosquito, the time depending on the temperature. The oocyst bursts and sporozoites are liberated into the haemolymph of the mosquito, from where they reach its salivary glands and enter the duct of the hypopharynx. The sporozoites will infect a human host when the mosquito bites and the life cycle is repeated again.

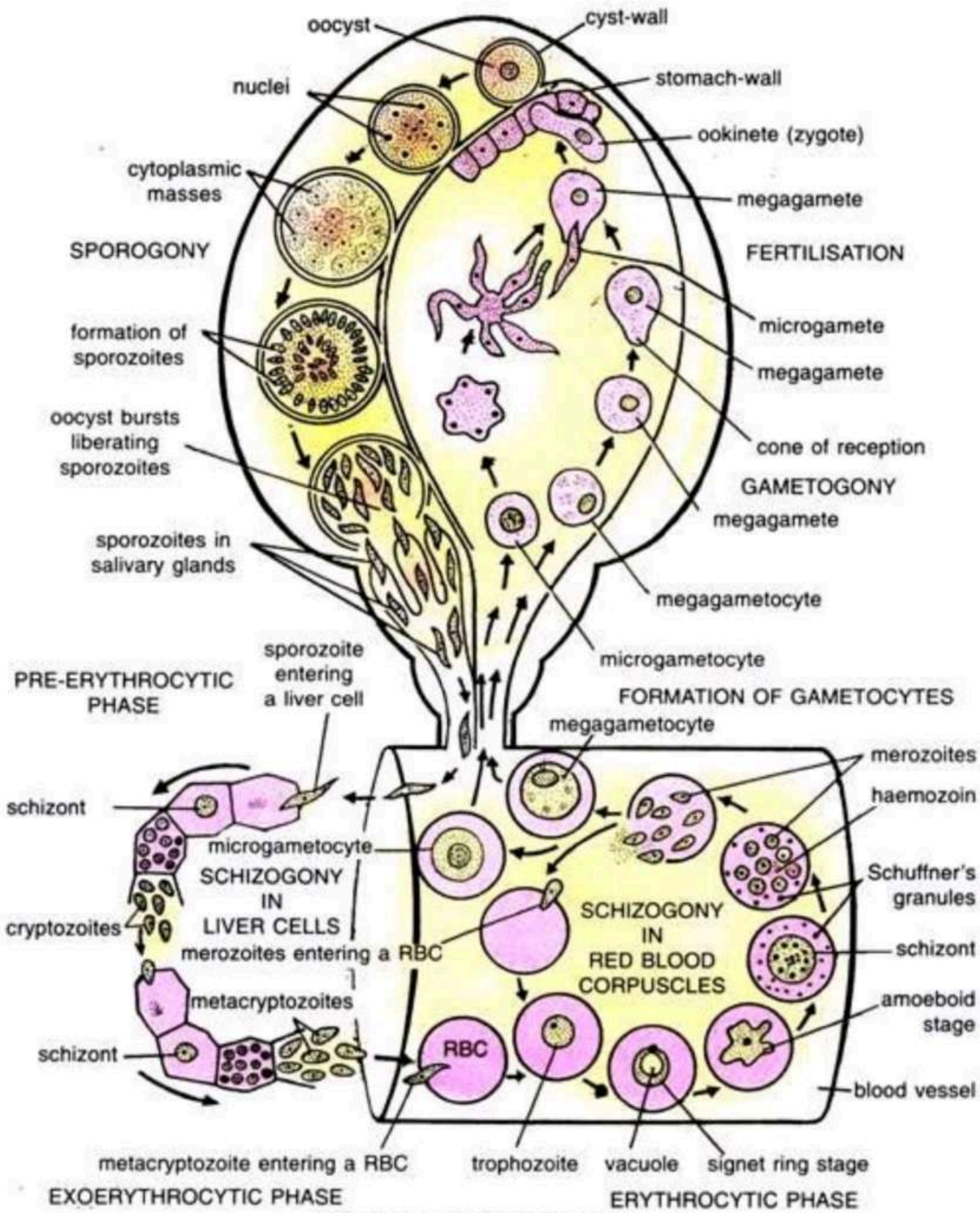


Fig. 19.3. *Plasmodum vivax.* Life cycle.

Pathogenicity:

The basic epidemiology of malaria is the feeling of feverish condition first several days after the infection of Plasmodium. The interval between the time of infection of the parasite and the appearance of symptoms of the malaria is called incubation period which varies 10-40 days and in P.

vivax it varies 13-17 days, and 9-12 in P. falciparum. The pre-patent period follows after incubation period which is the interval between the infection of the parasites and appearance of parasites in the red blood corpuscles. The symptoms of the infection at the end of the incubation period are head-aches, loss of appetite, limb pains, nausea, vomiting and sweating. Finally, the disease is characterized by paroxysm which is divisible into 3 stages, the cold stage or chill, the hot or fever stage and the sweating stage. In the hot or fever stage, the temperature rises as high as 106°F. The benign tertian malaria is caused by the infection of P. vivax and the most fatal malaria is malignant tertian malaria caused by the infection of P. falciparum.

The damage of the malignant malaria is caused by the blocking of the capillaries in the heart, intes-tine and brain, etc. by the infected red blood cells. The other names of malignant malaria are pernicious malaria, aestivo-autumnal malaria and oubtertian or tropical malaria.

The malaria fever occurs due to release of a toxic substance in the plasma of blood, the haemozoin pigments with the rupture of schizonts in the red blood cells. The haemozoin pigments induce high fever and shivering.

Prophylaxis (Prevention of infection):

The malaria can be controlled under fol-lowing categories:

1. Prophylactic use: Certain antimalarial drugs such as quinine, paludrine, daraprim and chloroquine should take small doses regularly as per doctor's advice which may be effective as a precaution before infection for the mosquito bites.

2. Use of antimalarial drugs: The most effective drugs are Quinine, Mepacrine, Chlo-roquine, Amodiaquine, Primaquine, Pamaquine, Qaraprim, Paludrin, Resochin, Proguanil, Suphones which may be used to suppress the symptoms of various stages. For malignant malaria Pamaquine and Primaquine drugs should be taken as per doctor's advice.

3. Protection against the bites of mos-quitoes:

i. Mosquito nets preferably insecticide treated nets should be used during sleep at night which prevent mosquito bites.

ii. Antimosquito creams such as bamber oil, odomos, mylol, dibutyl phthalate (DBP), mustard oil, is also effective which is smeared on the exposed parts of the body.

iii. Various kinds of mosquito coils con-taining cyclothrin, pyrethrum may be effective to protect the body from mosquito bites.

iv. Camphor, Oil of Citronella and Dime-thyl phthalate are used as mosquito repellents, causing insects to move away from their sources.

(i) Elimination of breeding sites of mosquitoes:

The breeding places of the mosquitoes are clean water that stagnates or flows slowly, must be eliminated in such ways:

a. Marshes, nullahs, stagnant water bod-ies, ditches must be drained off.

b. Drains and sceptic tanks must be cleared.

c. All water containing vessels and tanks must be covered with lids and clean at least once a week.

(ii) Destruction of larvae and pupae:

a. The larvae and pupae are killed by spraying kerosine oil, crude oil, petro-leum on the surface of water which forms a film on the water by which the larvae and pupae die for wanting of breathing. The use of Panama larvicide and Paris green in water is helpful to kill the larvae of mosquitoes.

b. Certain chemicals such as DDT, BHC are used as larvicides which are sprayed in the water, which kill the pupae and larvae by suffocation.

(iii) Biological control:

a. Certain fishes such as Guppy (Poecilia reticulatus), Stickle backs, Minnows, Trout, Gambusia (Gambusia affinis), Northo sp. Gold fish (Carassius auratus), Tilapia (Tilapia sp.) eat the larvae and pupae of mosquitoes (WHO Report).

b. Several types of virus, bacteria (Bacte-ria thuringiensis), Nosema (Protozoa) do harm the vectors of malarial parasites help in checking mosquito population.

(iv) Destruction of adult mosquitoes: Spraying of some of insecticides such as DDT, BHC, malathion, dieldrin, pyrethrum, etc.

Trypanosoma gambiense

It ia a protozoan flagellate parasite of human blood transmitted by Tse-tse fly. It is commonly distributed in central Africa, Egyptian countries and almost all territories which have low marshy land. *Trypanosoma gambiense* lives as a parasite in the blood, lymph, lymph nodes, spleen, or cerebrospinal fluid of man and in the intestine of blood-sucking fly *Glossina palpalis* (Tsetse fly). It causes sleeping sickness in man.

Life Cycle

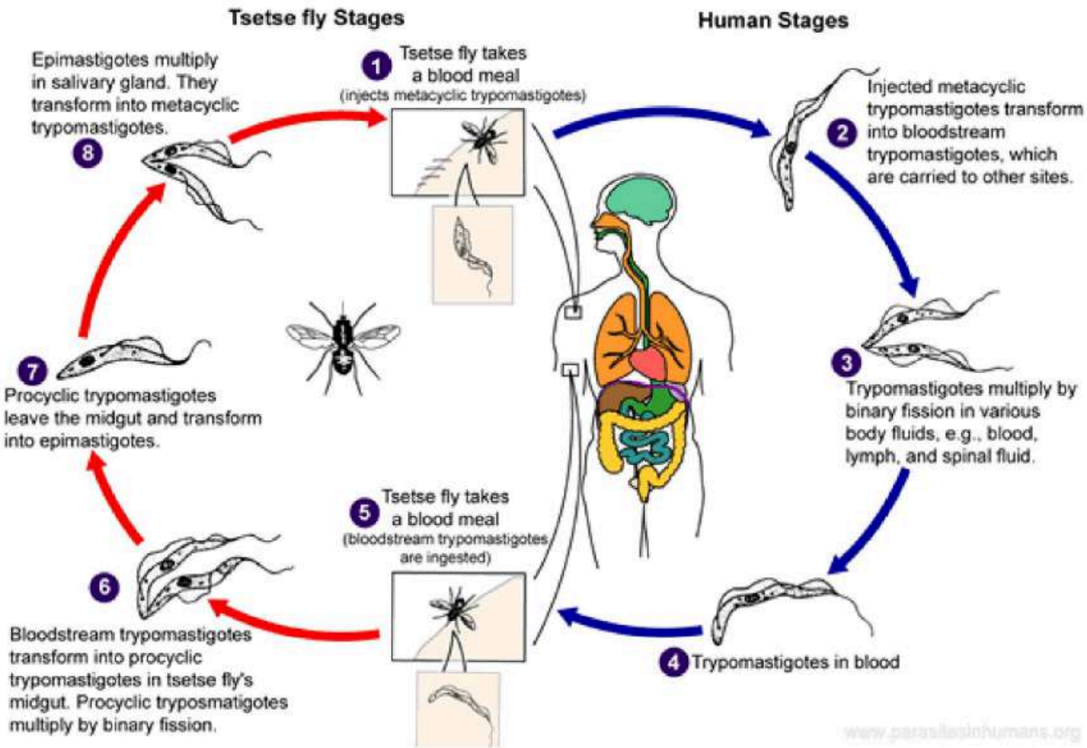
Trypanosoma gambiense is digenetic; i.e., it completes its life cycle in two hosts. The primary or definitive host is man. The mammals, like pigs, buffaloes, antelopes often act as reservoir hosts harbouring the parasite. The intermediate host is blood sucking insect called tsetse fly (Glossina palpalis).

Life cycle in man:

The metacyclic stage (infective form) of *T. gambiense* is introduced into the body of man by the bite of the tsetse fly, *Glossina palpalis*. The tsetse fly harbours the meta-cyclic form in the lumen of its salivary glands. When the vector sucks human's blood, it intro-duces the contained trypanosomes into his blood stream. During sucking through the proboscis, the fly releases metacyclic forms along with saliva. The saliva of tsetse fly contains an anticoagulant which prevents the clotting of blood.

Multiplication: All stages of Trypanosoma in man are extracellular as the parasites are found in blood plasma and not inside blood corpuscles. Within the host's blood the metacyclic forms (which are devoid of flagellum) become trans-formed into long, slender and flagellated forms. They swim within the human blood by the beating of their free flagella and the vibratile movements of the undulating membrane. The adult forms of the parasite multiply by longitudinal binary fission. The multiplication commences at the kinetoplast and is followed by the division of nucleus and cytoplasm.

Metamorphosis: When the glycolysis process is hampered and trypanosomes stop multiplying. The long slender parasites now shrink to short stumpy forms which are devoid of free flagellum. During transformation from long slender form to short stumpy form, the intermediate form along with a small free flagellum also appears. The stumpy forms do not feed and ultimately die. These stumpy forms remain latent till tsetse fly sucks them up along with the blood of the host. Unless this occurs within a reasonable time the stumpy forms degenerate and perish.



Life cycle in tsetse fly: When this insect vec-tor sucks the blood of an infected person, it also takes short stumpy forms of trypomastigote along with the sucked blood. Now these stumpy forms continue development in the midgut of insect vector.

Development in the Midgut of Insect Fly: Further change of trypomastigote occurs in the insect vector's midgut within peritrophic membrane and the short stumpy forms of the parasites trans-form into long slender forms. Now these long slender forms appear which pass to posterior end of the extra-peritrophic space (a space between the peritrophic membrane and epithelial cells), where they continue to multiply for some days. By the 15th day they escape from the peritrophic space and enter the lumen of the proventriculus (the periventricular form is the same as that of the midgut form)

Development within the Salivary Gland of Insect Fly: Later the long slender forms make their way into salivary glands through the hypo- pharynx. Here they multiply and change their morphology, first into epimastigote and then into the metacyclic stage (short stumpy forms of trypo-mastigote) which are infective to man. It has been reported that the time taken for the complete evolution of the infective forms (metacyclic stage) inside the vector insect is about 20 days. These flies remain infective for the rest of their lives, a period extending upto 185 days. When the vector fly bites a healthy person, it transfers the metacyclic forms along with saliva into his blood where they initiate another infec-tion.

Pathogenicity and Symptoms of Trypanosoma Gambiense:

The bite of an infected fly is usually followed by itching and irritation near the wound, and frequently a local dark red lesion develops. In blood, the parasite multiplies and absorbs nutrients from it. After a few days, fever and headache develop, recurring at regular intervals accompanied by increasing weakness, loss of weight and anaemia.

Usually, the parasites succeed in penetrating the lymphatic glands. Because of its infection, the lymphatic glands swell and after it the parasites enter the cerebrospinal fluid and brain causing a sleeping sickness like condition. Development of lethargic condition and recurrence of fever are the symptoms of its infection. Trypanosoma gambiense causes trypanosomiasis; most commonly referred to as sleeping sickness leading to coma stage and finally resulting into the death of the patient. In fact, two types of diseases are caused by Trypanosome which are essentially similar in symptoms. These are Gambian and Rhodesian sleeping sickness. The Gambian sleeping sickness occurs in western part of Africa and its vector is Glossina palpalis, while Rhodesian sleeping sickness occurs in rest of Africa and its vector is Glossina morsitans. The only difference between the two is that the latter is more rapid causing the death of the patient within 3-4 months of infection.

Diagnosis, Treatment and Prevention of Disease Caused by Trypanosoma Gambiense: The diagnosis is confirmed by examining fresh or stained peripheral blood or by examining the cerebrospinal fluid obtained by lumbar puncture or by examining the extract of enlarged lymphatic glands.

Treatment (Therapy): Arsenic and antimony compounds were until recently the drugs for treatment of trypanosomiasis, but now they are rarely used except for late stages when the parasites have invaded the central nervous system.

Prevention (Prophylaxis) : The following measures are suggested for preventing the infection of this parasite:

1. By eradicating the vectors. The infection of this parasite can be checked by completely eradicating the secondary host (Tsetse fly). For this, the endemic areas should be kept clean and regular spray of insecticides like DDT is suggested which help in eradicating the fly.

2. Care should be taken to keep the reservoir hosts free from its infection.

3. Preventive medicines should be taken frequently and periodically which help to a great extent from its infection

1.4 Life history and pathogenisity of Ancylostoma duodenale and Wuchereria bancrofti

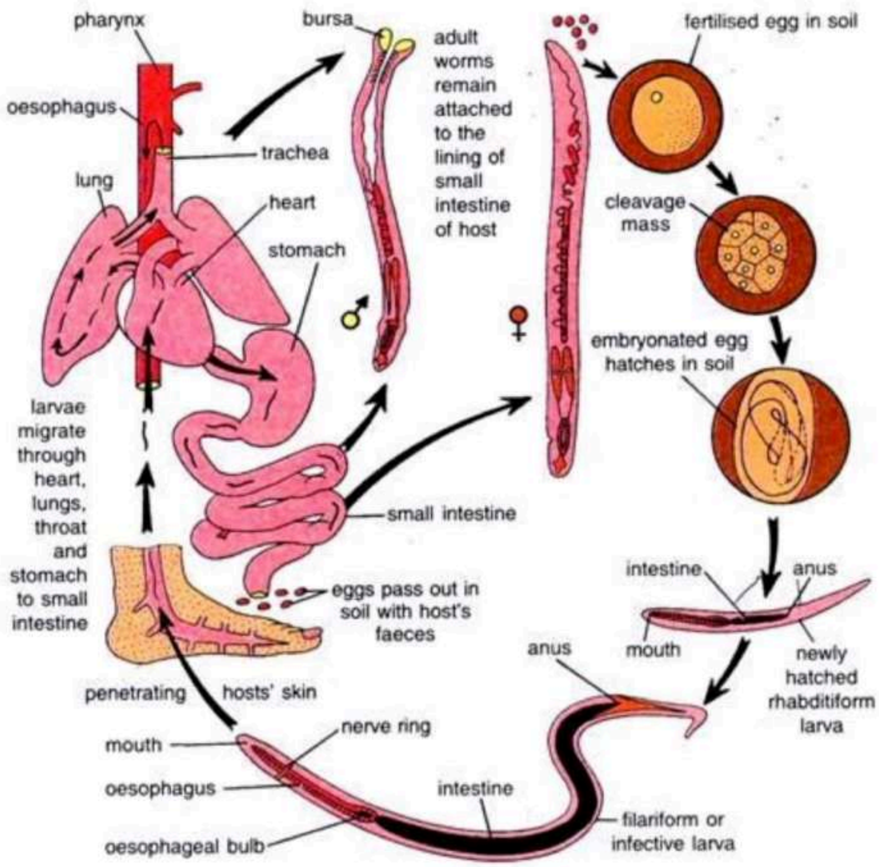
Ancylostoma duodenale

Ancylostoma duodenale is a species of the roundworm genus Ancylostoma. It is a parasitic nematode worm and commonly known as the Old World hookworm. It lives in the small intestine of hosts such as humans, cats and dogs, where it is able to mate and mature. It is also called the common hookworm.

Life History of Ancylostoma Duodenale:

The life history of Ancylostoma duodenale is monogenetic as no intermediate host is required; man is the only main host for Ancylostoma duodenale.

Copulation and Fertilization: Copulation occurs in the intestine of the host, during the process the copulatory bursa of male is applied on the vulva of female and sperms are transferred. In fact, during copulation the worms (a male and a female) assume a Y-shaped figure owing to the position of the genital openings. The sperms, thus, transferred come to lie in the seminal receptacles where fertilisation takes places. The fertilised eggs are then pushed into the uteri for laying through vagina and gonopore.



Egg Laying: The female worm lays eggs in the intestine of the host which pass out with faeces. On an average nearly 9,000 eggs are laid per day by a female. The eggs are oval or elliptical in shape measuring 65 pm in length by 40 pm in breadth, colourless and protected by a transparent hyaline shell-membrane. An egg that comes out of the host body possesses an embryo up to 4-celled or 8-celled stage. The eggs, which passed out with the faeces, are not infective to man.

Development in Soil: Under favourable conditions of environment like moisture, oxygen and temperature (about 68-85°F), the embryo develops into a rhabditiform larva or first stage juvenile; it is about 250 µm in length. This larva hatches out of the egg in the soil in about 48 hours. This larva possesses the mouth, buccal capsule, elongated pharynx, bulb-like oesophagus and intestine. It feeds on bacteria and other debris of the soil and moults twice, on the third day and the fifth day. It then develops into a filariform larva measuring about 500 to 600 pm in length. It is the infective stage of the parasite. This larva does not feed but remains infective and alive for several weeks under favourable conditions. The time taken for development from eggs to filiform larvae, is on an average 8 to 10 days.

Infection to New Host: The filiform larvae are infective to man. The larvae cast off their sheaths and penetrate the skin of a human host. The anterior end of the larva is provided with oral spears by which it penetrates the soft skin of the feet and hands, generally through hair follicles.

Migration and Later Development: On reaching the subcutaneous tissues, the larvae enter into the lymphatic's and small venules. They pass through the lymphatic-vascular system into the venous circulation and are carried through the right heart into the pulmonary capillaries, where they break through the capillary walls to enter into the alveolar spaces. They then migrate on the bronchi →

trachea → larynx, and crawl over the epiglottis to the back of the pharynx and are finally swallowed. During its migration, when it reaches to oesophagus, its third moulting occurs and a terminal buccal capsule is formed. The time taken in this migration is about 10 days. Thus, finally the growing larvae settle down in the small intestine and undergo fourth and final moult to become the adults. In about 3 to 4 weeks time they become sexually mature to repeat the life history again. The life span of the adult worm in human intestine has been estimated differently by different workers; generally it is believed to be 3 to 4 years.

Diagnosis, Disease and Pathogenicity of Ancylostoma Duodenale:

The infection of hookworm is easily diagnosed by the presence of its eggs in faecal smear from the patient. The disease caused by its infection is generally referred to as ancylostomiasis.

The hookworms are the most dangerous parasitic nematodes because they hold on to the intestinal villi and suck blood and body fluids of the host by their muscular pharynx, they also cut holes in the intestinal mucosa and leave bleeding wounds. It causes severe anaemia. In children, where incidence of infection is very great, they retard the physical and mental growth.

Some toxins secreted by the glands in the head region of worms cause stomachache, food fermentation, diarrhoea, constipation, dyspnea, palpitation of heart, eosinophilia, ill health and the patient may finally collapse.

During penetration of larvae in the skin, local irritation is caused resulting into inflammation of the surrounding tissues; these may result into tiny sores. The migratory larvae in lungs may cause haemorrhage and bronchial pneumonites.

Treatment and Prevention of Infection Caused by Ancylostoma Duodenale. Drugs like carbon tetrachloride, thymol, oil of chenopodium, hexylresorcinol, etc., are used effectively to control the infection of Ancylostoma. Some other anti-helminth drugs like tetrachloroethylene and blephenium are found to be more effective and are safe to be used.

Prevention of Infection by Ancylostoma Duodenale: The infection of Ancylostoma duodenale can be checked effectively by improving the sanitary conditions to avoid the contamination of faeces with the soil and other edibles, by protecting feet and hands from being touched with the soil. Children should be directed to keep their hands and nails clean.

Wuchereria bancrofti

Wuchereria bancrofti is a dreadful endoparasite of man; adults harbouring the lymphatic vessels and lymph nodes. Its life history is digenetic, as it involves a secondary host, the blood-sucking insects, i.e., the female mosquitoes of the genus Culex, Aedes or Anopheles; the secondary host for W. bancrofti in India and China is Culex pipiens, in Pacific Islands (except Fiji and New Caledonia) is Anopheles punctatus and in Polynesian Islands is Aedes polynesiensis. Wuchereria bancrofti is a human parasitic roundworm that is the major cause of lymphatic filariasis.

Life History of Wuchereria Bancrofti:

We know that Wucheria bancrofti is digenetic, i.e., its life history is completed in two hosts; man is the main host, while female mosquito, usually *Culex pipiens*, is the secondary host. Mature male and female worms copulate in the lymph glands of man where they usually live. Since female worm is viviparous or ovoviviparous, it delivers numerous larvae called microfilariae. The microfilariae are born in very immature stage.

However, microfilariae find their way into the blood stream where they can live for a considerable time without undergoing any developmental changes. As referred to, due to their nocturnal periodicity they are sucked up by the secondary host when it comes to take its blood-meal from the human body.

Pathogenic manifestations of heavy infection of *Wuchereria*

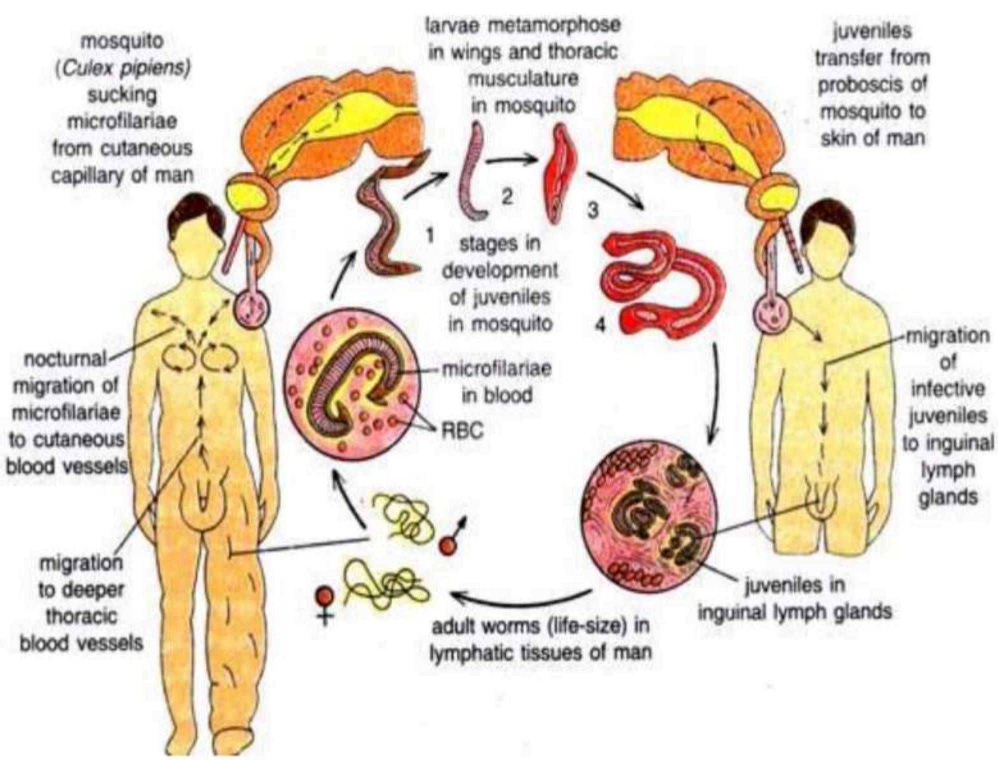
The microfilariae, after reaching in the body of the secondary host, undergo further development to become infective to man. In fact, immediately after their entry in the stomach of mosquito, the sheaths around their bodies are shed off and then they penetrate the gut wall within an hour or two and migrate to the thoracic muscles.

Here they become short and thick like sausages within 2 days having short spiky tails and measure 124 to 250 µm in length and 10 to 17 pm in diameter, they also possess rudimentary digestive tract. These are first stage larvae. Within next 3 to 7 days they grow rapidly and moult once or twice to become the second stage larvae; they measure 225 to 330 µm in length and 15 to 30 pm in diameter.

Finally, by 10th or 11th day they become fully grown and are referred to as third stage larvae; they measure about 1500 to 2000 pm in length and 18 to 23 µm in diameter. This stage is infective to man. These larvae are inactive and come to lie in the labium of the mosquito.

When the mosquito bites the warm and moist skin of man, the larvae creep out of the labium to the human skin, then they penetrate into the skin and finally come to settle down in the lymphatic's. Here, they grow and become fully adult and sexually mature within a period of 5 to 18 months.

These sexually mature worms start reproduction to repeat the life history again. The life span of adult worms is very long, probably ranging from 5 to 10 years.



Diagnosis and Disease of Wuchereria Bancrofti: The infection of Wuchereria bancrofti is diagnosed by the presence of microfilariae in stained blood smear and by the biopsy of lymph nodes. The disease caused by the infection of W. bancrofti is, in general, referred to as wuchereriasis or filariasis.

Pathogenicity of Wuchereria Bancrofti:

In fact, the pathogenic effects seen during filariasis are caused by living or dead adult worms.

A light infection does not produce serious effects; it causes filarial fever, headache and mental depression, etc. But, during heavy infection a large number of pathological effects are observed; in this condition they block the lymphatic vessels and glands causing lymphatic obstruction so that lymph cannot get back to the circulatory system.

Hence, there occurs accumulation of lymph in the affected organs due to which they swell fantastically, a condition called lymphoedema. When they infect lymph nodes then they cause lymphadenitis, in lymph vessels they cause lymphangitis and after infecting epididymis and related areas they cause hydrocele.

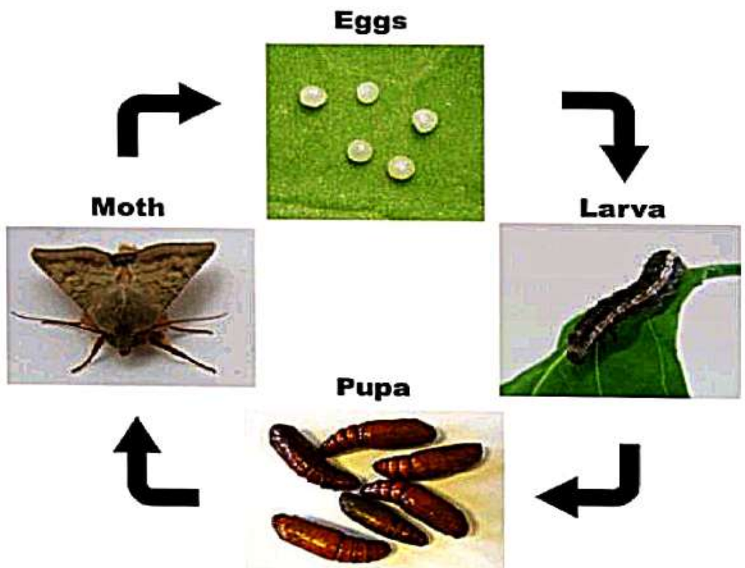
However, the affected organs sometimes become enormously enlarged, producing a tumour-like ugly look, this condition is called elephantiasis; the elephantiasis of feet, hands, scrotum, etc., are of common occurrence in the areas where W. bancrofti is prevalent.

Treatment and Prevention of Disease Caused by Wuchereria Bancrofti:

So far, no satisfactory treatment has been reported. However, heterazan and compounds of antimony and arsenic are used to reduce or eradicate microfilariae from the circulatory system. The only way of prevention is to protect our bodies from mosquito bite.

2.1 Insects of Economic Importance

1. Helicoverpa armigera



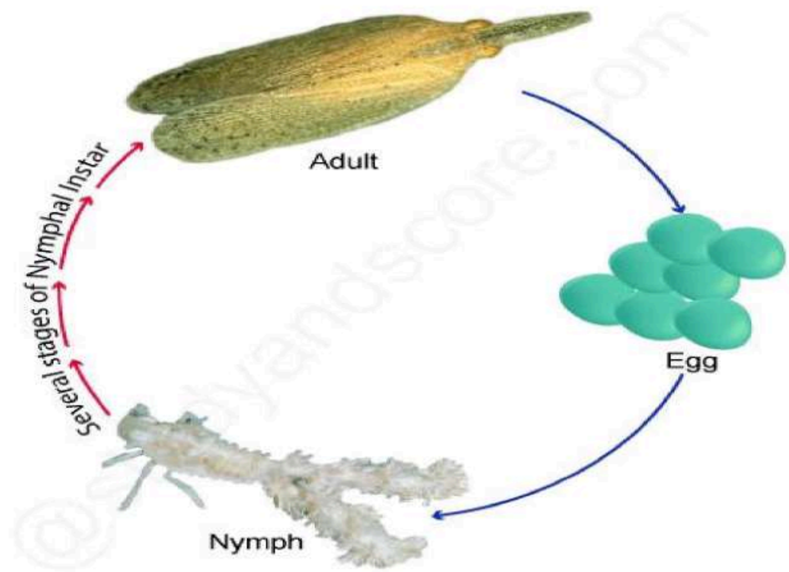
Biology: It is commonly known by the name Cotton Bollworm. The eggs are white to yellowish, brownish at hatching. Young caterpillars are pale green, but later instars are very variable in color (yellowish-green to dark brown) and markings. The adults vary greatly, too; the forewings are yellowish to orange in females and greenish-gray in males, with a slightly darker transversal band in the distal third. The kidney-shaped marking is slightly distinct and smoky.

Each female of H. armigera can lay several hundred eggs, distributed on all parts of the plants, flowers and fruit included. At optimal temperature, the larvae can hatch after less than three days. They then pass through four instars over a three to four week period.

Damage: The voracious caterpillars of H. armigera can feed on leaves and stems, but they show a strong preference for reproductive organs such as buds, inflorescences, berries, pods, capsules etc. They bore into these parts, leaving large, round holes. Older larvae often enter the plant tissue with the anterior part of their bodies only. Young instars, however, may disappear completely inside, so they are sometimes not discovered before the produce (e.g. tomatoes) is processed. Secondary infections by fungi and bacteria are very common and they lead to rotting of fruits. Injury to growing tips disturbs normal plant development; maturity may be delayed, and fruits are often dropped. So in cotton for example, attacked blooms will frequently open prematurely and stay fruitless: when the bolls are damaged, some will fall off, and those that remain either fail to produce lint entirely, or they produce lint of inferior quality.

Control: Useful non-chemical contribution to Integrated Weed Management. Careful tilling and removing harvest residues will expose the pupae to sun and predators, and can thereby significantly reduce the pest's population density.

2.Pyrilla perpusilla



Biology: This insect is a serious pest of sugarcane in northern India where it also occasionally feeds on maize, millets, rice, barley, oats, sorghum, bajra and wild grasses. Adult hoppers are straw coloured to brownish, with a pointed snout bearing piercing and sucking mouth parts. Adults are active fliers, migrating from one crop to another and breed throughout the year. Eggs are light yellowish in colour, oval, one mm long and laid on the lower surface of the leaf. Nymphs are initially greenish, later turn pale brownish, wingless.

Damage: Both adults and nymphs suck the cell sap of succulent leaves of sugarcane by their rostrum. As a result the leaves turn pale yellow. They secrete a sweet sticky transparent liquid known as honey dew which attracts the harmful fungi resulting into a good growth of black shooty mould due to which the photosynthesis is affected and hence productivity also. Because ef the attack of this pest the quality and quantity of sugar is affected.

Control: The egg masses should be collected and destroyed by burning, burying or spraying phenyl water. The pest can be controlled by spraying 0.05% of parathion, malathion, thiodon, fenitrothion or rogor. Dusting the plants with 10% Aldrin or dieldrin also helps.

3.Papilio demoleus

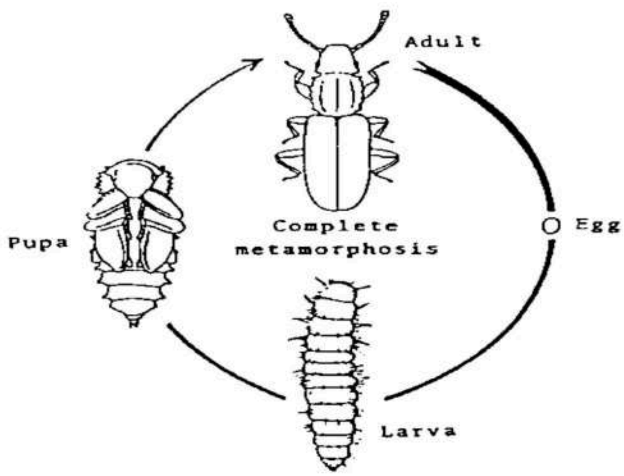
Biology: This is a common pest of all citrus plants. Adult is a large butterfly and has prominent black and yellow markings on the wings. They are active fliers and found throughout the year in plains. Eggs are small, round, smooth, yellowish and laid singly glued on to the tender leaves. They hatch in 3-6 days. First three instars of the larvae resemble bird droppings as they are brownish-black in colour, with one or two white patches. Last two instars are green in colour, sometimes with greyish markings. Pupation takes place on the plant. Pupa, which is called chrysalis, greenish to brown in colour, resembles a twisted leaf and remains attached to a branch with a fine silken thread. Pupal period is 8-15 days.

Damage: Larvae are voracious feeders of tender leaves and defoliate the trees. They eat leaves from margin inwards, leaving the larger veins intact. Younger plants cannot withstand defoliation and die.

Control: Handpicking and destruction of the larvae which are so prominent on the leaves helps to save the plants in nurseries. Dusting the trees with sodium fluosilicate or BHC 5% or spraying malathion, endosulfan, parathion, fentrothion 0.02% or lead arsenate 0.25% effectively controls the pests orchards.

Spraying spores of Bacillus thuringiensis gives high mortality of caterpillars.

4. Callosobruchus chinensis



Biology: It is commonly called pulse beetle. A pest of pulses, cowpea, soybean, gram, pigeon pea, lablab etc. Cosmopolitan in the tropics and subtropics of the world. Adult beetle is 3-4 mm long, female being larger, brownish in colour, broader at shoulders and rounded posteriorly. Adults show sexual dimorphism. Males possess deeply emarginated or indented eyes and prominently serrate antennae, while in female these characters are not distinctly marked. Fecundity is about 100 eggs per female. Eggs are whitish, elongated and stuck on the grains or on pods and sometimes on the surface of the container. Grubs are scarabeiform or eruciform, plump and with short legs and yellowish in colour. First instar larvae bear functional legs and a pair of thoracic plates to facilitate boring into the seeds. They feed on the inner contents of the grain and may damage several grains during development. Completion of life cycle takes 4-5 weeks and there may be 6-7 overlapping generations in a year.

Damage: Both larvae and adults cause damage to the grains. They bite holes in the grains to enter inside and feed on kernel, damaging several grains in the process. As the beetles can actively fly, the infestation can start in the fields, where the beetles deposit their eggs on the pods.

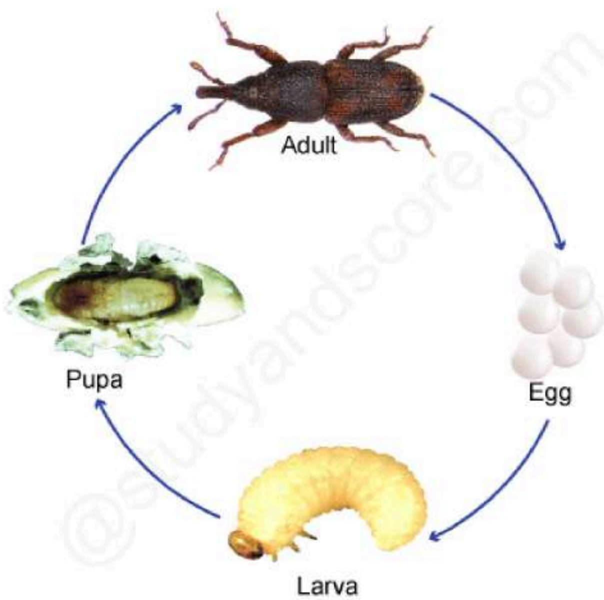
Control: Callosobruchus spp. may be controlled by fumigation treatment with phosphine

Intercropping maize with cowpeas, and not harvesting crops late significantly reduced infestation by C. maculatus

Good store hygiene plays an important role in limiting infestation by these species. The removal of infested residues from last season's harvest is essential, as is general hygiene.

Solarization (or drying and heating) can be used to control infestations of C. maculatus without affecting seed germination,

5. Sitophilus oryzae



LIFE CYCLE OF RICE WEEVIL (*Sitophilus oryzae)*

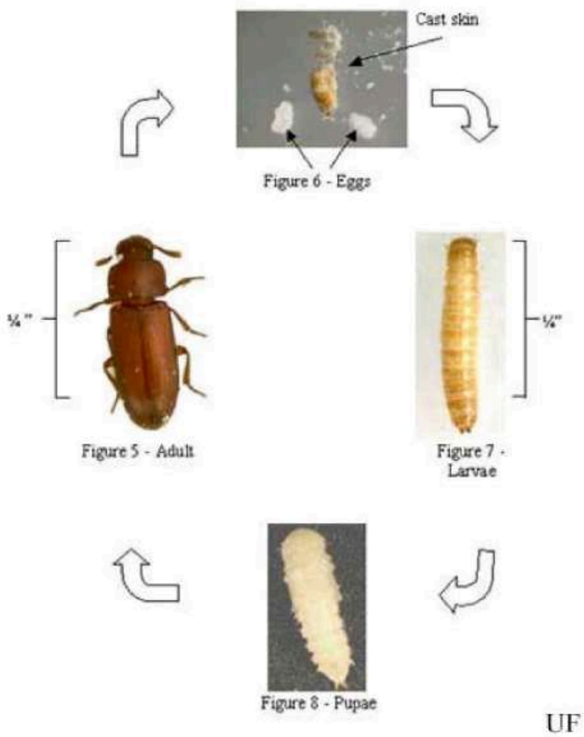
Biology: It is commonly called the rice weevil. This is primarily a pest of rice but occasionally attacks wheat, corn, jowar, flour, beans, dry fruits and biscuits. Adults are 2-3 mm long dark brown weevils, with four faint yellow spots on the elytra. Body is punctured with minute pits. Adults do not fly but try to crawl away when disturbed. Their longevity can be up to 5 months. Eggs are whitish, oval, 0.7 mm long. Females chew a small depression on the surface of rice grain, lay an egg in it and seal it with a gelatinous fluid for protection. Grubs make their way into seed to feed on kernel. They are plump,3-4 mm long, legless, dirty white in colour with a brownish head. Pupation takes place inside the grain. Pupa is light yellowish but later turns dark brown. Adult emerges by cutting a hole in the grain.

Damage: Larva as well as the adult cause damage to grains. Larvae feed inside the seed and make in hollow and exit by making a circular hole on the surface. Adults can damage several seeds by cutting an irregularly lined circular hole, through which they feed on the kernel.

Control: Good store hygiene plays an important role in limiting infestation by S. oryzae. he removal of infested residues from last season's harvest is essential.

Grain may be protected by the admixture of insecticide. Sitophilus spp. have a low susceptibility to synthetic pyrethroids but are readily killed by organophosphorous compounds such as fenitrothion and pirimiphos-methyl.

6. Tribolium castaneum



Biology: It is commonly called red flour beetle. It is a worldwide pest of stored products, particularly food grains. They are cosmopolitan in distribution. Larval and adult both the stages are found infesting and causing damage. The adults are reddish brown and are very active and survive in moderately cold winter in unheated buildings and often live for 2 years in adult stage during which period the fertilized female produces eggs. Eggs hatch into larva which are reddish yellow in colour which after 6 to 7 moultings change into pupae from which the adults arise.

Damage: These beetles cause serious damage in monsoon period. They heavily damage flour in the mills but sometimes damage the grains in store. Both the adult and larva are infective stages.

Control: Flour mills should be kept clean and dry

The infested portion of the flours should be removed

The adults or its other life stages should be removed from stores or godowns

2.2 Insects of Medical Importance

1.Pediculus humanus corporis,

Commonly known as body louse, it is the blood sucking ectoparasite of man and is cosmopolitan in distribution. It is found in the hairs of the armpits, clothes and garments. The asults are wingless, flattened, greyish white insects. It is comparatively larger then the head louse (*Pediculus humanus capitis*).

Medical Importance: They suck the blood, cause annoyance, itching and irritation and transmit certain diseases.

Epidemic typhus: This disease is caused by a PPLO, *Ricketsia prowazeki*, which multiplies in the gut of lice. Spores are released through faeces within 5 days of infection and can remain viable for 4 months in the dry conditions. They get into the human system through contact with blood, through wounds, conjunctive or by inhalation into lungs. The disease spreads in epidemic form and is capable of causing 100% fatality. Reservoir hosts are sheep and goats.

Trench fever: This is caused by *Ricketsia quintana*. The disease was common among soldiers during the world war II, when soldiers had to spend several days trapped in trenches and lice transmitted the disease in epidemic form. The mode of transmission is similar to the epidemic typhus.

Relapsing fever: This disease is transmitted by a spirochaet, *Borrelia recurrentis* which breeds in the haemolymph of the louse and escapes when the louse is crushed or dies due to the parasite. It gets into the human blood through wounds or scratches. This disease spread in great epidemic form during the World War I and II.

Local urticaria and itching: This is also called the Vagabond disease. Itching, rashes and discoloration of the skin takes place due to the allergic reaction to the bites and blood sucking by lice.

Control: Cleanliness and hygiene eradicates lice. In case of severity of infestation, clean shaving of head brings relief. Application of kerosene mixed with olive oil in equal ratio on the head kills lice. Lindane ointment, malathion (Lycil) and Mediker shampoo (also contains malathion) or any insecticide mixed with oil kills all lice on head. The application has to be repeated every week to kill nymphs emerging from eggs. Body lice can be controlled by steaming or boiling of clothes and bedding or rinsing clothes in weak insecticide solution.

2. Mosquito *(Anopheles, Aedes, Culex)*

The mosquito, whose name comes from the Spanish for "small fly", is a type of insect that belongs to the family Culicidae. There are thousands of species of mosquitoes, but a distinguishing characteristic is that the female possesses a tube-like mouthpart, called a proboscis, which pierces the skin of the host to draw blood. Female mosquitoes require the nutrients (mainly vitamins) in blood to produce eggs.

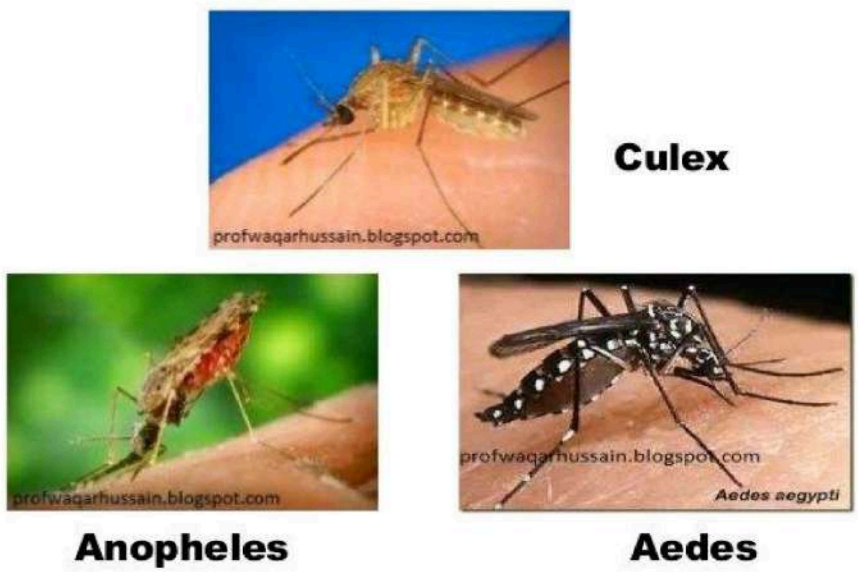
Mosquitoes feed primarily on vertebrates including humans and other mammals, as well as birds, reptiles, and others. Most species have a preference for either humans or certain animals as the source of their blood meal. They are attracted by body odors, carbon dioxide, and heat emitted by person or animal. Most mosquitoes prefer biting at certain hours such as dusk or dawn. Different species also vary in their preferred places to feed or rest; some prefer natural vegetative habitats, while others favor urban environments particularly trash or receptacles in yards.

While obtaining a blood meal from a host, the female mosquito injects some of its own saliva into the skin. The saliva contains anticoagulants and anti-inflammation substances that prevent the host's blood from clotting so that the proboscis does not become trapped in the host. Upon detecting a foreign substance, the immune system of the host releases histamine and cytokines, substances that cause the itching and wheals associated with mosquito bites.

Although the itching can be very irritating, the much more serious risk from mosquitoes is their ability to serve as vectors, or carriers, for a number of diseases, including Zika virus, dengue, West Nile, yellow fever, and malaria, among many others. The disease-causing viruses and parasites are carried by specific species of mosquitoes. The most prominent mosquito-borne diseases are transmitted by three genera of mosquitoes – Aedes, Culex, and Anopheles

Males of all species have rudimentary maxillae and mandibles so that they cannot suck blood but can suck fluids and nectar from flowers. They also possess very bushy whorl plumose antennae and tip of abdomen with characteristic male genitalia. On the other hand females have short hairs on the antennae and needle-like maxillae and mandibles for piercing the skin of host for sucking blood. Other characteristics are given below according to the species.

The adult mosquitoes



Culex: It is dull whitish mosquito having unspotted wings and makes humming sound when flying. There are overlapping scales and six transverse whitish bands on the abdomen. Thorax has no markings on the dorsal side. While resting it sits parallel to the ground. There are about 240 species in India out of which 4-5 are vectors of diseases. It breeds in cesspools, drains, disused wells and stagnated water. Polluted water is preferred for breeding. *Culex*, a large group of mosquitoes also known as common house mosquitoes, are the principal vectors that spread the viruses that cause West Nile fever, St. Louis encephalitis, and Japanese encephalitis, as well as viral diseases of birds and horses. *Culex* mosquitoes can also transmit the parasitic disease lymphatic filariasis and the bacterial disease tularemia.

Culex mosquitoes are distributed worldwide in tropical and temperate regions, with the exception of extreme northern latitudes. They feed at night on humans and animals and are found indoors and outdoors.

<u>Aedes:</u> This is called zebra mosquito as it has black and white bands on the abdomen and legs. The Aedes mosquitoes are the carriers of many viral diseases including Zika, dengue, chikungunya, yellow fever, and Rift Valley disease. The Aedes mosquitoes can be identified by the distinctive black and white markings on their bodies and legs. Unlike most other mosquitoes, Aedes mosquitoes are active and bite only during the daytime, with peak activity during the early morning and in the evening before dusk. There are two specific species of Aedes that are important transmitters of viruses – *Aedes aegypti* and *Aedes albopictus. Aedes aegypti*, also known as the yellow fever mosquito, is found in urban areas, is active both indoors and outdoors, and has a preference for humans as the source of its blood meal. *Aedes albopictus*, commonly referred to as the Asian tiger mosquito, is mostly associated with areas of vegetation and is found primarily outdoors; the female will bite domestic and wild animals, as well as humans. Because the *Aedes aegypti* mosquitoes live near and prefer to feed on people, they are more likely to spread viral diseases than are the *Aedes albopictus* mosquitoes.

Although the range of the two species of mosquitoes was originally confined to localized tropical and subtropical regions - *Aedes aegypti* in Africa and *Aedes albopictus* in Southeast Asia - they are both now distributed in tropical and subtropical areas worldwide. In the United States, *Aedes aegypti* is found in the more southern states, while *Aedes albopictus* can survive colder temperatures and is found further to the north.

Anopheles. Adults are dull whitish in colour having wings with blackish spots and dark veins. They make no noise while flying. There may be scattered scales on the abdomen. Thorax without any markings on the dorsal side and scutellum not lobed and has uniformly distributed hairs on its posterior margin. Maxillary palps in both sexes are equal to proboscis but in male they are clubbed at the tip. Adult in resting position makes an angle of 45 degrees against the surface.

Anopheles mosquitoes are best known for spreading malaria, although they can transmit other diseases. They are active between sunrise and sunset, and can be found both indoors and outdoors. The females feed on both humans and animals, but some species have a preference for one over the other; species that favor humans pose the greatest risk for transmitting malaria.

<u>Medical Importance:</u> These groups of mosquitoes cause irritation during biting, lead to allergy and suck blood. But theie main role is in transmission of number of diseases.

Chikungunya virus causes a disease that, while rarely fatal, can cause debilitating joint pain that can last for weeks. Typical symptoms include fever and rash, as well as pain. The virus, which is classified as an alphavirus, is similar to dengue virus. The two viruses produce many of the same symptoms and both are carried by the *Aedes* mosquitoes, primarily *Aedes aegypti.*

Dengue virus causes dengue fever, a disease characterized by high fever, headache, joint pain, and rash. A more severe form, dengue hemorrhagic fever, can include bleeding and breathing difficulty and is fatal in some cases. There are four types of dengue virus, and they belong to a class of viruses known as flaviviruses – the family that also includes the West Nile, yellow fever, and Zika viruses. Dengue, transmitted predominantly by *Aedes aegypti* mosquitoes, is found in more than 100 countries.

Yellow fever virus most commonly causes fever, headache, muscle pain, and nausea in those individuals who develop symptoms (many do not); these symptoms can initially be mistaken for malaria. The virus, classified as a flavivirus, is generally transmitted by *Aedes aegypti* mosquitoes, the reason that these mosquitoes are also known as yellow fever mosquitoes.

Zika virus, the most recent of these mosquito-borne viruses to emerge, causes no symptoms or only a mild disease that may involve fever, rash, and joint pain in most people who become infected. However, the disease can cause severe neurological defects in the developing fetuses of pregnant women who are infected with Zika virus. Zika virus is classified as a Flavivirus and is transmitted principally by the *Aedes aegypti* mosquito.

West Nile virus can cause death in humans and different bird species. Most people (80%) do not develop any symptoms. Most of the remaining individuals who become infected develop West Nile fever, which is associated with fevers, aches, and nausea. A small percentage (about 1 in 150 infected persons) develops West Nile encephalitis, a more serious disease that produces high fever, neck stiffness, convulsions, muscle weakness, paralysis, and possibly death. West Nile virus belongs to the flavivirus family of viruses. It is transmitted principally by *Culex* mosquitoes. Birds are the reservoir for the virus and mosquitoes acquire the virus when they feed on infected birds.

Culex (female) is the vector of filarial worm *Wuchereria bancrofti*, which causes filariasis in humans.

Different species of anopheles mosquito transmit malaria causing protozoan called *plasmodium.*

MOSQUITO CONTROL: Mosquito control efforts have not been successful because of the ability of mosquitoes to develop resistance against insecticides very quickly and their capacity to inhabit a variety of environmental conditions. The following measures are generally adopted to reduce mosquito populations.

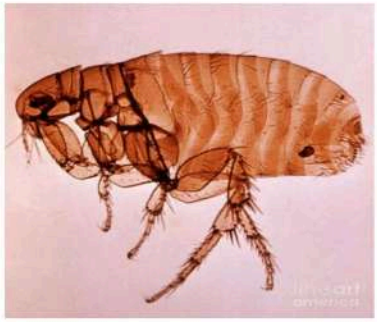
<u>Personal preventive measures:</u> Use of mosquito nets is an effective method to prevent adults from biting and transmitting malaria. Application of mosquito repellent chemicals, such as citronella oil, dimethylphthalate, odomos cream or pyrethrum cream also prevent mosquitoes from sucking blood. Mosquito repelling fumigants, e.g. tortoise mosquito coil contains pyrethrum in it and Goodknight mats or Allout liquids contain synthetic pyrethroids such as deltamethrin, decamethrin and allethrin. They effectively repel and confuse mosquitoes.

<u>Anti-larval measures:</u> Removal of breeding places effectively reduces mosquito population. Broken pots, old tyres, tins and other containers should be removed from the surroundings as they serve as breeding places for Aedes. Coolers and overhead water tanks should be periodically cleaned or treated with potassium permagnate to kill the larvae. Small water bodies, ditches and ponds that cannot be filled should be sprayed with light diesel or petroleum oil that makes a thin film on the water surface and clogs respiratory siphons of larvae. Use of Paris green (copper aceto-arsenite) also kills larval and pupal stages. Biological control of larvae and pupae in ponds has been achieved by releasing larvivorous fishes, such as the native Gambusia and Nothobranchius guntheri introduced by CIBC from Africa. These fishes actively feed on the larvae and can aestivate in mud when ponds dry up in the summer months. Naiads of dragonflies and damselflies are also effective predators of mosquito larvae and pupae.

<u>Anti-adult measures:</u>Trapping of adults by hanging black cloths to serve as hiding places during day time and then killing the adults by spraying insecticide should be done daily. UV electrocuting traps should be used to attract and kill adults. Destruction of tall grasses and bushes serve as resting places for mosquitoes in day time and hence should be removed from the surrounding areas.

Use of malathion and endosulfan aerosols in the colonies periodically has been effective in reducing their populations. Aerial sprays of pyrethrum, carbaryl, carbofuran, arprocarb mixed with mineral oil are still effective in killing adults. Synthetic pyrethroids are quite effective and new chemicals used against mosquitoes but are prohibitively expensive.

3. Xenopsylla cheopis



Fleas are small wingless insects, 2-3 mm long, with highly sclerotised, laterally compressed bodies and reddish-brown colour. Antennae short, stout, pectinate or clubbed and concealed in a groove. Mouth parts are modified for piercing and sucking. Legs adapted for clinging with curved claws. Hind leg longer, modified for jumping.

The Oriental rat flea (*Xenopsylla cheopis*), also known as the tropical rat flea, is a parasite of rodents, primarily of the genus Rattus, and is a primary vector for bubonic plague and murine typhus.

Medical importance: Fleas transmit plague that is caused by the safety pin bacillus called *Yersinia pestis or Pasturella pestis.* The disease is caused in man as well as in rats and produces three types of symptoms in man.

1. Bubonic plague. The bacillus infects lymphatic system, causing swelling and pain in the lymph glands but no fever occurs. Rats also suffer from similar symptoms.

2. Septicemic plague. Infection spreads to the blood vascular system causing fever. There is headache and pain in the back. Sudden chilliness, blood-shot eyes, rapid pulse, thick speech and high fever are other symptoms. In the case of prolonged illness spleen enlarges and becomes brick-red in colour and liver is also enlarged. Comma and death can occur due to heart failure in about a week.

3. Pneumonic plague. In this case bacillus multiplies in the lungs and pleural cavity, causing pneumonia-like symptoms. Yellowish fluid fills the lungs and pleural cavity, causing excessive coughing and heavy breathing. Infection can spread directly from man to man through droplets release during coughing. This is the most dangerous type of plague as it spreads very fast by droplet infection, particularly in high population density areas and brings about quick deaths.

Murine typhus: This is another disease transmitted by *Xenopsylla cheopis*. It is a mild typhoid fever caused by the PPLO, *Rickettsia mooseri*. The causative organism multiplies in the gut of flea and is excreted through faeces. Man gets infected either by contamination of wounds by the flea faeces or by inhalation of dust containing faeces.

Some fleas act as intermediate hosts for the tape worms like, Dipylidium caninum and Hymenolepis diminuta.

Control of fleas: Control of rats is an effective method of controlling fleas. Trapping, baiting and fumigation can eradicate rats. Cyanogas fumigation kills not only rats but also all stages of fleas in the rat burrows. Fumigation should be done every 2-3 months. Construction of rat proof godown having metalled doors and meshed windows is also an effective method to keep the rats away from human dwellings. Dusting the houses, floors, godowns and other places frequented by rats should be done frequently using residual insecticides such as BHC, endosulfan, dieldrin, aldrin etc. This will kill all stages of fleas as they breed in dust and abandoned corners.

Patients suffering from plague can be treated with streptomycin injections or oral doses of antibiotics such as tetracycline, sulphadiazene, chloramphenicol, doxycycline, azithromycin etc. given two or three times in a day.

2.2 Insect pests

Insect pests Of crops

S. No	Pest	Description
1	*Emmalocera depressella* (Sugarcane Root borer)	It is a major **sugarcane pest**, The caterpillar larva of the moth feed voraciously on the stem below the soil surface resulting into formation of dead hearts. The young sugarcanes die and the older ones dry and fall.
2	*Chilo Infuscatellus* (Sugarcane Shoot borer)	Its main host is **sugarcane**, but is also found feeding on bajra and maize. The caterpillar larva of this moth cause damage to sugarcane resulting into the formation of dead hearts
3	*Tryporyza nivella* (Sugarcane Top borer)	Its main host is **sugarcane.** The caterpillar of this moth feeds on growing buds and bores upto 4 to 5 nodes of the top shoot resulting in the drying of the leaves forming dead heart.
4	*Leptocorisa varicornis* (Rice bug or Rice Gandhi bug)	Its main host is **paddy**. It is a major pest of rice and attacks the paddy at the milky stage. Both nymphs and the adult suck the juice from th developing grains as a result of which mature grains are not formed.
5	*Hieroglyphus* (Kharif grasshopper)	It is a major pest of **paddy** crop. Both adult and nymph damage paddy crop by feeding on leaves and shoots

Insect pests of vegetables

S. No	Pest	Description
1	*Raphidopalpa foveicolis* (The red pumpkin beetle)	It feeds on **cucurbitaceous vegetables** like pumpkin, melon, cucumber etc. The adult beetles as well as grubs both are destructive stages, They feed on the leaves flower and buds of the younger plants.
2	*Pieris brassicae* (Cabbage butterfly)	They feed on **cabbage, cauliflower, turnip** etc. Caterpillar larva is the only destructive stage. They feed voraciously on plant leaves resulting into complete destruction of plant.
3	*Epilachna* (The Hada beetle)	These beetles feed on different solanaceous vegetables like **brinjal, Potato, tomato and bitterground.** The dults and grubs both feed on leaves of the plant resulting into complete defoliation.

4	*Dacus cucurbitae* (Melon fruit-fly)	It feeds on **cucurbitaceous** plants. The damage is caused due to maggots by feeding on the almost ripe fruits riddling them and polluting the pulp

Insect pests of oilseeds

S. No	Pest	Description
1	*Athelia lugens* (Mustard sawfly)	Its main host is **mustard**. The damge is caused by the caterpillar larval stage who feeds on leaves and shoots
2	*Bagrada cruciferarum* (Painted bug)	It feeds on **mustard**. Nymph and adult both are destructive stages which suck cell sap from leaves and developing pods.
3	*Acherontia styx* (Til Hawk moth)	It is a pest of **sesamum**. The larva feed voraciously on the leaves and defoliate the plant.
4	*Dichorocis punctiferalis* (Castor shoot and capsule borer)	It is a regular pest of **castor**. Caterpillar larva is the damaging stage which kills the terminal shoots.

Insect pests of tea

S.No	Pest	Description
1	*Heliopeltis theivora* (Tea mosquito bug)	Both nymphs and adults are damging stage. They suck sap from, leaves buds and tender stems
2	*Andraca bipunctata* (Bunch caterpillar)	Larva is the damaging stage. It first feeds on leaf surface by scrapping, later feeds on leaf margins and they remain clustered in bunches on branches.
3	*Biston supprersaria* (Tea semilooper)	Damaging stage is larva. It feeds on leaf surface by scrapping and later feeds on leaf margins.

Insect pests of Coffee

S. No	Pest	Description
1	*Xylosandrus compactus* (Coffee shoot hole borer)	The adult and larva both cause infestation. They form tunnel inside the branches of coffee resulting intowilting, defoliation and ultimately plant dies.
2	*Xylotrechus quadripes* (Coffee stem borer)	The larva causes infestation which bores into coffee stem forming tunnels inside the shoot. The infestation causes killing of young plantsand the older plants become unhealthy.

2.4 Insect pest management

Of all demands of man, food is of prime importance. But the fact is that one third of the food produce is lost to pest and diseases world over. Probably man's struggle against pests of crops is as old as agriculture itself. So the entomologists and farmers together must evolve methods to develop and apply the effective control measures against insect pests in order to save the crops in the field as well as under storage. Insect control programme in its broadest sense includes everything which makes the survival of insects difficult and at the same time checks their multiplication. For this purpose the insecticides has revelutionised the protection technology and with the help of insecticides most of the pest population is being managed effectively in very short period. But these insecticides have not been found much effective against fruit flies, borers and polyphagous pests. The control of pests can be broadly divided into natural and applied control. The natural control agencies do not depend upon the activities of human beings and cannot be influenced much by man. The success of applied control depends completely upon human beings for their application. If the population of insects is not being controlled by natural agencies like climatic factors, topographic factors and natural enemies, then the man made efforts are being applied to check the growth of pests. The various forms of applied control are as.

1. Mechanical Control

Destruction of the pest by mechanical means such as burning, trapping, protective screens and barriers or use of temperature and humidity is often useful.

a. **HANDPICKING**: When the infestation is low, the pest is conspicuous and labor is cheap, the pest stages can be destroyed by mechanical means. Eggs of grasshoppers can be destroyed by hand. Alfalfa aphids can be killed by using chain drags on plants less than 10 inches long. Locust nymphs which are congregating can be beaten by sticks and brooms. European corn borer in the stalk can be killed by running the corn stalks through the stalk shredder. Handpicking of sugarcane borer eggs, cabbage butterfly eggs, sawfly larvae on mustard, Papilio larvae from citrus plants and stages of Epilachna beetle is very effective, especially in small areas.
b. **BURNING**: Controlled burning is sometimes recommended to control certain pests. Weedy fallows harboring European corn borers are burnt to destroy overwintering pest stages. To eradicate the pink bollworm dried cotton stalks are piled and dried. Trash and garbage, weeds etc. are collected and burnt to destroy pest stages. Flamethrowers are used to burn locust hoppers and adults that are congregating and marching.
c. **TRAPPING**: Trapping is popular method to lure insects to bait, light etc. to kill them. Traps usually fail to give adequate crop protection but prove useful to know population build up and are convenient to collect insect samples. Many trap designs have been developed room time to time to suit different insect species. Hopper-dozers were formerly used to collect grasshoppers. In these the insects after hitting the back of the machine fall to the bottom and then through a narrow opening collect into a box.

Yellow-pan traps containing water and few drops of oil were proved useful in killing hopper adults on paddy, sugarcane and wheat crops.

Sticky traps are boards of yellow color smeared with sticky substance, which trap and kill the flying insects that are attracted to and try to rest on it.

Pitfall traps are pan-like containers bearing insecticide and embedded below the ground level. Crawling and fast-running insects often fall into them and die.

Light traps attract night-flying insects, which fall into a container having insecticide, water or oil, or hit an electric grid. Light source emitting UV light is most attractive to insects.

Pheromoe traps are particularly effective against the lepidopterous pests. Females release specific pheromone to which males are attracted from considerable distance.

d. **BARRIERS**: In certain instances, barriers may prevent insects from infesting the crop. Cloth screens over seedbeds protect the younger plants from insects, like flea beetles, hoppers, armyworms etc. Metal collars around young plants protect them from cutworms. Trench barriers are used to stop chinch bugs, armyworms, locusts etc. Metal or concrete barriers are used against termites. Barrier spraying of residual insecticides has become more popular against termites, locusts and several other insects. Sticky bands applied around mango tree-trunks during December-January prevent the upward movement of mango mealy bugs, which upon hatching begin to crawl up the trunk to reach the leaves.
e. **TEMPERATURE CONTROL**: Temperature extremes are fatal to insects. This method is used against stored grain pests. Low temperatures that are enough to dormancy can prevent damage. Low temperatures are utilized for the control of insects in flourmills and warehouses. Exposure to subzero temperature for 24 hours is lethal to most of the insects.
f. **DRYING:** Insects infesting stored grains require certain amount of moisture to develop. Neither the rice weevils nor the granary weevils can survive moisture contents as low as 8.0%. Drying the grains either in the sun or by heat blowers reduces infestation of majority of stored grain insects.
g. **RADIATION**: Gamma radiation kills all stages of the pests in storage conditions. This is a common method employed to kill insect stages during export or imports of huge quantities of grains, fruits and vegetables.
h. **ULTRASONIC VIBRATIONS**: Moths are often sensitive to bats' ultrasonic signals and quickly escape from the area. Imitation of the bat's echolocation system helps in scaring away the lepidopterous insect pests from the area.

2. Cultural Control

Cultural control includes such methods of planting, growing and harvesting crops, which will reduce crop damage. Slight modification in the crop rotation, weed control, disposal of crop remnants, resistant varieties, time of planting and harvesting may prove important in combating some insect pests. Control by cultural means can be achieved by the following methods:

a. **By resistant varieties:** Some varieties of plants show greater resistance to pest damage and should be planted if found desirable from other standpoints. For example, Pawnee-wheat is resistant to Hessian fly; Atlas-sorghum is resistant to chinch bug, rice varieties, namely, IR-36, Pattambi-33, IR-42 are resistant to brown planthoppers. Resistance is hereditary and can be utilized in breeding programmes. There can be several types of characters that make the variety resistant. They may be physical, like hairy leaves, which pose difficulty to potato leafhopper in feeding. Varieties of corn with long tight husk are injured less by corn-earworm. Shape of the onion leaves has an important bearing on the resistance against thrips. Certain chemicals like oxalic acid provide resistance to rice varieties against plant hoppers.
b. **By ploughing**: Timely ploughing can disturb and kill the insect pests, eradicate weeds upon which they might feed, expose them to natural enemies or to harsh weather, and bury the pest stages so deeply that few adults can emerge.Plowing effectively controls corn root-aphids because it disturbs and kills them and destroys the weeds upon which they might feed before

the crop is planted. Early ploughing exposes many white root-feeding grubs, which are then destroyed by birds.

c. **By planting practices**: Some pests remain in the seed from harvest to planting time, and can start infestation. Good seed-bed preparation can not only bury many potential pests like Hessian fly but by conserving moisture gives the plant a higher chance of survival and the pests can be easily sprayed down in a smaller area. Date of planting may have an important bearing upon insect infestation. If planting coincides with the emergence or immigration of the adult pest, the crop is likely to be infested severely. Late planting of cotton is likely to be severely infested by the boll weevil because it will fruit at a time when the weevils would be most numerous. Depth of planting is important in the case of potato which if planted deeper, checks infestation of potato tuber moth, since the moth is unable to lay eggs through the cracks in soil.
d. **By harvesting practices**: Control of a number of leguminous pests is possible by timely and thorough mowing of the field. Clean cutting eliminated any leftover plants on which the insects may breed. Uniform mowing on community bases eliminated the existence of tender side-growths on which the insects can breed and live. Mowing indirectly kills the nymphs of Lygus bugs since they are exposed to high temperature, and prompt removal of the hay from the field exposes the pest on bare ground. No stubbles should be left while harvesting.
e. **By crop sanitation:** Destruction of crop residues is a good preventive measure, since it eliminates further insect breeding by cutting off their food supply. Destruction of corn, rice, sugarcane and wheat stubbles is recommended against shoot borer larvae and pupae. Harvested sugarcane crop produces secondary growth on which a sizable population of borers and hoppers can build up for the next season.

   <u>Weed control</u>: Many insects will develop on weeds very different from the crop botanically. Weed control therefore reduces infestation. Leptocorisa and Pyrilla can feed on many grasses in and around the fields. Green leafhoppers of rice can breed on barnyard grass.

   <u>Destruction of volunteer crops</u>: Volunteer crops are those which grow from self-sown or spilled seeds, or which sprout from stubbles. They should be destroyed. A summer rain may cause germination of seeds scattered during the harvesting times. Roots of harvested cotton will sprout and produce an earlier crop on which the pink bollworm can complete one generation and when the main crop emerges there is already a sizable population of the pest available.
f. **By isolation from the secondary host plants**: Insect damage can often be reduced by planting the crop as far away as possible from the other crops, which may serve as secondary hosts. Armyworms may breed on wheat and barley and later may migrate to corn and sorghum. The infestation of potato by potato-aphid, Macrosiphum solanifoli has been found to be associated with rose bushes on which this species passes the winter. Sesamia inferens can migrate from wheat to rice and sugarcane.
g. **By closed seasons:** A monophagous species can be eradicated by not growing the crop for a year or two. Closed seasons are practiced in tropical countries to decrease the damage of the pink bollworm. This is done by not growing cotton collectively by all farmers for a couple of years.
h. **By crop rotation**: Crop rotation is effective against pests that feed on relatively few plant species, and are incapable of long distance migration. Usually graminaceous and leguminous crops are grown alternatively.
i. **Pasturing:** Where enough animals are available, pasturing heavily damaged fields may utilize the remaining plants as fodder and pest stages are destroyed by feeding and trampling by the animal herds.

j. **Fertilizing:** Nitrogenous fertilizers in some soils tend to increase the susceptibility of sorghum to chinch bug. Rapidly growing cotton is more attractive to bollworms, leafworms and fleahoppers. Barley, wheats and oats can withstand greenbug infestation better when fertilized and irrigated.
k. **Flooding:** It is sometimes possible to destroy pests by flooding, as in the rice fields it destroys many migrating sugarcane pests like armyworms. Plowing followed by flooding kills pink bollworms in cotton.
l. **Trap crops:** A trap crop is a small planting of the susceptible crop made earlier than the main crop for the purpose of diverting the insects from the main crop. The plant in trap crop should be very attractive to the insect. For example broom grass is planted around wheat fields in Canada, against wheat stem sawfly, Cephus cinctus. The adult sawflies oviposit in broomgrass stem, usually in large numbers. The wheat crop when planted escapes oviposition. The emerging larvae cannibalize one another and only one larva per stem has a chance to develop, which is usually parasitized. The trap crop thus harbors parasites, which migrate to the wheat crop. Trap crops have been tried in rice against planthoppers

3. Biological Control

Regulation of pest abundance below the level of economic injury is the target of biological control, which is usually done by study, importation, augmentation and conservation of beneficial organisms for the regulation of harmful animal's population. Most of the agricultural pests are insects and these have natural enemies, which are also mostly insects. Therefore most of the examples of biological control come from insects.

Definition: Biological control is the action of natural enemies (parasites, predators and pathogens) in maintaining another organism's population density at a lower level than would occur in their absence.

The importance of biological control has lately been enhanced due to the fact that overwhelming use of insecticides has led to the resurgence of the pests and resistance to insecticides by the pests like mosquitoes, houseflies and stored grain pests. Biological control is based on the utilization of ecological principles; hence it is frequently called Applied Ecology. Maintenance of the balance of nature is an important aspect of biological control.

Natural Biological Control: includes role of natural enemies to contain pest populations in an undisturbed environment.

Applied Biological Control: includes manipulation of biotic factors (natural enemies) by man to reduce the population of a pest species.

Pests of foreign origin usually do not cause serious damage in their native country because there they are kept under check by natural enemies. But when accidentally introduced into a new country they multiply unchecked and become serious pests. Role of biological control is to find out natural enemies of such pests and introduce them in the areas of pest outbreak. Against pests of domestic origin also exotic natural enemies of species closely related to the indigenous pest are imported and released.

Examples: Control of cottony cushion scale (Icerya purchasi) by using vedalia beetle (Rodolia cardinalis) in California in 1988 is an outstanding success story. In 1887, citrus industry in California suffered massive destruction by the cottony cushion scale. Chemical control had failed. A German scholar, Albert Koebele, was assigned the job to find out natural enemies of this pest in its native home, Australia and New Zealand. In Australia, Koebele found a ladybird beetle, Rodolia cardinalis and a dipteran fly, Chryptochaetum feeding on the pest stages. He dispatched many consignments of the two species to USA for release in the orchards. Chryptochaetum failed to establish but Rodolia multiplied so fast that by July, 1889 the scale was virtually wiped out from the valley

Applied biological control is practiced in the following three ways:

a) Importation and colonization of exotic natural enemies: When the target pest is of foreign origin, it is always advantageous to search for its natural enemies in the country of its origin. It is taken as a general rule that the predominant natural enemy occurring at relatively low host densities in the native home offers greatest promise for introduction to new environment. Usually the dormant stage of the parasite (eggs or pupae), or the dormant stages of the parasitized host are shipped. Releases should be timed with the availability of the host stages to be parasitized. To evaluate the effectiveness of the natural enemy introduced, samples are collected at regular intervals and analyzed as life-table data.

b) Conservation and inundative releases of indigenous natural enemies: Conservation of natural enemies demands judicious and minimal use of insecticides on crops, so that parasites and predators are not unnecessarily killed. Selective insecticides which are not harmful to the natural enemies are used, such as organophosphates and methyl esters. Use of favorable application technique, e.g. soil application of systemic insecticides, seed treatment and use of baits, helps to conserve the natural enemies. Sometimes natural enemies are collected from the field, mass-bred in labs and then released in the field, much like biological insecticides, e.g. use of Trichogramma and Bacillus thuringiensis.

c) Manipulation of natural enemies: When a parasite or predator fails to become effective, ecological, biological and physiological studies are conducted to find out reasons for failure. There are various possible ways of enhancing the effectiveness of natural enemies as follows:

· Development of resistant strains of parasites by artificial selection under controlled conditions.

· Provision for supplementary food for adults.

· Use of behavior modifying chemicals (semiochemicals) is sometimes helpful. Extracts of tomato sprayed on corn increases parasitization of Heiothis zea. The predator Chrysopa is strongly attracted to honey dew of aphids. Synomones are chemicals produced by plants which attract natural enemies and Kairomones are chemicals released by host insects that attract natural enemies.

· Genetic improvement of natural enemies by hybridization and artificial selection of different strains, which increases vigor and effectiveness of parasites and sometimes even resistance to insecticides. Intercropping is known to augment parasitic activity.

Advantages: It is a long-time self-perpetuating control of the target pest. Unlike insecticides, there is no fear of pest developing resistance. There is no fear of environmental pollution. In this method balance of nature in the ecosystem is not disturbed. This is a long-term control method and cost of controlling the pest is economical. There is no fear of pest resurgence, as normally happens by the application of insecticides.

Disadvantages: Biological control is a long-term process and takes years before natural enemies could be established and during this period the pest can cause immense damage. Often natural enemies fail to establish, leading to failure of the entire programme. In case of pest outbreak, biocontrol fails to provide immediate relief. In some cases a natural enemy also damages some useful animals or plants. Biocontrol doesn't provide surety. The projects usually have equal chances of failure or success.

4. Integrated Pest Management (IPM)

It is that method of pest control, which utilizes all suitable techniques of pest control to reduce pest populations and maintain them below economic injury level.

IPM is also defined as a stable system of crop protection, which based on the ecological relations within the crop and the environment, combines several methods of pest control in such a way that the pest is prevented from causing economic injury.

The idea of integrated control emerged independently in California and in Netherlands, where it was first known as harmonic control. The term pest management arose in Canada and Australia. It is also called protective management and was originally coined to define the blending of biological control agents with chemical control because these techniques used independently, either failed to produce satisfactory results or caused environmental problems. Therefore, need arose to consolidate these two methods and also other possible means into a unified programme to manage pest population so that economic injury is avoided.

Components of Integrated Pest Management

Various components and techniques that can be utilized in Integrated Pest Management programmes are as follows:

a. **Cultural control**: Use of resistant varieties of crops is a promising technique in IPM. Moderately to low level of resistance is best integrated with chemical and biocontrol agents. Crop rotation and sanitation are also used to reduce the pest population to lower levels.
b. **Mechanical control:** Use of screens or barriers or handpicking in nursery stage of the crops and use of light traps to kill egg-laying adults can bring down the population for the other methods to be effective.
c. **Biological control:** Natural enemies are commonly utilized in IPM programmes. Emphasis is given to protection and augmentation of indigenous natural enemies and recolonisation of those that have been wiped out due to indiscriminate use of insecticides.
d. **Chemical control**: Minimal use of insecticides is recommended in IPM. Rule of the thumb is not to use insecticides unless absolutely necessary. Application methods that do not bring insecticides in contact with natural enemies are favoured in IPM programmes
e. **Regulatory methods**: Plant and animal quarantines by the government and collective eradication and suppression in large areas help in providing long-lasting management. International efforts to suppress noxious pests like locusts have proved fruitful.In most of the cases, chemical, biological and varietal resistances are combined to manage the population of pest species.

Role of biological control in IPM

Being safe, permanent and economical, biocontrol should be of primary consideration in any IPM programme and should not be taken up only when other methods fail. In IPM biological control need not achieve complete success, since other methods combined also contribute in achieving the goal.

There are three major ways to integrate biological control in IPM programmes:

1. conservation and augmentation of natural enemies already available,

2. Importation and colonization of exotic natural enemies and

3. Mass culture and release of indigenous as well as exotic natural enemies.

Conservation is done by using selective insecticides to which natural enemies are resistant or use of soil application methods or habitat management like planting of nectar producing flowering plants in the vicinity of the crop. Cultural practices which maintain diversity of crops in the area are usually beneficial for the natural enemies. Intercropping of selected crops is known to augment parasitic activity. Integration of moderately resistant crop varieties with natural enemies is currently a popular component of pest management.

Role of insecticides in IPM

When pest populations reach above tolerable levels, insecticides provide immediate control. But great majority of insecticides are broadly toxic and therefore ecologically disruptive. Great need for IPM is to develop selective or even specific insecticides which will have negligible effect on non-target species. Modification of dosage, times of application, formulations and placement of material can be utilized to increase selectivity of chemicals. Successful use of pesticides of mites illustrates bright future for selectivity. Use of pheromones, hormones, repellents, antifeedants and sterilants are selelective in their action and hence must be encouraged.

An elementary integration is the application of insecticides and pheromone traps to reduce male population of the pest before undertaking control through sterile male technique, since the latter is more successful at lower pest densities. An example is the control of Mediterranean fruit fly (Ceratitis capitata) on Procida Island in Italy.

Role of varietal resistance in IPM

Use of resistant varieties is a less utilized concept. A low plant resistance is better since it does not impose too much stress on the pest species to change its behavior and develop biotypes. It also harbors natural enemies at low pest densities. A highly resistant crop, on the other hand, wipes out not only the pest species but also the specific natural enemy fauna from the area.

An interesting integration of resistance, cultural practice and chemical control is the planting of trap crop of a susceptible variety or attractive crop on the borders and main crop in the middle, and then spraying only on the susceptible variety where the pest would naturally congregate.

An integration of resistance and biocontrol was shown in California by planting moderately resistant variety of barley and sorghum which complemented the activity of the parasite Lysiphlebus testaceipes in reducing green bug (Schizaphis graminum) population. Advantages of varietal resistance in IPM programmes include: its specificity, easy compatibility with other methods, cumulative effect is carried through generations over a long period and non-disturbance of ecosystem.

Examples of Integrated Pest Management

A. **Cotton pest control in Peru**: Developed by Wille (1951) in Canete Valley which is a self-contained ecosystem surrounded by arid areas. Due to extensive use of organic insecticides and subsequent resistance developed by the cotton pests, the valley was led to the brink of disaster. The following steps were taken to save the crops:

- Prohibition of ratooning.
- Prohibition of synthetic organic insecticides and return to the old calcium and lead arsenates and nicotine sulphates.
- Repopulation of the area with; natural enemies introduced from the surrounding regions.
- Establishment of deadlines for planting, ploughing, irrigation, pruning and harvesting.
- Employment of cultural practices, which led to the establishment of healthy, uniform stands.

As a result of this IPM programme, the pest problem was solved and the whole agro-ecosystem twined into a self-balanced system.

B. **Integrated Pest Management in Paddy:** FAO developed an intercountry programme for IPM in South and Southeast Asia by integrating biological, chemical and cultural control methods.

C**. Integrated Pest Management in Sugarcane**: Chemical control is not successful in sugarcane fields because of technical and mechanical problems of insecticide applications and also insecticide contamination eventually reaching humans. Integration of biological contraol, particularly the egg parasite, Trichogramma species and modification of cultural practices has been found to keep the pest densities below economic injury levels.

D**. Integrated control of locusts**: FAO undertakes constant surveillance throughout the breeding areas and follows the following IPM programme: Eggs are destroyed by ploughing or flooding (mechanical control). Nymphs are controlled either by direct spraying by aircrafts or by barrier spraying, baiting, trenching or burning by flame-throwers. Repellents like neem-oil are sprayed on crop at the time of swarming. Swarms are either sprayed while resting on ground or by aircrafts while migrating. Some biological control is achieved by conserving predators in the breeding grounds.

As we have mentioned previously the mouthparts are homologous with the insectan legs. The main evidence we have to support this comes from comparing the musculature of both the legs and the mouthparts, and by comparing the appendages from different arthropods.

* So, before we get to the mouthparts we need to briefly discuss the generalized arthropod leg. We will discuss the arthropod legs in much greater detail later in the semester. The generalized arthropod leg can be divided into 2 basic regions: the **COXOPODITE** and the **TELOPODITE.**

* The primitive telopodite was composed of the following leg segments: the **TROCHANTER(S), FEMUR, PATELLA, TIBIA, TARSI,** and **PRETARSA.**

* The primitive coxopodite consisted of 2 segments: the **SUBCOXA** and the **COXA.** The subcoxa is not always present in more advanced forms. The subcoxa is stationary, immovable, and incorporated into the pleural wall of the body segment where it becomes, according to Snodgrass, the pleuron, the sclerotization of the pleural wall. The coxa, is now the movable limb basis.

* Inherent in this view is the fact that the insect coxa does not contain elements of the subcoxa. Snodgrass repeated this view in 1950. He further stated that the mandibles were homologous with the coxa; thus, the mandibles have no subcoxal component.

* So, now lets look at the mouthparts.

LABRUM

* The labrum or upper lip is an integral part of the chewing mechanism although unlike the three gnathal mouthparts, it was not modified from appendages. This ovoid sclerite probably represents a portion of the old prostomium overhanging the mouth. It is a broad lobe suspended from the **clypeus** and forms the upper lip. In other words, the labrum simply serves as an upper lip for the preoral cavity, connected with the head capsule only along its proximal margin and freely articulating with the clypeus. Its ental surface may be membranous, and may be produced into a median lobe, called the **epipharynx**. There may also be a mass of sensory pits and setae on its ental surface. Two sets of muscles control the movement of the labrum (see fig. 2.2A in Chapman). One set connects with the anterior margin and moves the labrum away from the mandibles. The other set connects on the posterolateral margins on a couple of small sclerites called **tormae** (sing. **torma**); these move the labrum closer to the mandibles.

MANDIBLES

* The mandibles are the first gnathal segments. The corresponding appendages in the Chelicerata are the pedipalps (the chelicerae are evidence of the intercalary segment, and not homologous with any appendages in present day insects). The mandibles are the paired, hollow, but heavily sclerotized, unsegmented jaws arising directly behind the labrum. The shape and structure of the mandibles can vary greatly; for example, in some insects (such as the grasshoppers and crickets) the mandibles are short and stout, and possess both cutting and grinding ridges, while in others (such as predaceous beetles) they are long and sicklelike.

* In the Crustacea, a great diversity of mandibular form is evident. A well-developed **telopodite** is often present (e.g. *Anaspides tasmaniae*). In this case, a broad **basendite** is present that is entirely movable upon the coxopodite, and which is formed into an **incisor** and **molar region.** The coxopodite has both subcoxal and coxal components.

* In the Diplopoda, the mandible consists of a large basal portion, the coxopodite, which shows a subdivision into subcoxal and coxal portions. Snodgrass recognized the subcoxal portion as the **cardo** and the coxal portion as the **stipes.** There is a distal lobe which is apparently a **basendite**, homologous with the **lacinia** of the insect maxilla.

* The mandibles of the Chilopoda are similar to those of the Diplopoda but the coxopodite is not subdivided. But it does have subcoxal and coxal components. An articulated basendite is present, again homologous with the **lacinia.**

* In the Apterygota, the primitively wingless insects, the mandibles are similar to the Chilopoda and the simpler Crustacea in all groups except the Lepismatidae (Thysanura). The Lepismatidae (silverfish & firebrats) are more closely allied with the Pterygota. In the entognathous groups (Protura & Collembola) and the Archeognatha (Microcoryphia), the mandibles are relatively long and slender and have a single point of articulation (see fig. 2.3 in Chapman). This is called **monocondylic articulation**. The question of whether the mandible of Apterygota is subdivided into the subcoxa and coxa is not addressed by Snodgrass on p. 136, but if we assume that there is homology between the ambulatory limb and the mandible, then we should assume that the mandible of Apterygota is homologous with the coxa of the limb. The subcoxal element will have migrated into the wall of the head capsule. The musculature, having both dorsal and ventral muscles, suggests that the mandibles evolved from the basis of a leg-like appendage provided with the usual tergal and sternal promotor and remotor muscles.

* A different view is given by Matsuda (1965) based upon supposed homologies of the maxillary and mandibular muscles. In a nutshell, this author claims that the insect mandible has subcoxal components because the maxilla has, in his opinion, a subcoxal component (the cardo). Snodgrass holds that the cardo and stipes together represent the coxa. The cardo is subcoxal in origin for Matsuda and Chaudonneret (1950). So, the muscles of the mandible and maxilla can be homologized, therefore, because the maxilla possesses subcoxal components, the mandible does as well.

* The mandibles of the Pterygota and the Lepismatidae differ from those we've seen so far in that they possess 2, not 1, articulations (called **dicondylic articulation)** with the head capsule (see fig. 2.2b in Chapman). The primary (or primitive) point of articulation is accomplished by means of a knob situated on the posterior angle of the mandible, called the **posterior condyle,** which fits into a pocket provided by the ventral margin of the **postgena**. The **anterior mandibular articulation** is a much less prominent projection which is accomodated by a notch in the lateral margins of the **postclypeus** (Chapman says this articulation is with the **subgena**). These mandibles tend to be shorter and more heavily sclerotized, and the cuticle of the cusps is often hardened by the presence of zinc or manganese.

* Two apodemes accomodate the movement of the mandible. The **anterior rotator muscle** and the **posterior rotator muscle** in the Apterygota have become the **adductor** and **abductor** (**note:** abductor muscles move the distal part of an appendage away from the midline of the body, while adductor muscles move the distal part of an appendage towards the body) musles in the Pterygota. The **adductor tendon** is a broad apodeme connecting the mesal margin of the mandible with a set of powerful muscles. These **adductor muscles** close the jaws in the cutting or grinding function. Opening the jaws is accomplished by a comparatively weak set of **abductor muscles** attached to the **abductor tendon** which operates on the outer angle of the mandible. The mandibles, then, are rocked forward with a powerful stroke and backward on a horizontal plane by 2 opposing sets of muscles, while the 2 points of articulation serve as a hinge.

MAXILLA

* The maxillae are paired structures arising directly behind the mandibles, they are broadly united with and articulate with the ventral margin of the postgena; they are segmented and each maxilla bears a feelerlike organ, the **palp.** The basal segment of the maxilla is the **cardo** (pl. = **cardines**), the second segment is the **stipes** (plural = **stipites**). In many insects (including the Orthoptera) the cardo is actually composed of 2 segments. The proximal extremity of the cardo fits into a notch or **maxillary articulation** in the posterior margin of the postgena. The segmented (5 segments in the Orthoptera) palp arises from a lobe on the stipes called the **palpifer** (the apparent first segment or basal attachment of the first maxillary palpus). Distally, the stipes bears 2 lobelike structures: the medial elongate jawlike structure is called the **lacinia,** and the lateral lobelike structure is called the **galea**, either or both may be absent. The palp and the galea are

probably sensory in function, while the lacinia probably functions as another cutting and grinding structure similar to the mandibles. Articulation of the opposing maxillae is on the same horizontal plane as the mandibles.

* Anterior and posterior rotator muscles connect to the cardo; ventral adductor muscles connect the tentorium with both the cardo and stipes. Flexor muscles are contained within the maxillae, connecting from the stipes to both the lacinia and the galea; also, there is a lacinial flexor muscle connecting to the cranium. Neither the lacinia nor the galea have extensor muscles. The palp has elevator and depressor muscles, and each segment has an intrasegmental muscle which causes the next segment to flex.

* The maxilla of the lower Pterygota is more generalized than the 2 other gnathal appendages. Snodgrass considered the cardo and stipes collectively to be the coxa. Matsuda and others claim the cardo is the subcoxa. No good embryological evidence supports this but paleontological evidence does. The palpus is the telopodite. The lacinia and galea are the basendites. There is no evidence for the palpifer to be considered a segment homologous to any limb segment.

LABIUM

* The labium is a single structure, but evolved from 2 maxilla-like structures, and lies behind the maxillae. The labium represents the paired 3rd gnathal appendages that have fused together, and they are sometimes called the 2nd maxillae of the insects.

* The basal part of the labium (equivalent to the maxillary cardines) is called the **postmentum**. The postmentum may be subdivided into a proximal **submentum** and a distal **mentum**. Distal to the postmentum (equivalent to the maxillary stipites) is the **prementum**. The prementum functions similarly to the labrum, it is the posterior lip the closes the mouth opening. The prementum distally bears four lobes, collectively called the **ligula**; the two inner lobes are called the **glossae** (equivalent to the maxillary lacinia) and the two outer lobes are called the **paraglossae** (equivalent to the maxillary galea). These lobes may or may not be present, or they may be fused to form a single median lobe. The prementum also bears laterally on each side a palpus, often composed of 3-segments. The basal region from which the labial palpus arises is called the **palpiger**.

* The distal, free-moving part of the labium including the prementum, the palps, and the terminal lobes (glossae and paraglossae) is sometimes called the **prelabium.** The proximal portion of the labium, including the postmentum (mentum + submentum), which articulates directly with the cervix, and appears to be closely associated with the postocciput as the sclerite of its origin is sometimes called the **postlabium.** The line of flexion between the prelabium and the postlabium is sometimes called the **labial suture.** All the proximal muscles of the labium are inserted on the movable prelabium.

* The musculature of the labium is similar to the maxillae, but there are no muscles that attach to the postmentum. The ventral adductors connect the tentorium to the prementum. Glossae and paraglossae have flexor muscles, but not extensors. There are some muscles in the labium that have no equivalents in the maxillae; these are involved in regulating the flow of saliva, or to move the prementum.

HYPOPHARYNX

* The hypopharynx is an extremely important organ which is generally neglected. It functions as the tongue and has salivary duct openings at its base. It is located below the pharynx, directly posterior to the mouth opening.

* Most of the hypopharynx is membranous, but the **adoral** surface (surface towards the mouth opening) is sclerotized distally, and proximally contains a pair of **suspensorial sclerites**, which are hinged to a pair of **lingual sclerites**; muscles attached to the above sclerites allow the hypopharynx to be moved back and forth. The lower ends of the suspensorial sclerites bend mesad, forming a U-shaped band, called the **suspensorium**. The small lateral arms of the suspensorial sclerites are called the **loral arms**.

* The food is passed over the hypopharynx on its way to the mouth, over the surface of the hypopharynx between the suspensorial sclerites (HS). This surface is usually depressed and is called the **sitophore**. It is the floor of the **cibarium**. Below the hypopharynx and above the inner aspect of the postlabium is formed another cavity called the **salivarium** into which the salivary duct opens.

THE MECHANISM OF INGESTION

* The food delivered from the mandibles into the cibarium is passed on into the mouth by muscular action of the cibarial walls, probably assisted by an adoral movement of the hypopharynx itself.

* **Constriction of the cibarium:** The sitophore has a sheet of transverse muscle fibers attached laterally on the suspensory arms (HS), and the opposing clypeal surface is likewise covered with a layer of transverse fibers which together serve to constrict the cibarium.

* **Dilation of the cibarium:** There is a prominent set of muscles called the intraclypeal muscles (5A & 5B) serve at the same time to compress the clypeus and dilate the cibarium.

* On its lower aspect, the cibarium is dilated by the action of the **fan-shaped muscles originating on the tentorium** (Fig. 7A).

* A primitive sucking pump is produced when the hypopharynx is pushed against the upper surface of the cibarium and the muscles just noted act alternately to dilate and compress the cibarium. No new structure is needed to develop the sucking pump of insects like the mosquito or cicada.

HAUSTELLATE MOUTHPARTS

* There are no fossil records or species in existence that can give us satisfactory clues to the intermediate steps that may have occurred in the evolution of the haustellate mouthparts. The feeding mechanisms for the various haustellate orders of insects (Hymenoptera, Lepidoptera, Diptera, Hemiptera-Homoptera, etc.) are not comparable, that is the elaboration of the basic mandibulate structures into a sucking tube has been different in each group. All of the mandibulate structures have been preserved in the Hymenoptera and Hemiptera, although they are very modified. But the mandibles are completely lacking in some Lepidoptera and Diptera. One structure that all of the haustellate insects do have in common is the modification of the cibarium into a pumping apparatus referred to as the **cibarial pump.**

<u>**Piercing-sucking mouthparts**</u> - Hemiptera

* The long and conspicuous, 3 to 4-segmented **labium** (sometimes called the rostrum) is not involved in the elaboration of the actual piercing-sucking tube. It is an ovate cylinder with heavily sclerotized walls and a shallow dorsal groove or **dorsal gutter.** This is such a highly specialized structure that the elements of a typical mandibulate labium are obscure. The purpose of the labium is simply to serve as a sheath for the sucking mechanism that lies encased in its dorsal gutter while at rest. During feeding, the labium is actually withdrawn and does not enter into the tissues of a host. There is a cluster of papillae at the distal end of the labium which probably is probably sensory in function.

* The piercing-sucking mechanism is a closely appressed bundle of 4, hair or needle-like shafts or **stylets.** An examination of the musculature at the base of these stylets leads us to believe that they were modified from typical appendicular mandibles and maxillae. In gross appearance, the stylets appear to be a single, hair-like bristle. A cross-section, however, reveals that 4 distinct heavily sclerotized and elaborately sculptured structures are involved. The outer pair are the **mandibular stylets** which are grooved to fit an inner pair of **maxillary stylets.** The mandibles are the principal piercing stylets. Note that the tips are pointed and provided with sharp cutting plates and recurved spines for anchoring the stylets in host tissue. The tips of the maxillae are also pointed, but their structure would indicate that they are secondary to the mandibles as penetrating organs.

* The cross-sectional view illustrates the longitudinal grooves and mortising that holds the maxillary stylets together and provides longitudinal tubes. The dorsal tube or **food canal** leads to the cibarium, while the ventral tube or **salivary canal** opens into the salivarium. Mortise joints also hold the mandibular stylets firmly to the maxillae. Although the stylet bundle is securely united, each of the grooved mandibular stylets may move freely and independently upon the maxillae in a longitudinal plane. This forward and longitudinal movement of the mandibles is accomplished by **protractor muscles** arising from the **mandibular apodeme** and attached to the base of the stylet. The maxillary stylets as a unit are also protracted by muscles attached to a **maxillary apodeme** anchored on the posterior tentorium.

* Penetration of host tissue is accomplished by the alternate and individual protraction of each mandibular stylet. When the pair of mandibular stylets have reached a maximum protraction, the pair of maxillary stylets are protracted to a position that is even with them, and the cycle is repeated. Recurved barbs on the tip of the mandibular stylets serve to hold the entire bundle in position in the host tissue during each cycle of protraction. When the stylets have reached a desirable feeding site, saliva is pumped down the salivary canal by means of the elaborate **salivary syringe**, and liquid food is pumped up the food canal by means of the cibarial pump.

* The **labrum** is a sharply pointed flexible flap articulating at its base with the **anteclypeus** and lying over the dorsal gutter of the entire first basal segment of the labium. This modified labrum is more than a simple covering flap. Examination of the ental surface will reveal a deep groove which ensheathes the basal portion of the stylet bundle. This is the **labral stylet groove** which serves to hold the stylets in position before their separation in the head cavity.

Piercing-sucking mouthparts - Diptera (Mosquito)

* **Note:** Diptera mouthparts in general - there is a wide variety of mouthpart types within the Order, but in all types, the salivary canal is within the hypopharynx, and the food canal is formed between the labrum and the other mouthparts. The mandibles and maxillae are styliform in species that suck blood from vertebrates, but they are usually lacking in other species, including the blood-sucking Cyclorrhapha. When they are present, they are the penetrating organs; when they are not present, often the labium is the penetrating organ (if it is expanded and lobe-like, it is called the **labellum**).

* The mosquito mouthparts are also of a piercing-sucking type. Although they are similar to the Hemipteran mouthparts in some respects, they are very different in other respects.

* The encasing sheath is still made up of the **labium**, but now there are 6 stylets rather than the 4 found in the Hemiptera. In addition to the pair of **mandibular stylets** and the pair of **maxillary stylets**, there is also a **labral stylet** and a **hypopharyngeal stylet.** The **maxillary palps** are also well-developed. The **salivary channel** is in the hypopharyngeal stylet. The **food channel** is between the grooved labral stylet and the hypopharyngeal stylet. The labium does no piercing and folds up or back as the stylets enter the tissue.

* Other flies (such as robber flies) are similar except that there are no mandibular stylets and the principal piercing organ is the hypopharynx. There are 4 stylets: the labrum, maxillae, and hypopharynx. The salivary channel is still in the hypopharyngeal stylet, and the food channel is between the labrum and hypopharynx.

* In still other flies (such as horn fly or stable fly) the principal piercing structure in these flies is the labium; the labrum and hypopharynx are slender and stylet-like, and lie in a dorsal groove of the labium. The labium terminates in a pair of small hard plates, the **labellum**, which are armed with teeth. The salivary channel is still in the hypopharynx, and the food channel is still between the labrum and the hypopharynx.

Sponging mouthparts - Diptera (house fly)

* The entire proboscis resembles a stubby, foot-like organ when it is protracted for feeding. In this position, we can recognize 3 distinct regions: 1) a comparatively soft, cone-shaped basal region or **rostrum,** 2) a cylindrical

median region or **haustellum,** and 3) a distal pair of fleshly lobes forming the foot or **labella.** When at rest, the haustellum is partially retracted within the rostrum and is folded anteriorly upon it, while the ventral surface of the labella is tipped upward and posteriorly from its horizontal feeding position.

* The base of the proboscis or the rostrum is largely membranous except for a large U-shaped anterior sclerite identified as the **clypeus**, and 2 small lateral sclerites or **maxillary plates** bearing unsegmented palps which are the **maxillary palps**. The maxillary plates may simply be a remnant of the maxillae or a palpifer.

* The haustellum is a fleshy cylinder which is entirely membranous except for a posterior plate descriptively identified as the **thecal plate,** and a sclerotized dorsal groove or **labial gutter.** Overlying the labial gutter is the **labrum.** Note that the labrum is ovoid in cross-section and deeply grooved on its ental surface. The **hypopharynx** is stylet-like in form and underlies the labrum and lies within the gutter.

* The **salivary gland** provided with a pumping mechanism or **syringe** empties directly into the tubular hypopharynx. The longitudinal groove of the labrum forms a short sucking tube leading from the labellum to the cibarial pump.

* The labella are fleshy lobes forming a foot-like pad at the distal end of the proboscis. It is assumed by morphologists that these lobes are modifications of the labial palps although their resemblance to palps appears quite remote. During feeding, the labella are broadly expanded and directly contact the food souce. The labella is deeply incised on its anterior margin, and the incision corresponds with the groove of the labial gutter. A V-shaped sclerite, the **discal sclerite**, margins the apex of this labellar incision.

* Food passes directly into the food channel formed by the labrum and hypopharynx. A series of tubes transversely line the labellar lobes and empty into large **collecting channels** which parallel the discal sclerite. These tubes are referred to as the **canaliculi,** or pseudotracheae since they remotely resemble the tracheal tubes of the respiratory system. There are 5 sclerotized teeth anchored on the discal plate on the mesal margin of each labellum. These minute teeth are the **prestomal teeth.** When the labella are pressed against a surface and presumably rotated, the prestomal teeth may serve as a cutting and rasping device.

Rasping-sucking mouthparts - Thysanoptera
* Thrips - cone shape formed by clypeus, labrum, and labium.
* Only left mandible present - used to penetrate the plant tissue.
* Maxillary stylets held together to form food channel.
* There is no salivary channel - salivary duct opens in front of esophagus.

Siphoning mouthparts - Lepidoptera
* There is considerable simplification in the formation of the sucking tube in the Lepidoptera. The long, coiled tubular structure bears a superficial resemblance to the ensheathing proboscis of the Hemiptera, but close examination reveals that the proboscis of the Lepidoptera is actually the sucking tube and that it is not a modification of the labium. In cross-section, the proboscis is composed of 2 ovoid cylinders, deeply grooved on their mesal surface, and fitted together by mortise joints so that the longitudinal grooves form a channel or **food canal.** Examination of the basal structures of each half of this proboscis gives us satisfactory clues to its origin.

* Two articulatory sclerites can be readily identified as the **cardo** and **stipes**. Identification of the proboscis as a modification of the maxillae is assured by the inconspicuous, 2-segmented **maxillary palp** borne by the stipes on its ventral margin. The long, sucking tube must, then, be one of the maxillary endites, and each half of the tube is usually identified as the **galea.** At the base of the proboscis, the galea are divided and the food canal empties through a narrow canal into a large, bulbular **cibarial pump.** There is no salivary channel, although adult Lepidoptera do have saliva.

* All of the other typical mandibulate mouthparts are reduced or wanting except for the conspicuous **labial palps.** These palps are usually 3-segmented. The **labium** itself is greatly reduced to a simple oblong **postmental** sclerite articulating with the **cervix,** and a plate-like **prementum** occupying the ventral aspect of the head and bearing the **labial palps.** The **mandibles** are either not present or are represented as vestiges by 2 sclerites arising at the lateral margins of the **labrum.** The **labrum** is a small flap at the base of the proboscis. A fleshly distal tip of the labrum may serve to cover the food canal as it extends into the cibarium. There appear to be no remnants of the **hypopharynx.**

<u>Chewing-lapping mouthparts</u> - Honeybee.

* The **labrum** is a simple flap, and the **mandibles** are preserved as in the typical mandibulate form. Although the **mandibles** are strong **dicondylic** structures, they are no longer employed for tearing and grinding in the ingestion of food. Their function in the drone and queen is obscure, but in the worker the mandibles are employed for grasping, cleaning brood cells, shaping wax, and other duties of the hive. A sexual dimorphism is evident in the form of the mandibles. The ental surface of the worker bee mandible is a flat and apparently effective spatulate tool. The drone, of course, has little interest in the labors of the hive, and the hairy mandibles have relatively less functional form.

* The maxillae, labium, and hypopharynx have been greatly modified into a sucking tube. The head of the honeybee is hypognathous and the **postmentum** is a very small triangular sclerite in comparison with the greatly expanded **prementum**. The **prementum** is a completely sclerotized half-cylinder. This cylindrical structure is completed by the membranous **hypopharynx** on its dorsal surface. There is a **salivary gland** and a small **salivarium** which empties at the apex of the hypopharynx between 2 suspensory rods or **ligular arms**. At the apex of the prementum is a small triangular plate described as the **distal plate of the prementum**, but which may be the **ligula.**

* Two pair of appendages and a median tube complete the labium. The large, segmented outer pair are the **labial palps.** Note that the basal 2 segments are elongated, flat and L-shaped in cross-section. The distal 2 segments of the labial palps are small and typically **palpiform.** A median pair of spoon-shaped appendages are the **paraglossae.** The salivary duct opens at the base of the paraglossae, and when the paraglossae are drawn together they close ventrally over the base of the median glossa. Although the median tube is referred to as the **glossa**, it is an unpaired structure and is only remotely homologous with the glossae of chewing insects. At the tip of the glossa is a spoon-shaped segment given the descriptive but anatomically incorrect name of **flabellum.**

* The maxillae are readily identified as the flat appendages on either side of the labium. The cardo articulates directly with the postmentum by means of a V-shaped sclerite or yoke described as the **lorum,** and with the postgena by means of an articulatory flange. The **stipes** bear a greatly reduced 2-segmented maxillary palp, a weakly sclerotized and lobular **lacinia**, and an elongated and flattened **galea.**

Antennae - review antennal parts and types from text books. You should know the basic parts: scape, pedicel, and flagellum. And you should know the various types of antennae (e.g., moniliform, clavate, labellate, etc.)

Eyes - we will discuss eyes later in the course when we discuss sensory structures.

STRUCTURE OF INSECT HEAD

Insect head is a Anterior most part of insect body it is hard and highly **sclerotized** compact structure which consisting of six segments that are fused to form a **head capsule.** The insect head consists of mouthparts, compound eyes, simple eyes (ocelli) and a single pair of antennae.

The head segments can be divided in to two regions i.e. **procephalon** and **gnathocephalon** (mouth).

Insect head formed by the fusion of six segments that can be divided in to two regions i.e. **procephalon** and **gnathocephalon** (mouth parts).

Six segments of head are represented as.

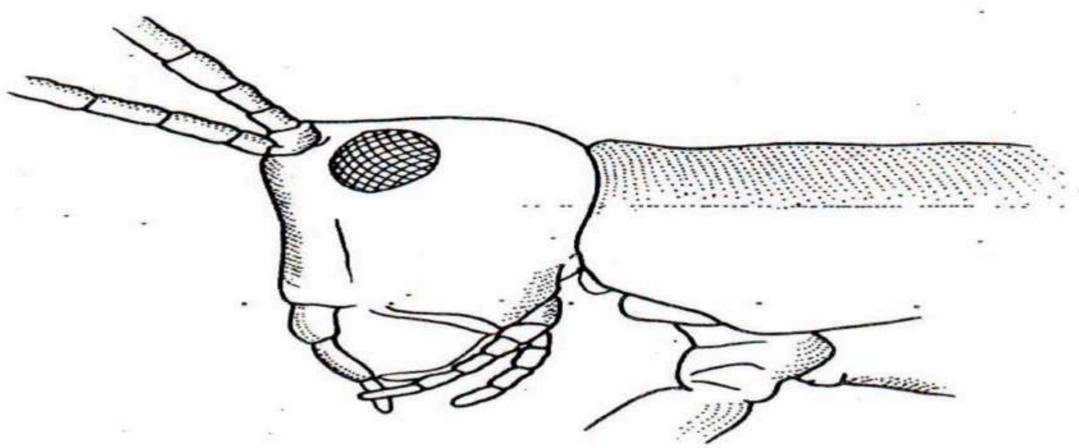
Segment	Appendages
I Pre antennary segment	No appendages
II Antennary segment	Antennae
III Intercalary segment	No appendages
IV Mandibular segment	Mandibles
V First maxillary segment	Maxillae
VI Second maxillary / labial segment	Labium

TYPES OF INSECT HEADS

Based on the inclination of long axis of the head and orientation of mouth parts there are three types of insect heads.

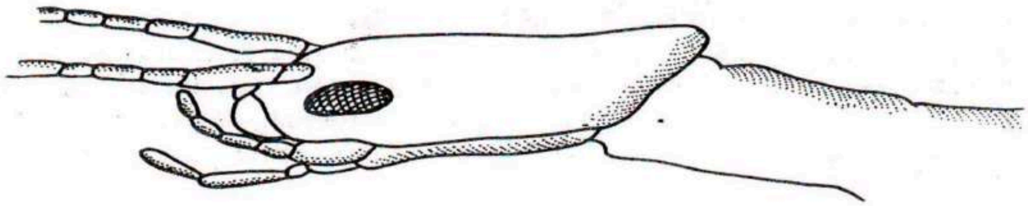
(a) Hypognathous (Hypo – Below: Gnathous – Jaw)

The head remain vertical and is at right angle to the long axis of the body and mouth parts are ventrally placed and projected downwards. This is also kwown as **Orthopteroid** type.. **Eg:** Grass hopper, Cockroach



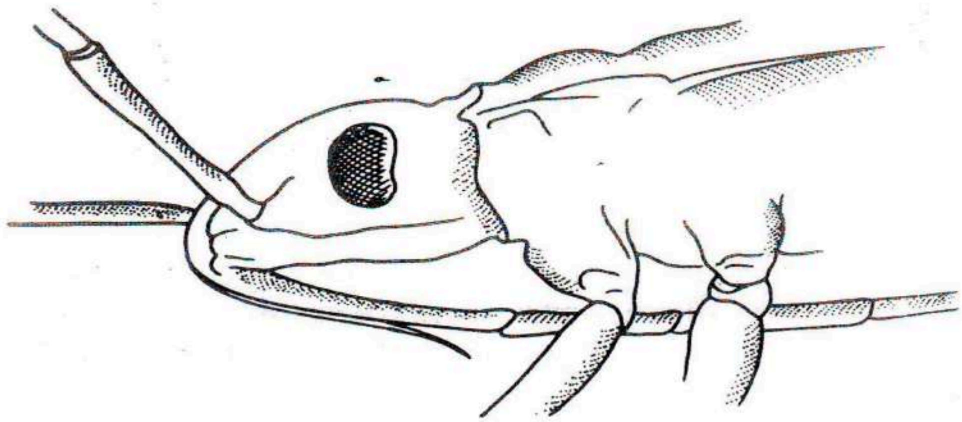
(b) **Prognathous** : **(Pro – infront: Gnathous – Jaw)**

The head remains in the same axis to body and mouth parts are projected forward.. This is also kwown as **Coleopteroid** type..Eg: beetles



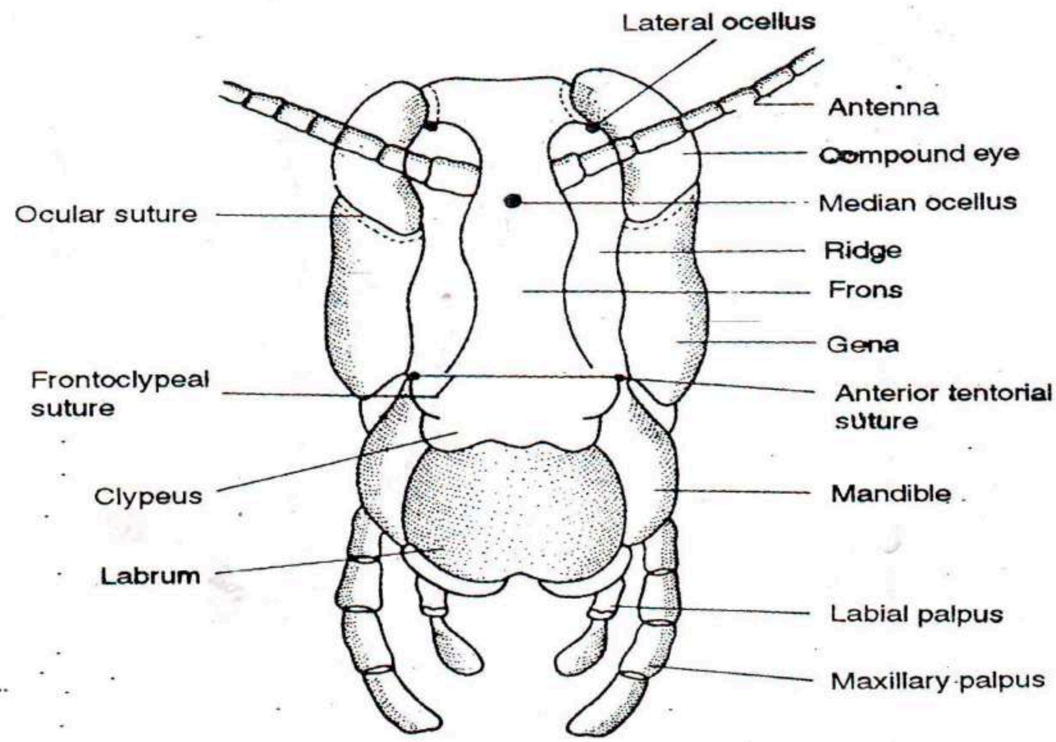
(c) Opisthognathous : (Opistho – behind: Gnathous – Jaw)

It is same as prognathous but mouthparts are directed back ward and held in between the fore legs. .This is also kwown as **Hemipteroid or Opisthorhynchous**.. Eg: bugs

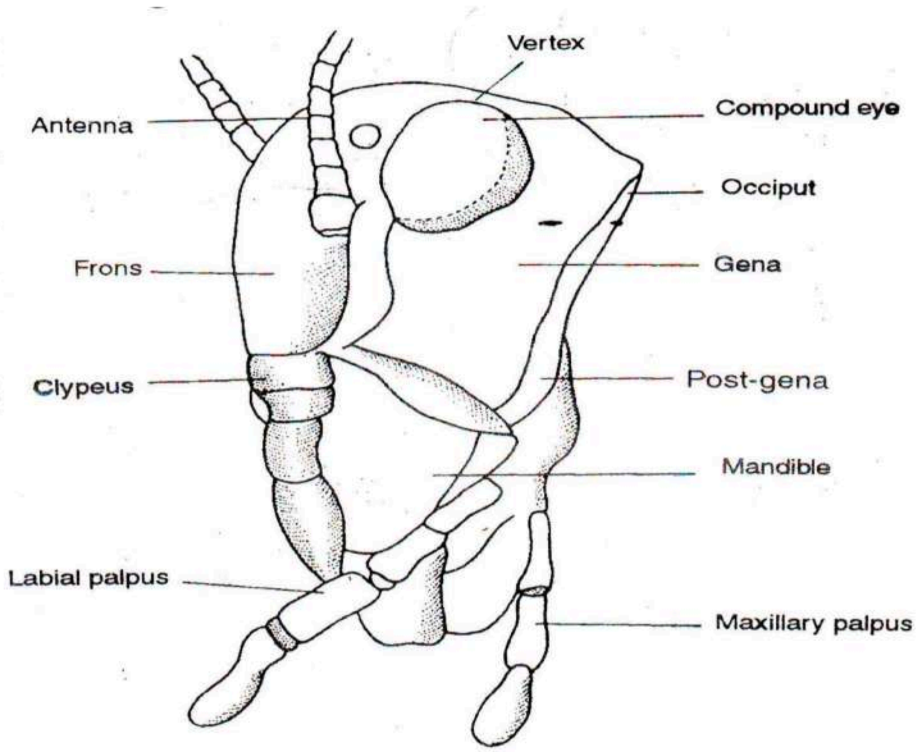


Sclerites and Sutures of Head

The head capsule is formed by the union of number of sclerites or cuticular plates or areas which are joined together by means of cuticular lines or ridges known as **Sutures.** These sutures provide **mechanical support** to the cranial wall.



Frontal View of Insect Head



Lateral View of Insect Head

Sclerites of Head

A general insect posses the following sclerites.

1. **Labrum :** It is small sclerite that forms the upper lip of the mouth cavity. It is freely attached or suspended from the lower margin of the **clypeus.**
2. **Clypeus:** It is situated above the labrum and is divided in to anterior **ante-clypeus** and posterior **post-clypeus.**
3. **Frons :** It is the facial part of the insect consisting of **median ocellus**.
4. **Vertex :** It is the top portion of the head behind the frons or the area between the two compound eyes.
5. **Epicraniun :** It is the upper part of the head extending from vertex to occipital suture.
6. **Occiput :** It is an inverted "U" shaped structure representing the area between the epicranium and post occiput .

7. **Post occiput :** It is the extreme posterior part of the insect head that remains before the neck region.
8. **Gena :** It is the area extending from below the compound eyes to just above the mandibles.
9. **Occular sclerites :** These are cuticular ring like structures present around each compound eye.
10. **Antennal sclerites :** These form the basis for the antennae and present around the scape which are well developed in Plecoptera (stone flies).

All the above sclerites gets attached through cuticular ridges or sutures to provide the attachment for the muscles inside.

Sutures of Head

The common sutures present in head are

1) **Clypeolabral suture :** It is the suture present between clypeus and labrum. It remains in the lower margin of the clypeus from which the labrum hangs down.

2) **Clypeofrontal suture or epistomal suture:** The suture present between clypeus and frons.

3) **Epicranial suture:** It is an inverted 'Y' shaped suture distributed above the facial region extending up to the epicranial part of the head. It consists of two arms called **frontal suture** occupying the frons and stem called as **coronal suture.** This epicranial suture is also known as **line of weakness** or **ecdysial suture** because the exuvial membrane splits along this suture during the process of ecdysis.

4) **Occipital suture:** It is 'U' shaped or horseshoe shaped suture between epicranium and occiput.

5) **Post occipital suture:** It is the **only real suture** in insect head. Posterior end of the head is marked by the post occipital suture to which the sclerites are attached.

As this suture separates the head from the neck, hence named as real suture.

6) **Genal suture:** It is the sutures present on the lateral side of the head i.e. gena.

7) **Occular suture:** It is circular suture present around each compound eye.

8) **Antennal suture:** It is a marginal depressed ring around the antennal socket.