MSCZO612

Laboratory Course: (Entomology)
M.Sc. Zoology IV Sem

DEPARTMENT OF ZOOLOGY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY

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(MSCZO-612)

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Course Title and Code : Laboratory Course: (Entomology): (MSCZO-612)
ISBN :
Copyright : Uttarakhand Open University
Edition : 2023
Published By : Uttarakhand Open University, Haldwani, Nainital- 263139

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Course 1: Laboratory Course: (Entomology):
Course code: (MSCZO-612) Credit: 3

SOS/MSCZO612/ Practical Zoology M.Sc. Zoology 4th Sem.

ENTOMOLOGY

Course III: Laboratory Exercise (MSCZO612) Practical Zoology

UNIT WISE CONTENTS

Candidates must produce at the time of practical examination their preparations, collection and practical record books containing a complete record of the laboratory work done during the session. The practical work shall comprise of following units:

Block I: Laboratory Course, Entomology

Unit 01: Insect Anatomy and Physiology Exercise

1.1 Objectives

- Describe the scope as well as importance of insect anatomy and physiology
- Insect anatomy and physiology
- Importance of haemolymph
- Learn the role of nerves in coordinating different insect function
- Understand the role of vitamins, proteins, amino acids, carbohydrates, lipids, minerals and other food constituents in insect nutrition

1.2 Introduction

Entomology is a branch of zoology, which deals with the study of Hexapods (insects). The word entomology has been derived from Greek word viz., Entomon= Insects and logos = study. The origin of insect dates back to about 350 million years ago. Of the estimated 1.35 million living species of animals more than 9, 00,000 are insects. Their capacity for multiplication and wonderful adaptations has made them a serious threat to human being and their existence. They compete man for 03 basic needs viz., Food, clothing and shelter. Among these, food is common to both of us. With increasing human population, food is now becoming scare and to secure food, human finds insect as his first enemy. Due to this reason, entomology finds its scope in the area of plant protection.

Study of insect anatomy and physiology aims at understanding the insect body organization, their function, habitats, distribution, behaviours, relation to one another and to the surrounding in which they live, their classification, development and their economic importance. In agriculture, insect is both foe (harmful insect) as well as friends. In their attempt to secure food, insects inflict considerable damage to almost every part of the plant.

Additionally some insect spread deadly diseases such as sleeping sickness, malaria, plague, typhus etc.

Insect physiology encompasses the physiology as well as the biochemistry of insect systems. Insect body is usually made up of three main part or tagmata viz., the head, thorax and abdomen. The head region includes six segments with compound eyes, ocelli, antennae and mouthparts (which vary according to the diet of insect e.g. Biting and chewing, Rasping, chewing and lapping, and sucking type).

The thorax is made up of three segments: viz., the pro, meso and meta thorax, each having a pair of leg (insect legs may differ, depending upon its function, e.g., digging, jumping, running and swimming). Usually the middle and the last segment of the thorax have paired wings. The abdomen of insect generally encompasses 11 segments, containing the digestive as well as reproductive organs. Some of the exercises regarding insect anatomy and physiology are given below:

1.3 Study of models of Nervous System of Insects

(A) Caterpillar

Requirement: Caterpillar, Micropipette, Petridish filled with paraffin wax, Stereoscopic dissecting binocular microscope, Forceps, needles, Chloroform or ethyl acetate

Principle: Kill the caterpillar with chloroform or ethyl acetate and prepare it for dissecting in paraffin wax

Method: Fix the caterpillar in paraffin wax with dorsal side facing upwards in Stereoscopic binocular microscope. Now cut the posterior side and slowly pull towards the gut. During this operation ventral chain of ganglion will be exposed. Now free the gut from anus with slight cut and remove it. In a laboratory experiment, it is difficult to justify the effort involved in tracing all nerves and their innervations.

Result:

1. **Central nervous system:** (Brain, sub oesophageal ganglion, three thoracic ganglion and 8 abdominal ganglia)

2. **The visceral (sympathetic or stomatogastric) nervous system:** (Nerves and ganglia associated with foregut)
3. **Peripheral nervous system:** (cranial nerves associated with ventral chain of ganglia)

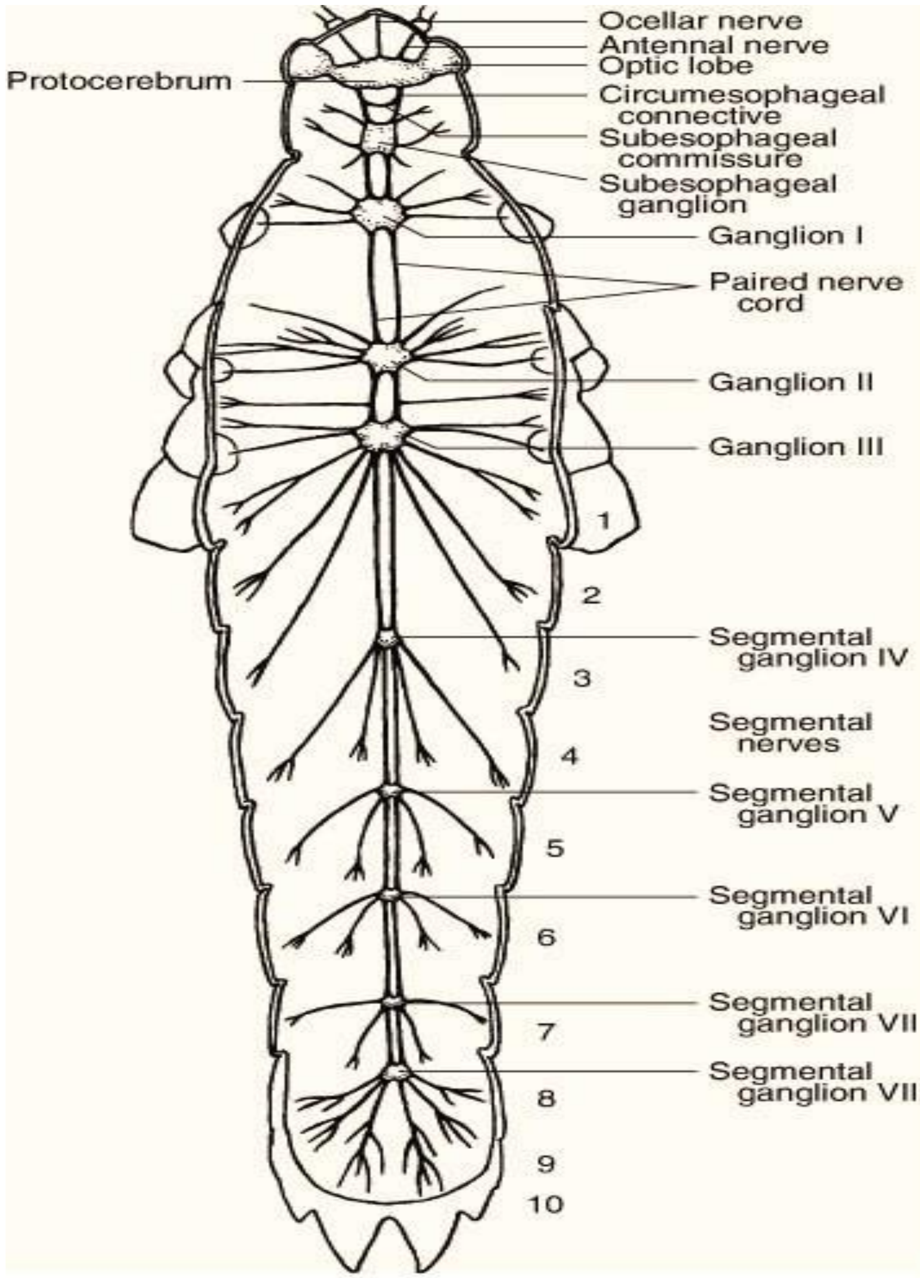


Fig. 1.1. *Nervous system of caterpillar*

As the nervous system is easier to be visualize from abdominal, we must start from the back abdominal region and follow towards cephalic end.

I. Abdominal ganglia

- **First six abdominal ganglia:** The first 6 abdominal ganglia same in each of the segment and are located in the middle of their respective segments. Each ganglion is connected to the succeeding ganglion with a pair of interganglionic connectives (connectives are ganglia joined to each other with longitudinal bundles of axons). On each side latero-anterior margins of the ganglion arises a pair of lateral nerves. To supply ventral side are ventral nerves which run parellel to trachea. Median nerves give rise to two diverging transverse nerves. Transverse nerve and lateral nerves are joined just lateral to ganglion and formed a network of plexus of nerve fibre.
- **Seventh and eighth abdominal ganglia:** These situated in the 7^{th} and 8^{th} segment are the terminal ganglia of abdomen. It is very hard to externally distinguish the interganglionic connectives between them as they are very short. These bear a pair of lateral and ventral nerves. nerves. Transverse and lateral nerves are connected with the help of plexus. The eighth ganglion is composite one. Find a short median nerve arising dorsally at the junction of the 7^{th} and 8^{th} ganglia. Relatively a large lateral nerves arise from the posterior end of the 8^{th} abdominal gagnlia, which pass well into the eighth segment before branching. A pair of ventral nerves will be noticed to leaves the posterior end of the 8^{th} ganglia.

II. Thoracic ganglia

- For three thoracic segments there are 3 thoracic ganglion.
- Mesothoracic and metathoracic ganglia as well as nerves are alike, therefore, the description of metathorax will serve for both. Remove the fats as well as ventral muscles to follow the nevves from first abodominal ganglion. Meta and mesothoracic ganglia are connected through a pair of interganglionic connectives. The lateral nerves do not directly leave the metathoracic ganglion instead, follow the interganglionic connectives for a short distance before diverging and these

independently pass off in a latero-cephalic direction. The short median nerve leaves the posterior side of the mesothoracic ganglion instead of being attached to connectives. It produces a pair of transverse nerves which join the lateral nerves at the sides of the metathoracic segment. The lateral nerves from the metathoracic ganglion are also joined to the transverse nerve coming from the metathoracic ganglion by a pair of unitive nerves. Associated with the unitive nerves is a plexus. A similar relationship exists between the lateral nerves of the mesothoracic segment and the transverse nerves issuing from the prothoracic ganglion. The prothoracic ganglion is connected with the suboesophageal ganglion by a pair of short interganglionic connectives.

III. Cephalic ganglia

❖ It will be necessary at this time to crack the head open along the ecdysial line and to trim the foregut upto the brain. Before removing the crop, note the delicate nerve running along the dorsal median line of the foregut. This is the recurrent nerve which belongs to the stomodeal nervous system.

Suboesophageal ganglion and brain are situated in the head. Gently remove the remaining part of the foregut without damaging the brain. Find the suboesophageal ganglion. It give rise to mandibular maxillary and labial nerves. Two large connectives extend from the anterior end of the suboesophageal ganglion, these are the circumoesophageal connectives one on each side of the gut, upto brain.

The brain lies above the gut, the two large tubes seen in the dorsal dissection are the protocerebral lobes. Several nerves leaves the anterior, ventral surface of the brain, these supply the optic, antennal and clypeolabral organs. Immediately anterior to the median part of the brain are a number of muscle fibres which serve the dorsal dilators of the pharynx. Push these back and locate the short frontal ganglion connectives which join the brain to a small median ganglion. This lies on the dorsal surface of the gut and is called frontal ganglion. The delicate recurrent nerve which follows the median line of the crop, and which was noted earlier in this exercise, proceeds posteriorly from the frontal ganglion. The frontal ganglion, the frontal ganglion connective and the recurrent nerve are the part of the stomodeal nervous system.

(B) Adult

Requirement: Adult insect, Micropipette, Petridish filled with paraffin wax, Stereoscopic dissecting binocular microscope, Forceps, needles, Chloroform or ethyl acetate

Principle: Kill the caterpillar with chloroform or ethyl acetate and prepare it for dissecting in paraffin wax

Method: Fix the head of the insect specimen with the help of pins in the mandibles. Hold the insect specimen (Fig. 1.2) with left hand and clip its wings. Fix the specimen in a dorsal position on a dissecting tray with the help of pins passing through abdominal sterna and coxa of legs. Carefully remove the epicranial plate of the head capsule and expose the cerebral ganglia. Cut the pharynx and pull it out with the oesophagus. Remove the viscera to expose the ventral nerve cord. Expose the roots of the circum-oesophageal connectives on the lateral sides of the brain and trace them to the points where they meet the sub-oesophageal ganglia.

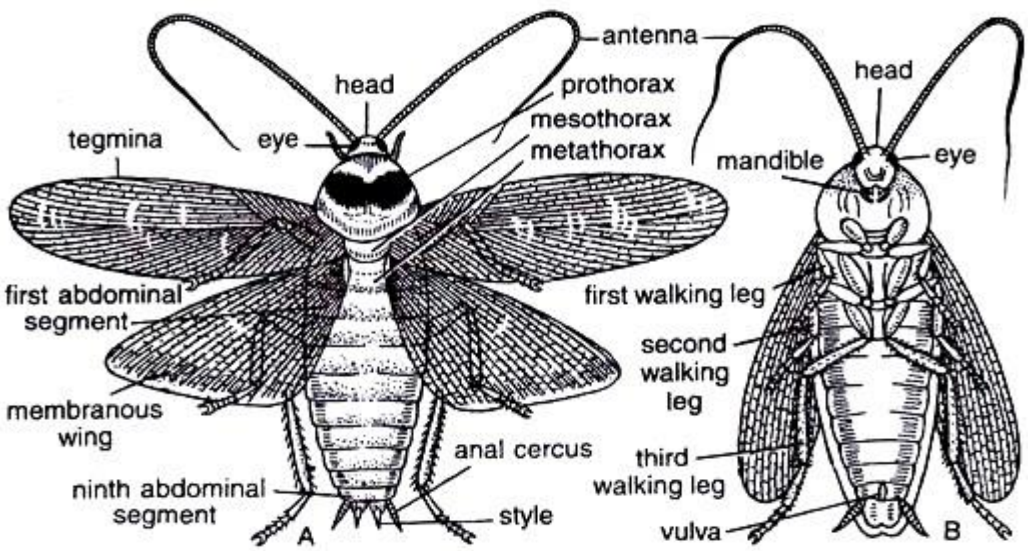


Fig 1.2: Cockroach (Periplanata americana),

A. Dorsal view (male) B.Ventral view (female)

Result: The nervous system of insect can be divided into following 03 sub divisions.

i) **The central nervous system**

ii) **Peripheral nervous system**

iii) **Visceral or sympathetic nervous system**

The central nervous system of cockroach (Fig. 1.3) consists of the supra-oesophageal or cerebral ganglia, sub-oesophageal ganglia and circum-oesophageal connectives in the head and a double ganglionated ventral nerve cord in the thorax and abdomen. The brain or supra-oesophageal ganglia are a pair of large, closely apposed ganglia in the head. From the lower side of the brain, a pair of short, thick circum-oesophageal connectives is arised which runs around the oesophagus and meets the sub-oesophageal ganglia. The sub-oesophageal ganglia are a pair of large ganglia present on the ventral side of oesophagus. The ventral nerve cord runs along the ventral wall of thorax and abdomen and possesses 09 fused ganglia, out of which 03 are thoracic and 06 are abdominal in positio

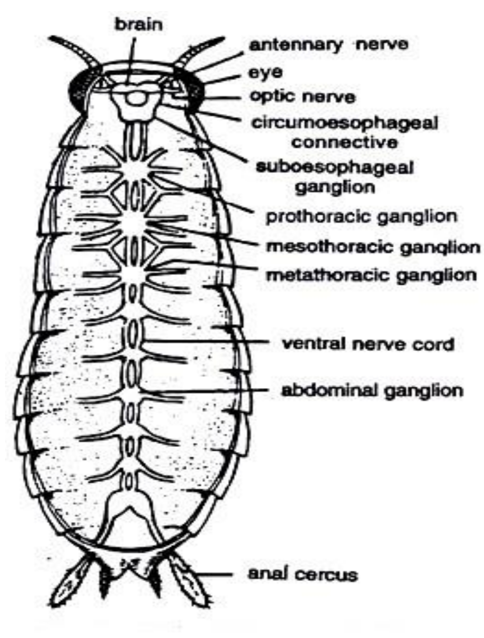


Fig 1.3: Nervous System of Periplanata americana

Out of the 06 abdominal ganglia, the First 05 are present in the first 05 abdominal segments and the last one is present a little behind the sixth abdominal segment. The thoracic and abdominal ganglia are resulted due to the fusion of paired ganglia except the sixth abdominal ganglion which is formed by the fusion of several ganglia and hence largest in size. The peripheral nervous system consists of nerves starting from the ganglia of central nervous system and supplying to various organs in the periphery. From the brain arises a pair of optic and antennary nerves supplying to eyes and antennae respectively. The sub-oesophageal ganglia supplies paired nerves to mandibles, maxillae and labium. The thoracic and first five abdominal ganglia give-off paired segmental nerves to appendages, muscles and other structures. From the sixth abdominal ganglion arise several nerves which are supplied to different parts of sixth and the remaining posterior segments. The sympathetic or visceral nervous system consists of a small frontal ganglion in front of the brain dorsal to pharynx, an oesophageal ganglion on the dorsal side of oesophagus and a large visceral ganglion on the dorsal surface of crop.

1. 4 Counting of Haemocytes in Insects

Requirement: Living Cockroach or grasshopper, Ringer's Solution, glass slide, Micro-syringe, Methylene blue and Eosin stain (aqueous).

Principle: Methylene blue stains the living tissues whereas eosin is a cytoplasmic stain.

Method: Place a drop of Ringer's solution on the clean Slide. Detach an antenna or other appendage of the cockroach. Dip the base of antenna into the Ringer's solution. Shake the slide for a few seconds to mix the contents. Now spread the contents over the slide. Keep the slide for few minutes to settle down the blood cells. Stain the content with methylene blue followed by eosin for differential staining. Allow to dehydrate the content into various gradients of alcoholic series, and mount in DPX.Observe the slide under the compound microscope to see the different types of blood cells.

Results: There are 02 types of cells in the haemolymph of cockroach which are amoebocytes and chromophils. Amoebocytes are comparatively large sized cells with large nuclei. However, chromophils are smaller in size with smaller nuclei but deeply stained. Observe the following various types of haemocyte under the microscope.

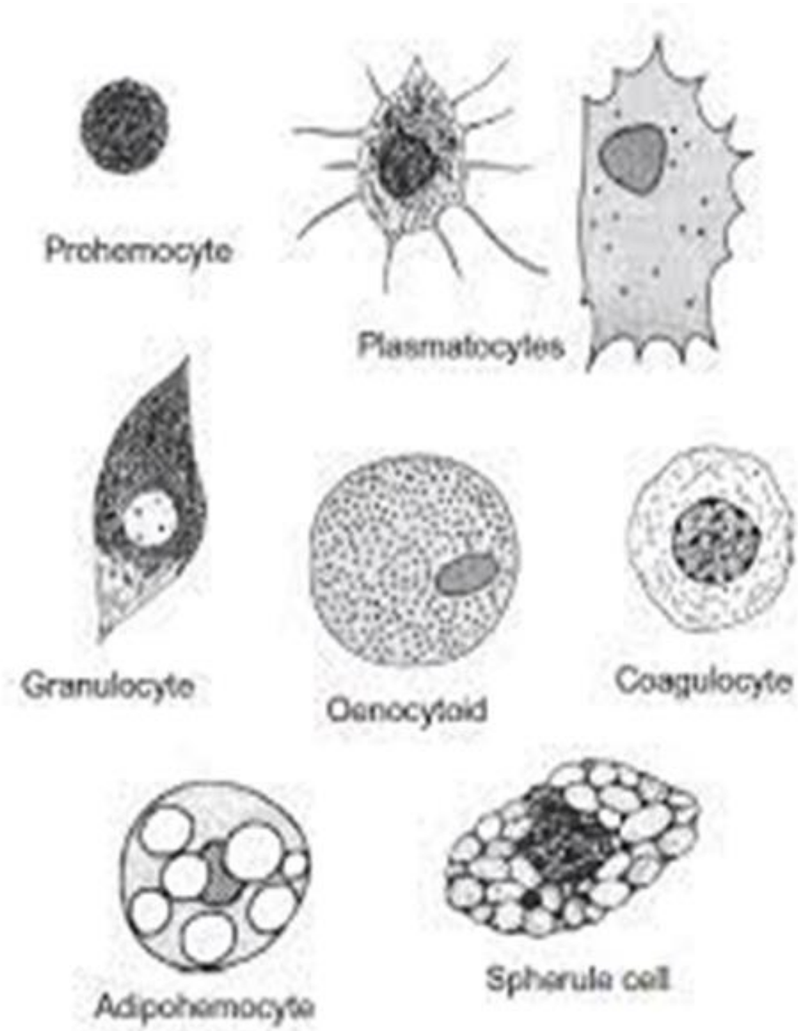


Fig 1.4: *Haemocytes in Insects*

1.5 Estimation of Proteins ,Sugar and Lipids in Insect Haemolymph by Colorimetric Methods :

Requirement:

Procedure:

Collection of Haemolymph: Collect Larva or grub of a particular insect, rinsed it with distilled water and dried the same on filter paper. Now cut one of the pro legs in thorax region and allowed the haemolymph to be poured over phenylthiourea crystals in tubes kept in ice. Haemolymph was then centrifuged at 1000 g for 10 min. for chemical determination.

i) **Molischs test for carbohydrates:** Now take test tubes and add sample of haemolymph. Add few drops of Molischs reagent in it and shake the test tube so that two solutions get mixed up thoroughly. Now add conc. H_2SO_4 in test tube gently along its side so that the two solution didn't mix.

Result: A pink or purple coloured ring appears at the junction of two solutions. H_2SO_4 reacts with carbohydrates and forms furfural derivatives, which on reaction with naphthol of Molisch's reagent gives pink or purple ring at the surface because acid is heavier and does not mix with solution until stirred.

Inference: The given sample has carbohydrates.

ii) **Test for protein:** Take sample from haemolymph in a test tube. Add 1 ml of 40% of NaOH solution in the test tube to make the test solution strongly alkaline and stir it thoroughly. Then add 2 drops of 1% $CuSO_4$ solution.

Result: Violet or pink colour appears which disappears if excess of $CuSO_4$ solution is added.

Inference: it indicated that the given sample contains protein.

iii) **Test for Lipids:** Take 0.5 ml of ether or chloroform in a test tube and add 0.5 ml of haemolymph drop by drop. When fully dissolved add one drop of Sudan III regent.

Result: Red colour appears, indicates that the sample contains fats.

1.6 Permanent preparation of sting apparatus of honey bee/wasp, tympanum of locust, salivary glands of Cockroach, mouth parts, legs and wings of different insects.

Requirement for preparation of permanent Mount: Different gradient Alcohol, double distilled water, Xylene, Canada balsam or DPX, Slide, Cover slip

Method: The method of permanent slide preparation includes: Killing, Fixing, Washing and Mounting on the slide

1. For the study of sting apparatus of honey bee/wasp, tympanum of locust, salivary glands of Cockroach, mouth parts, legs and wings of different insects, permanent slide preparations can be done.
2. The wings can be dissected from the specimen with the help of fine forceps or micro pins. Usually, the wings are not treated with KOH solution.
3. For the dissection and slide preparation of other parts of insect, the specimens were either given hot KOH treatment or cold KOH treatment. For cold treatment the specimen to be treated, can be put in 10-12 % KOH solution overnight or till clearing.
4. For hot treatment, the specimen can be put in corked vials containing 5% KOH solution and kept in a hot water bath at a temperature of 30˚C to 40˚C for the time till clearing, depending upon the nature of the material.
5. After KOH treatment, the material should be washed with distilled water.
6. The material should be then dehydrated in ascending grades of alcohol, i.e. 30%, 50%, 70%, 90% and absolute (100%) (for 10 minute each) followed by clearing in the clove oil.
7. Mounting should be done in mounting material, *viz.* D.P.X. or Canada balsam. The insect specimen or its parts must be gently transferred from the clearing medium to mounting material on the glass slides.
8. Arranged the material with fine needles in proper manner to view the character. Slides with mounted material can be normally kept in fiat trays for material drying or can be dried in an oven till the outer mount dried up.

Sting Apparatus of Honey bee:

Dissect the sting apparatus of honey bee and prepare a slide by the above procedure.

1. Sting apparatus of honey-bee is modified ovipositor, found at the posterior extremity of abdomen in the worker bee. It consists of alkaline and acidic glands in the 9^{th} tergite, fulcrum, lancette with terebra, bulb, levering plates and gland.
2. Sting is made up of 2 pairs of gonapophyses.
3. The 8^{th} segment forming stylets, and 9^{th} segment stylet sheath, which enclose poison canal.
4. Stylet is modified sting and lies in sting chamber. Stylet sheath and stylet contain pointed spines or barbs. The main function of sting in worker bees is to stinging. While stinging the victim, the muscle of 9^{th} tergite drives the style and stylet sheath for the secretion of venom from poison gland.
5. The bite of the sting causes burning sensation, pain and swelling of the part concerned.

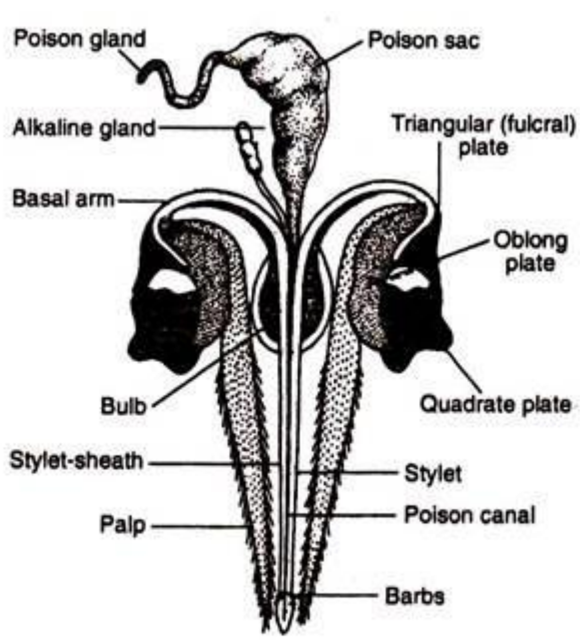


Fig:1.5 *Sting Apparatus of Honey Bee*

Tympanum of Locust:

This is a membrane stretched across tympanic cavity responds to sounds produced at some distance, transmitted by airborne vibration.Tympanal membranes are linked to chordotonal organs that enhance sound reception.

In Acrididae (Locust and Grasshopper), tympanum is located one on either side of the first abdominal segment. In the locust e.g., *Schistocerca gregaria*, the tympanal membrane (TM) can be recognised by its shiny and semitransparent appearance.

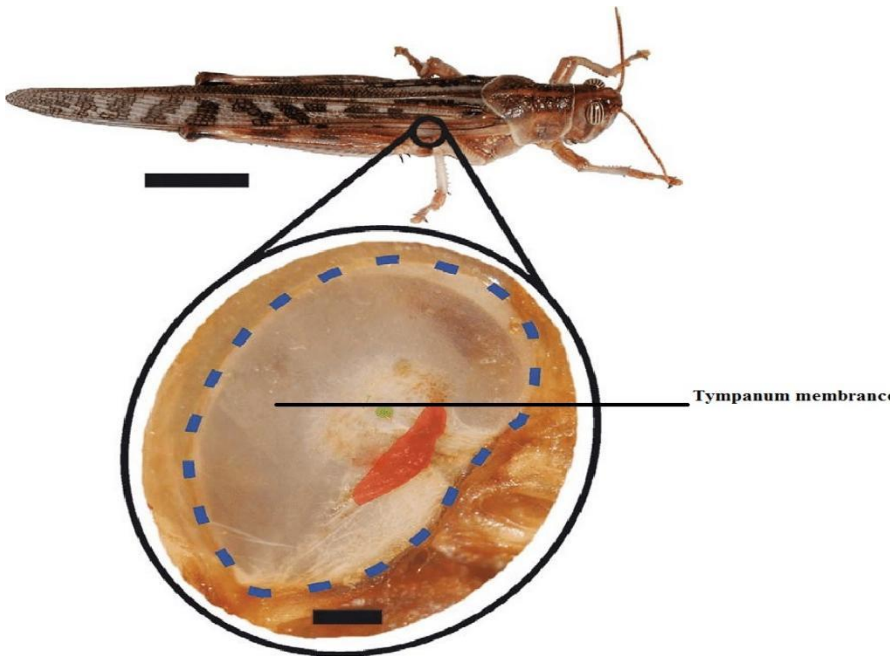


Fig: *1.6 Tympanum of Locust (Windmill et al., 2008)*

Salivary glands of Cockroach:

1. The salivary glands of cockroach open on the Hypopharynx.
2. Hypopharynx is a tongue-like structure, through which the salivary glands secrete saliva.
3. Salivary glands are paired and white structures and are situated one on either side of the crop in the prothoracic region.
4. It consists of several lobes of secretory acini. They are composed of a glandular part and a hollow receptacle or reservoir.

5. The receptacle is situated between paired glands of each side and remains connected through a duct.
6. The ducts of each gland unite to a single efferent salivary duct that then fuses with the opposite duct to form the main salivary duct.
7. Two reservoirs are associated with the secretory tissue.
8. The reservoirs open into reservoir ducts that accompany the efferent salivary ducts.
9. These glands are compressed, made up of hexagonal glandular cells and each of them opens into a small narrow duct.

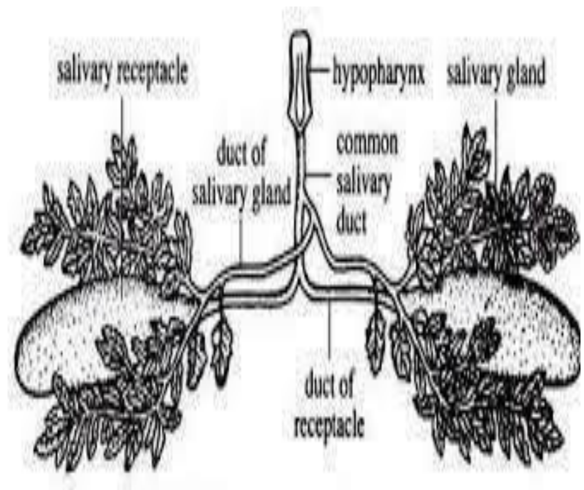


Fig:1.7 Salivary gland of cockroach

Mouth parts of insects:

Insects have developed a wide range of mouth parts, according to mode of their feeding. The earliest insects had developed chewing type of mouthparts with a variety of specialisation. Most specialization have evolved afterwards e.g. piercing and sucking (mosquitoes and true bugs). Although these both types of insects pierce and suck while female mosquitoes feed on animal blood in contrast to most true bugs which feed on plant sap.

Following are the mouth parts observed in different insects:

1. **Biting and Chewing type of Mouth part:**

   As stated above that Biting and Chewing type of mouth parts are thought to be the most primitive type as the other types of mouth parts are supposed to be evolved from these mouth parts. This type of mouth parts consists of the labrum (upper lip), mandibles, first maxillae, second maxillae (lower lip/Labium), hypopharynx and epipharynx.

The labrum is median, slightly rectangular flap-like. Mandibles are paired and with toothed edges on their inner surfaces. First maxillae paired and lie on both side of head capsule, possessing a maxillary palp (five-jointed) which is a tactile organ. First maxillae aid in holding food.

Second maxillae are paired but fused forming lower lip. Its main function is to push back masticated food into mouth. The hypopharynx is tongue-like process at its base opens the salivary duct. The epipharynx is also single membranous piece lying under the labrum and withholding the taste buds.

These types of mouth parts are considered as primitive found in Apterygota, Paleoptera, Dictyoptera (cockroaches), Orthoptera (grasshoppers, crickets), and other insect feeding on solid food material.

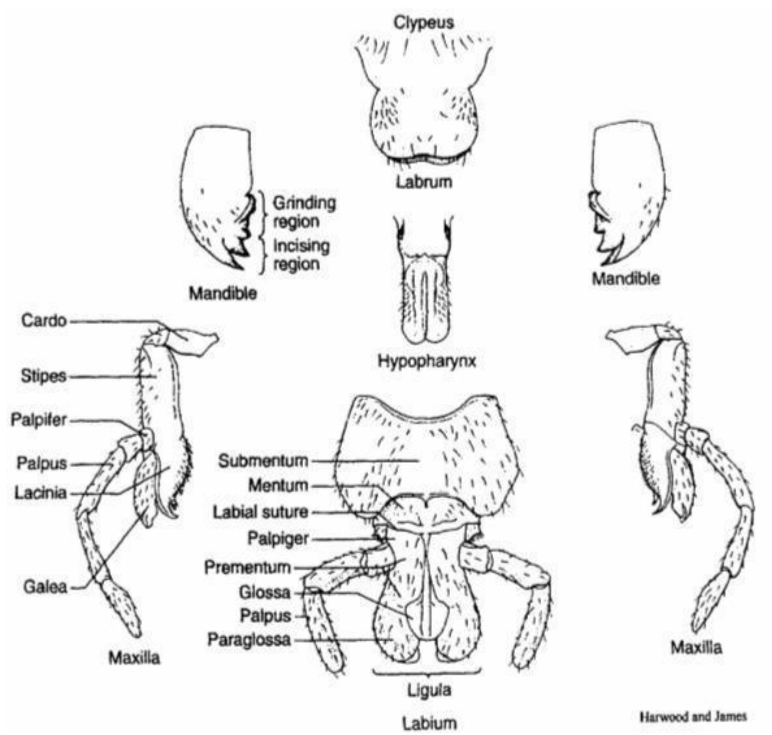


Fig:1.8 *Chewing and Biting type of Mouth part*

2. **Chewing and Lapping Type of mouth parts:**

This type of mouth parts are modified for collection of the nectar as well as pollen from flowering plants and for moulding the wax. Such mouth parts are found in the members of Order Hymenoptera e.g. honeybees, wasps, etc. These mouth parts consist of the labrum, epipharynx, mandibles, first pair of maxillae and second pair of maxillae.

Labrum lies under the clypeus, below the labrum lies fleshy epipharynx which is an organ of taste. Mandibles are short, smooth and spatulated. These are situated on both side of the labrum and used in moulding wax during comb formation.

Labium is reduced to paraglossae, the glossae are united and elongated to form tongue having small honey spoon or labellum. Labial palps are elongated.

First pair of maxillae placed at the sides of labium, they bears small maxillary palps, lacinia much reduced but the galea are elongated and blade-like.

Galea as well as labial palps form a tube like structure enclosing the glossae which moves up and down during nectar collection from nectaries. Nectar is sucked up through this tube, with the pumping action of pharynx. The labrum and mandibles help in chewing the food.

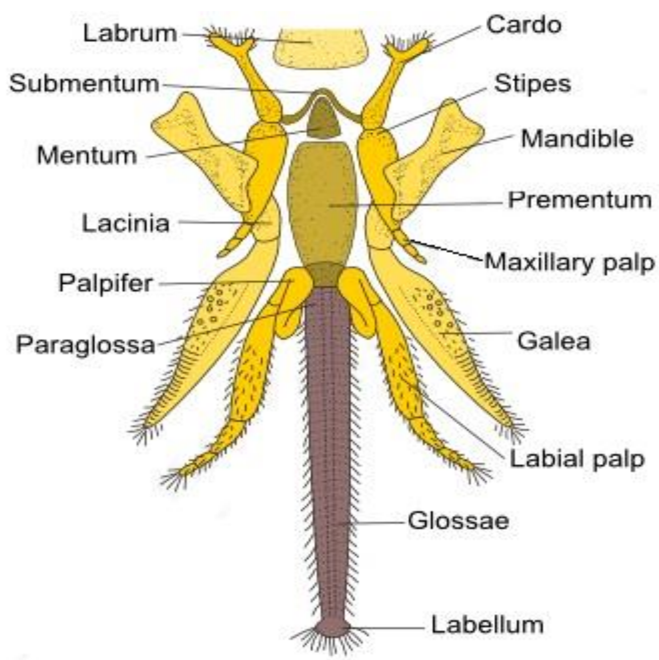
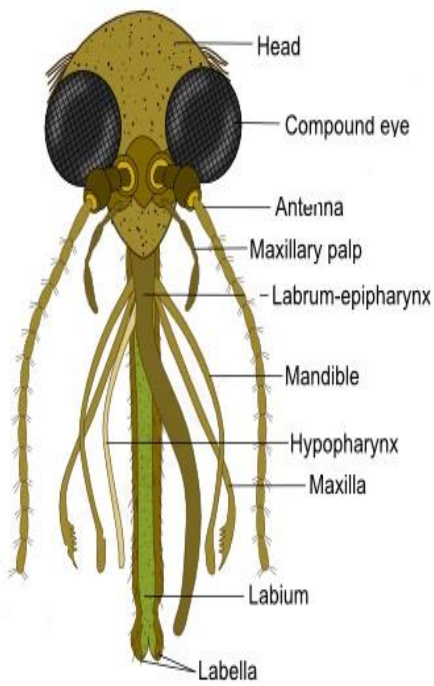


Fig: *1.9 Chewing and Lapping Type of mouth parts*

3. **Piercing and Sucking type of Mouth parts:**

Mouth parts are elongated and slender to form a beak like structure. Stylets are needle like which are enclosed and protected with lower lip. Maxillae as well as mandibles are slender and elongated. Upper lip is short and flat. Hypopharynx is elongated, palp are either absent or poorly developed. All the stylets are joined to form a food channel and salivary duct. Stylets are inserted into food source either of animal or plant tissue to suck up fluid by pumping the wells of mouths cavity. Examples: Bugs (Heteroptera), Lice (Anoplura), Flees (Siphonaptera) and mosquito (Diptera) possess this type of mouth parts.



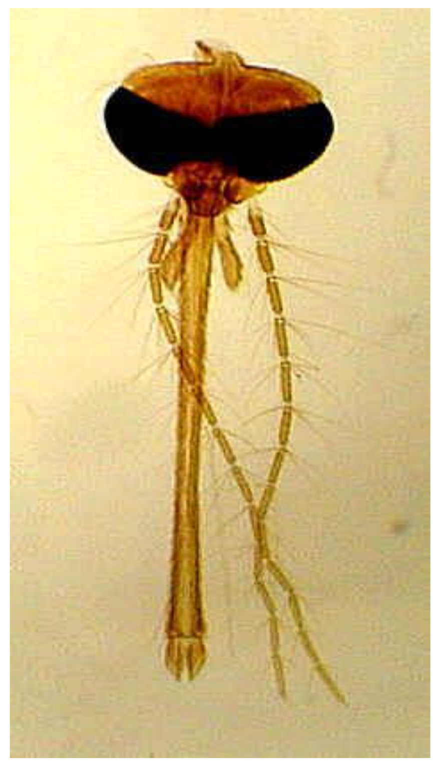


Fig:1.10. *Piercing and sucking Type of mouth parts*

4. **Rasping and sucking type of mouth parts:**

This type of mouth parts is intermediate in structure between the piercing –sucking and chewing-lapping type of mouth parts. They are asymmetrical due to the absence of right mandible. Rasping cone made up of stylets. Left mandible, maxillae and hypopharynx is elongated and look like stylet. Both the pair of palps are present. Upper lip (labrum) and hypopharynx constitutes the food channel that lies in the head capsule. Whereas lower lip along with hypopharynx forms the salivary duct. Oozing sap is sucked by rasping cone. Example: Thrips.

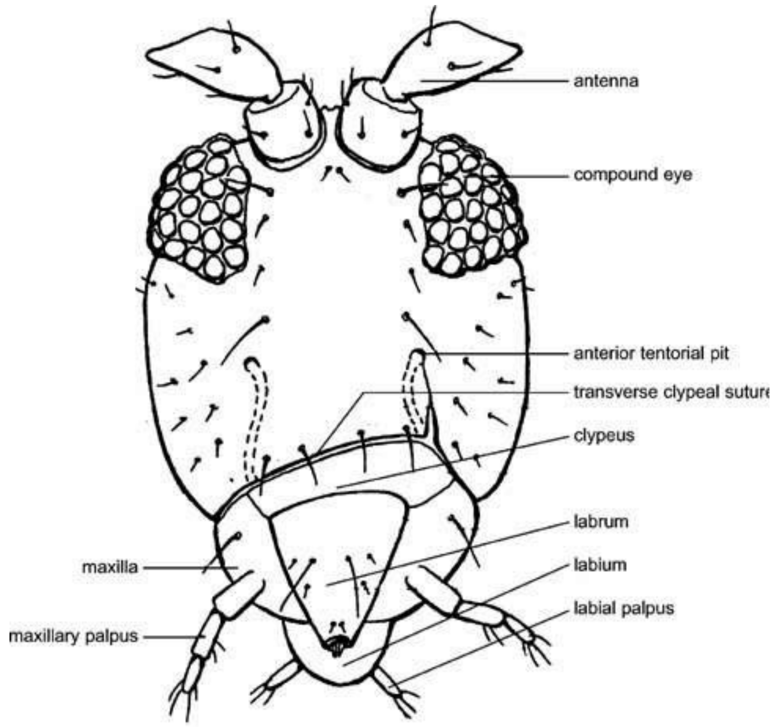


Fig:1.11 *Rasping and Sucking type of mouth parts*

5. **Siphoning Type of mouth parts:**

This type of mouth parts are adapted for sucking the food like flower nectar and fruit juice. These are found in butterflies and moths. These consist of small labrum, a coiled proboscis, reduced mandibles and labium. Hypopharynx and epipharynx are not found.

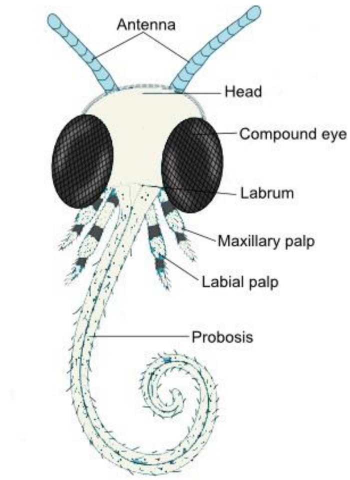


Fig: *1.12 Siphoning Type of mouth parts*

The labrum is triangular sclerite attached with front clypeus of in the head. Proboscis is formed by well-developed, greatly elongated and modified galeae of maxillae, which is grooved internally to form the food channel through which food is drained up to mouth. When at rest, it is tightly coiled beneath the head.

The extension of proboscis is attained by exerting a fluid pressure of the blood. Mandibles are either absent or greatly reduced, situated on lateral sides of the labrum. The labium is triangular plate-like bearing labial palps.

6. **Sponging Type of Mouth parts:**

This kind of mouth parts are well adapted for sucking up the liquid or semiliquid food and are present in houseflies. They consist of labrum- epipharynx, maxillae, labium and hypo pharynx, mandibles are entirely absent. In fact, in this type of mouth parts, the labium, i.e., lower lip is well developed and modified to form a long, fleshy and retractile proboscis.

Mandibles are absent, maxillary palps represent the maxilla. Lower lip is divided into rostrum and houstellum. The end of labium is modified into sponge like structure labella, which is traversed by pseudo-tracheae which converge at one point and open into food channel.

Hypopharynx and epipharynx constitutes food channel which leads into the oesophagus. Labella thrust to the liquid food and is taken up with capillary action of pseudo-tracheae.

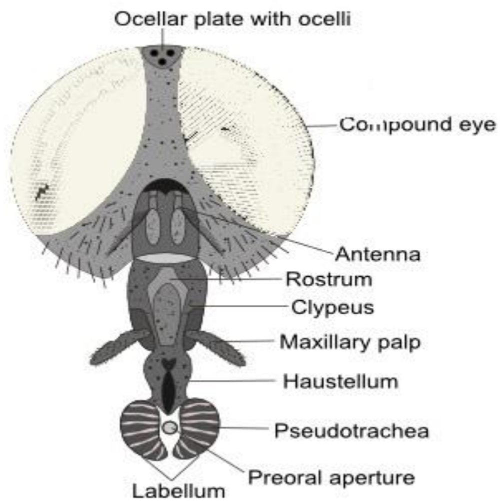


Fig:1.13 *Sponging Type of mouth parts*

Legs of insect:

Adaptive radiations in insects are witnessed by wide range of modification in the legs. According to different mode of living insect legs are adapted for walking, running, jumping, grasping, swimming and clinging. Insect legs are composed of six distinct segments (from anterior to distal end) namely

- **Coxa:** It is tubular, broad, triangular, oval or spherical in shape. The proximal part is known as subcoxa. The subcoxa is attached to the pleuron by an articular membrane called the coxal corium.
- **Trochanter:** It is small segment sometimes divided into two (Odonata). It is freely movable by a hinge joint on the coax and it firmly fixed with femur
- **Femur:** It varies in shape and size in different insects. It is the largest and strongest part of the leg and in the hind leg of Orthoptera it is very much enlarged for leaping.
- **Tibia:** It is generally slender and long and provided with spines in some insects. It bears a single or many tibial spurs on the distal end

- **Tarsus:** The tarsus is usually made up of 2 to 5 segments, the tarsomeres but it is unsegmented in primitive insects. On the lower surface of each tarsal segment are small pads, the pulvilli or plantulae.
- **Pretarsus:** It is terminal part of the leg. It bears a pair of movable lateral claws and between them is median pair called the arolium and a median bristle called the empodium. On the ventral side the pretarsus bears a median plate, the unguitractor for attachment to the flexor muscles of the claws.

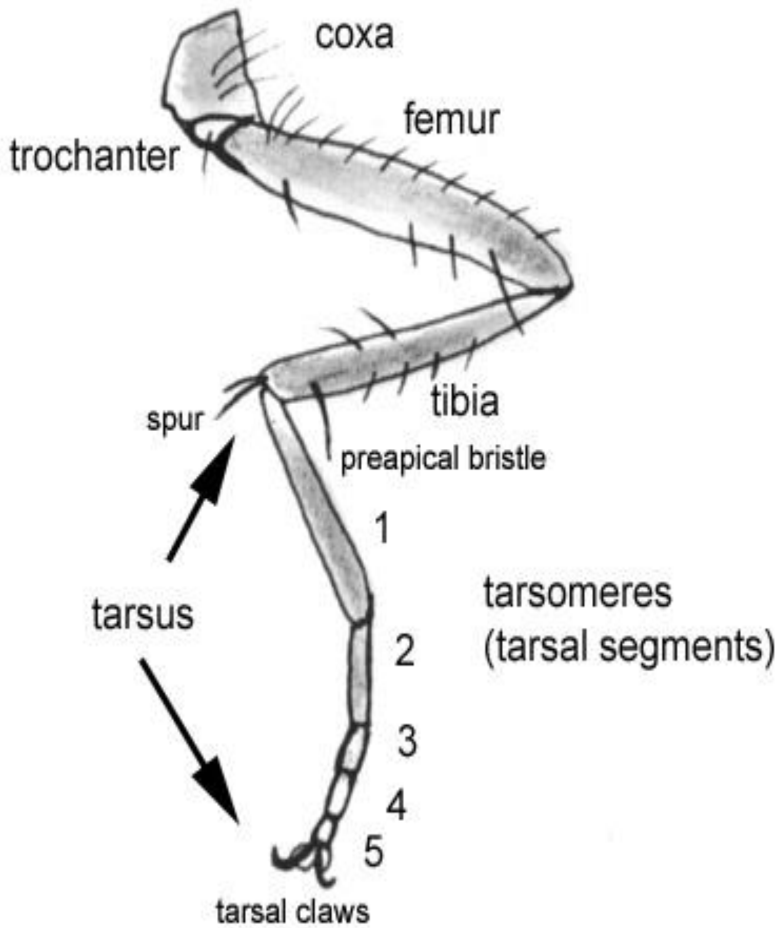
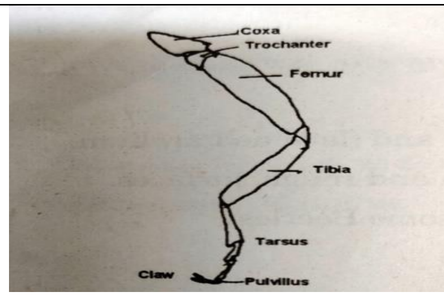
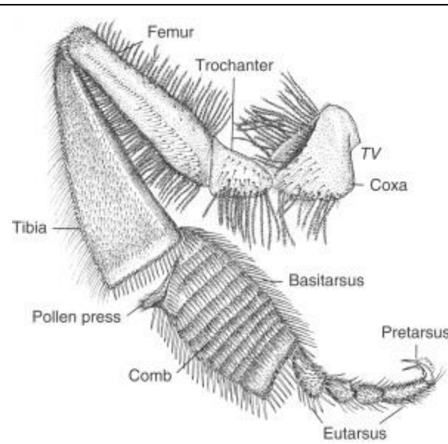
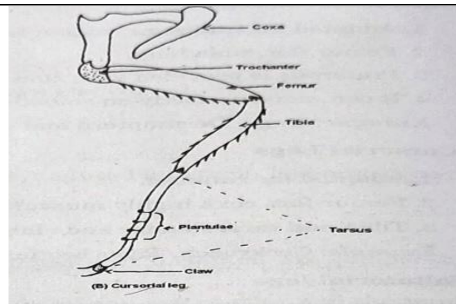
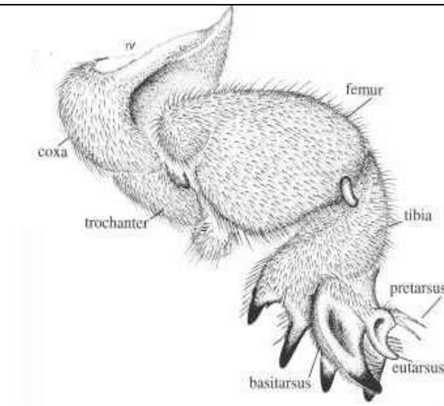
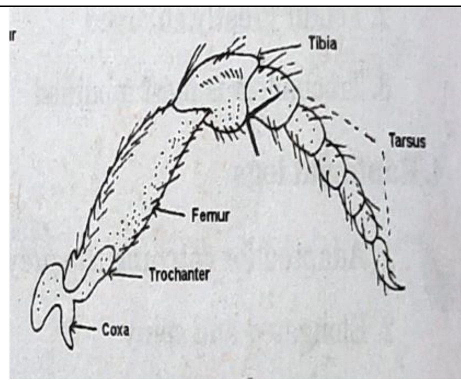
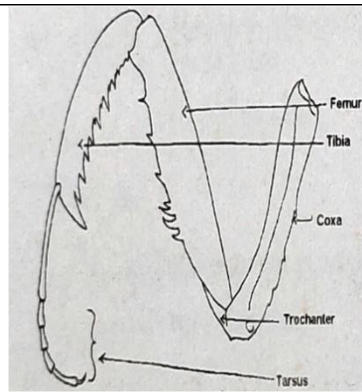
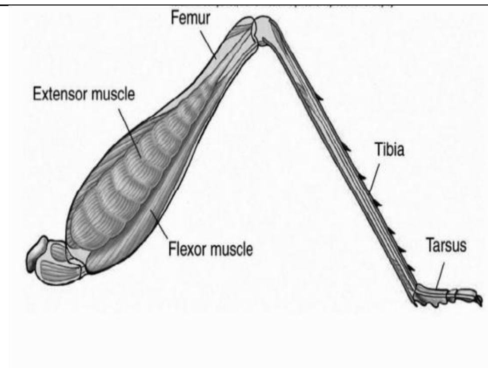
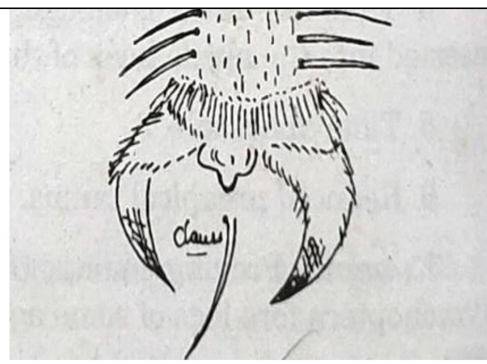


Fig:1.14 *Segments of Insect legs*

Following are some of the legs adaptation exhibited by Insects:

Type	Shape	Characters
1. Ambulatorial (Walking legs)		Coxa is small, femur is slender and flat and tibia is long. Pretarsus provided with long claws. Examples: Dermaptera, ants,
2. Climbing or sticking (Adhesive type of legs)		Pretarsus is highly modified and represented by a pair of claws and a pair of pad like structure, pulvilli found at the base of claws. They are densely clothed with numerous hairs which secrete sticky substance. Example Housefly
3. Corbiculate (Pollen collecting legs)		The tibia of hind leg is dilated and covered with long dense hairs forming a pollen basket. The first tarsal segment is flattened & its inner surface is densely clothed with several rows of spines forming a brush. It helps in collecting the pollen adhering to the hairs of its body. Example: Honey bees

4. Cursorial (Walking and running legs)		These are adapted for running. Femur is flat, cox is highly muscular, tabia and tarsi slender and elongated. Example: Cockroach, Tiger Beetle.
5. Fossorail (Digging legs)		Tibia and tarsi are flattened and shaped like shovels for digging the soil. Tarsi and pre tarsi reduced. Fore tibial digital processes are used for digging. Exaples: Gryllotalpa (Mole cricket), Nymph of Cicada
6. Natatorial (Swimming legs)		Femur, tibia and first four tarsomeres are broad and flat with marginal setae forming oar like structure. These legs are adapted for swimming . aquatic bugs facilitate swimming with the help of long hairs on mid and hind legs. Example: Water beetle, Notonecta, Belostoma.

7. Raptorial (Prehensile legs)		These are adapted for catching and holding the prey in between the greatly enlarged and ventrally grooved femur bugs and blade like curved tibia. Coxa is long. Examples Preying mantis (Forelegs), hind legs of some parasitic hymenoptera
8. Saltatorial (Leaping/ jumping legs)		Femur is enlarged. Tibia is elongated and is spined dorsally, when its strikes the ground surface the insect jumps or leaps. Examples Grasshopper, cricket
9. Scansorial (Clinging or clasping Legs)		These legs are adopted for clinging. Padded projection is present at the distal end of the tibia and pretarsus is modified into an enlarged claw shaped structure which fits into pad. Example Head lice
10. Stridulatorial (Sound producing)		Femur of the hind leg is provided with a pair of pegs on its inner side, these rub against outer surface of each tergum for coastal margin of the forewing there by produce sound. Example: Cricket

Wings of insects:

Insects are the only invertebrates on earth that can fly. Insect wings develop as evaginations of the exoskeleton during the morphogenesis but they become fully functional in the adult stage of an insect.

Wing Venation

The archedictyon name given to the hypothetical scheme of wing venation proposed for in insect. Speculation and fossil evidence are combined to form this theory. Since all the winged insects are thought to have evolved from common ancestor, the archediction represents that template which has been modified by the natural selection for 200 million years. According to current opinion, the archedictyon contained 6-8 longitudinal veins. These veins as well as their branches have been named according to a system devised by John Comstock and George Needham -- the Comstock-Needham System.

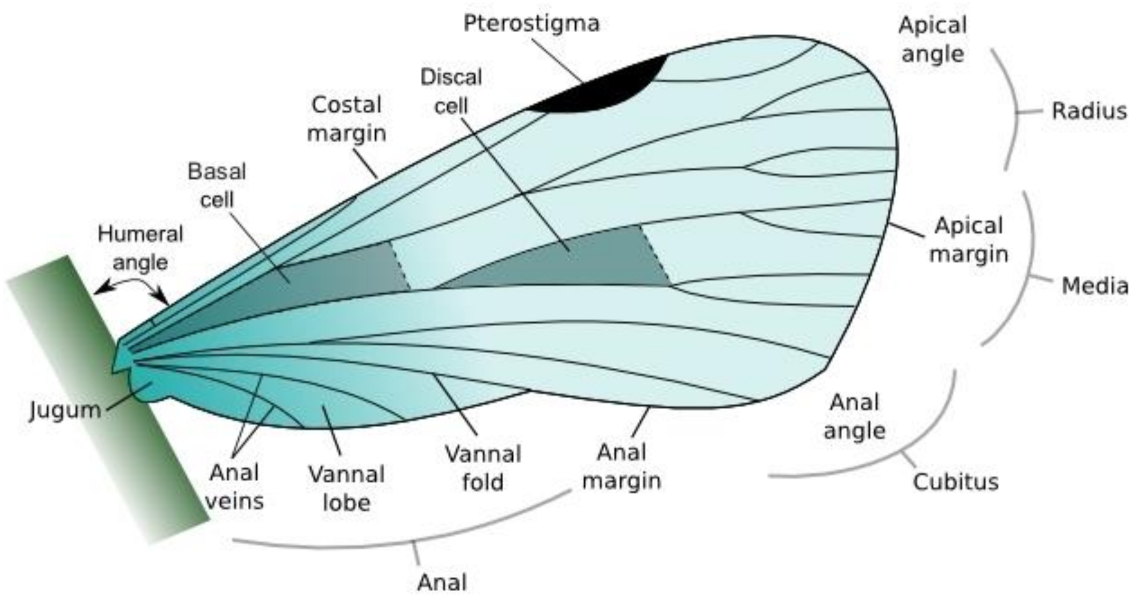


Fig:1.15 Wing venation in insect

The wing veins of archedictyon plan are listed below:

1. **Precoasta (PC):** This vein is fused with costa in all extant insects, mostly unrecognisable.

2. Costa (C): At the leading edge of the wing, strong and marginal, extends to the apex of the wing, it is unbranched.

3. Subcosta (Sc): The second longitudinal vein, mainly the subcosts posterior sector (SCP). Sc is reduced or fused with R in most Hemiptera.

4. Radius (R): The third vein, usually the strongest vein on the wing, with branches usually cover the largest area of wing apex. RP (radius posterior) is often referred to as radial sector (Rs) and the end branches as R1-5.

5. Media (M): The fourth longitudinal vein, MA and MP usually with 4 branches each. In some insect groups MA fused with R so only MP on the medial area. In this case the MP1-4 are often referred as M1-4.

6. Cubitus (Cu): Fifth longitudinal vein, CuA (Cubitus Anterior) may branch to 4 or fewer veins. CuP (Cubitus Posterior) is unbranched, lies near the claval fold and reach the wing posterior margin.

7. Anal veins (A): Veins behind the cubitus, AA (anal anterior) and AP (anal posterior) are usually separated by the anal fold. In Neoptera, AA is always fused with Cu or CuP. In the hind wings of most orthopteroid insects, there is a large anal area where anals branch several times to form a fan-like folded wing.

8. Jugal (J): Small veins in the jugal area, found only in Neoptera.

Cross-veins are transverse veins joining longitudinal veins to provide rigidity of the wings. Their names are based on the position relative to longitudinal veins. In Orthoptera and Odonata the cross veins are numerous but in other insects there is a definite number of cross veins, with specific positions and designations.

The main cross veins are:

(1) Humeral cross vein (h)-lies between the costa and the subcosta

(ii) Radial cross vein (r)-lies the R1 and first four of Rs.

(iii) Sectorial cross vein (s)-lies between two forks of Rs.

(iv) Median cross vein (m)-lies between the second and third media M, and M.

(v) Median-cubital cross vein (m-cu)-runs between the media (M) and cubitus (Cu).

(vi) Radial-median cross vein (r-m) runs between the radius and media. The black pterostigma is carried near the wing tip, between RA1+2 and RA3+4.

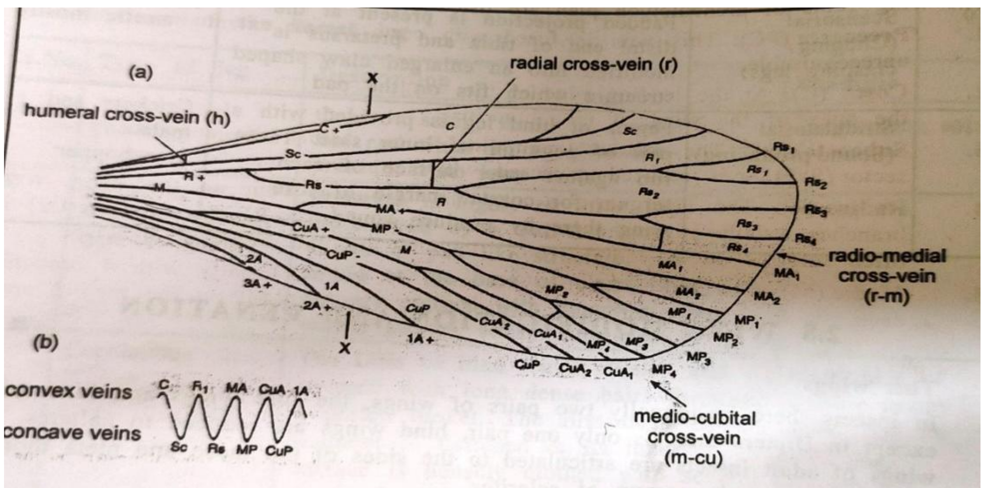
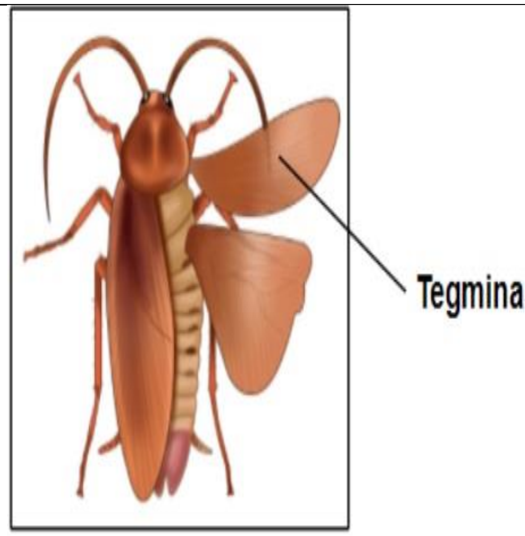
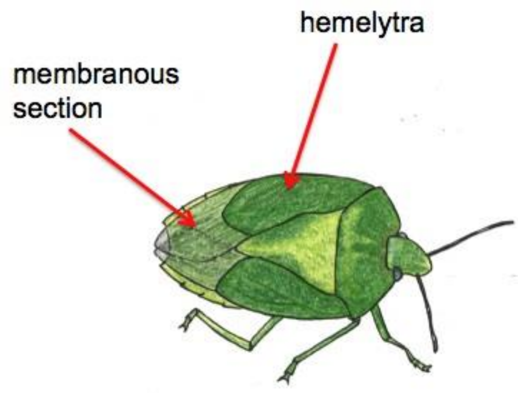
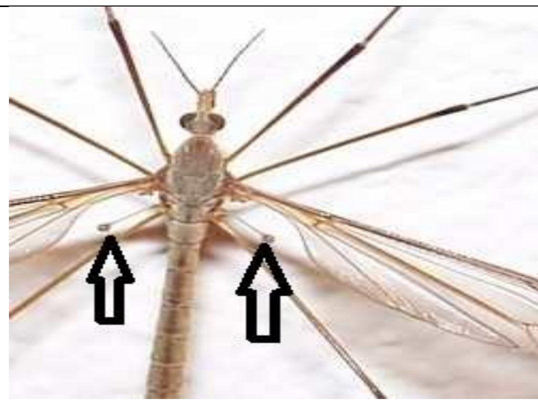
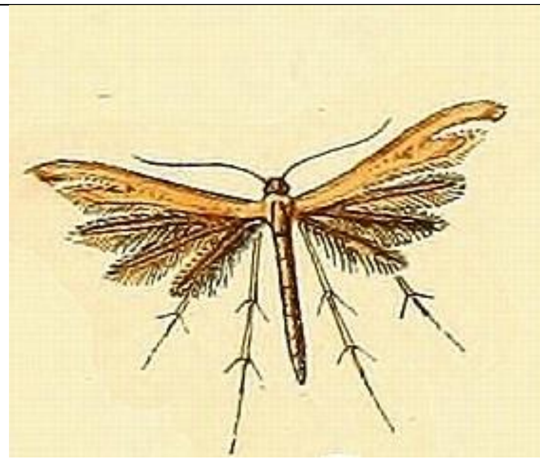
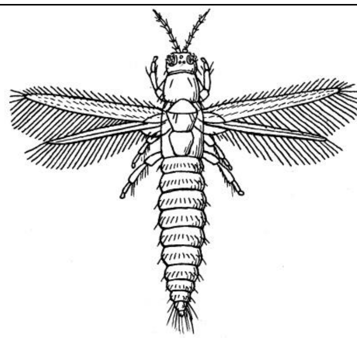


Fig: 1.16 Wing venation

The wings may be membranous, parchment-like, heavily sclerotized, fringed with long hairs, or covered with scales. Most of the insects have two pairs of wings -one pair on the mesothorax and one pair on the metathorax (but never on the prothorax). Wings in insect serve not only as organs of flight, but are also adapted variously as protective covers viz., (Coleoptera and Dermaptera), thermal collectors (Lepidoptera), gyroscopic stabilizers (Diptera), sound producers (Orthoptera), or visual cues for species recognition and sexual contact (Lepidoptera). Following are the insect modification usually observed in insec

Type	Structure	Description
1. Tegmina		These are the forewings of Orthoptera, Dictyoptera and Phasmida, which are tough and leathery
2. Elytra		The forewings of Coleoptera and Dermaptera are much hardened and sclerotized to form a horny sheath, which protect the membranous hind wings.

3. Hemelytra		This type of wing is found in Heteroptera (Hemiptera), where the forewings are hardened apically but is membranous distally and is called hemelytra or half-elytra. It is divided into two parts. Clavus, a basal narrow area near scutellum and corium or terminal broad area. Corium is again divided into a dorsal coastal narrow strip called embolium and a triangular apical region called cuneus.
4. Halters		The hind wings of Diptera are modified into clubbed shaped halters. These are extremely small and are very slender proximally but knobbed distally. These help to maintain stability or balance during flight.
5. Pseudohalteres :		The forewings of Strepsiptera. These are very small and club shaped and help in balancing the body during flight.

6. Fissured or clofted:		Both wings of plume moth. The front wing is longitudinally divided forming a fork like structure where as hind wing is divided twice resulting into two forks with three arms. All the forks have small marginal hairs.
7. Fringed		Both wings of thrips. The wings are highly reduced, narrow and membranous with highly reduced wing venation. The wings are fringed with long marginal hairs giving a feather like appearance.
8. Membranous		Both wings of dragon flies, wasps, bees and forewings of flies. Hind wings of grasshoppers, beetles and bugs. The wings are always thin, membranous with highly developed venation. These are useful for flight.

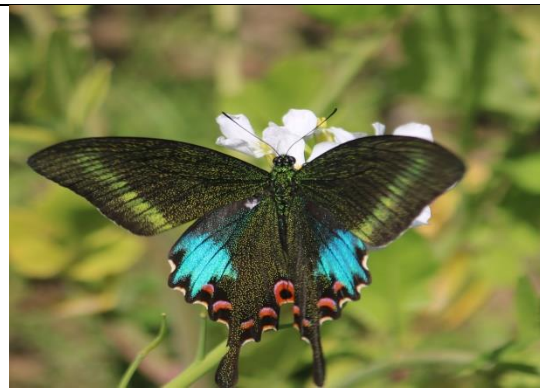
9. Scaly		Both wings of butterflies and moths. The wings are thin, membranous but covered with over lapping scales all over the surface hence the name scaly wings. These wings are useful for flight.

Fig 1.17

1.7 : Microtomy of Insect Tissues

Study of histology of a tissue involves microtomy. Cytological, histopathological and histochemical studies are also done with the help of this technique. It requires a set procedure which is followed step to step. Any fault in the steps involved can spoil the whole study. The procedure is being described in brief.

1. Fixation of material

The tissues are fixed in appropriate fixative. The specific tissues are dissected out with speed in physiological saline and fixed immediately. Bouin's fluid take minimum time (24 hrs) for proper fixation. Even the material can be left indefinitely in Bouin's fixative. Use 70% alcohol for insects. Cernoy fluid takes 2 to 4 hrs for fixation.

2. Washing

After the fixation, the tissue is washed properly so that the fixative goes out of the tissue. It is washed with distilled water or the jar can be kept under running tap water taking care so that the tissue may not be washed off. If the fixative is alcoholic then it is washed in alcohol. In case of cornoy's fluid they are washed in absolute alcohol (2-3 changes)

3. Dehydration and clearing

As usual it is passed through 30%, 50%, 70%, 90% and absolute alcohol. When fix in 70% then transfer the tissue in 90% for two hrs. Dehydration is necessary so that the wax can be deeply penetrated. After dehydration it requires to be transparent which is done by clearing agent. Xylene is generally used. Do not leave the tissue in Xylene for more than the time it is required otherwise the tissue will be brittle. Cedar wood oil was also used but it requires more time. Methyl benzoate can also be used. The tissue are directly put into paraffin wax from the clearing agent. One or two changes of melted paraffin wax will remove the clearing agent completely from the tissue. It also facilitates proper penetration of the wax into the tissues.

4. Embedding and Block making

Embedding can be done using metal L' blocks or paper boats. Paper boats can be easily made by using a wood piece. Paraffin wax is melted at 60-62°C temperature therefore keep the temperature of the oven at 60°C (Bees wax + paraffin, 1:3). After the wax is melted filter it so that all dirt can be removed otherwise the razor can be spoiled causing nicks to it. Pour the melted wax in 'L' moulds or paper boats and transfer the tissue into it. Orient it properly taking every care and mark the orientation of the tissue by a arrow mark with pen or pencil (in case of paper boats). It requires care and expertise. After the solidification of the wax in 'L' moulds or paper boats, remove it and put it into the tray of water. It solidify properly now. Blocks are now trimmed properly. The trimmed blocks are mounted on the block holder of the Microtome.

5. Section Cutting

Set the microtome at the desired thickness at which the sections are to be cut (0.5 or 0.6 mm). At 0.7 mm thick sections will be there. Now start rotating the wheel. As soon as the block mounted on the holder makes a contact with razor, the section of the wax will be cut. A continuous ribbon is in the view now. As soon as the ribbon is 1-2 inch long put a fine brush below it and move it away from the microtome. After a length of about 6-7 inch cut the ribbon and place it on the clean slide. Take another ribbon likewise. For proper adherence of sections, it is required that a small drop of Mayer's albumin is rubbed on the slide. The sections are properly affixed now. Put the slide on the hot plate so that the sections are properly spread out along with slight melting of wax. Label the slide by using diamond point pencil.

7. Staining

All the wax is removed from the sections first. Put the slide in a coplin jar filled with xylene (make two changes) then to absolute alcohol for 5-6 minutes. It is dehydrated in descending series upto 30% alcohol and then to distilled water (two changes of 5 minutes each). Now use the aquous stain haematoxyline. Keep the slide under-running tap water to remove the excess stain and proceed the slide for dehydration in ascending series i.e. 30%, 50%, 70% alcohol. Now stain it with eosin. Bring it back to 70% then 90% alcohol, absolute alcohol and xylene (6-10 minutes). Mount the slide in D.P.X. Keep it for drying at room temperature or in oven at 60°C for few hours.

SUMMARY OF THE PROCEDURE

↓

Tissue fixed (70% alcohol)

↓

90% alcohol (2 hrs)

↓

100% alcohol (1/2 hr)

↓

Xylene (20 minutes)

↓

Bess wax + Paraffin wax..... (Use less bees wax in summers) (1:3)

↓

Wax+ xylene (15 minutes)

50:50

↓

Wax pure (45 mintues)

↓

Block preparation

↓

Trimming of blocks

↓

Section cutting

↓

Ribbon of sections

↓

Spreading of sections

↓

Drying (overnight)

↓

Xylene (1/2 hr two changes of 20+10 minutes)

↓

absolute alcohol (5-6 minutes)

↓

90% alcohol (5 minutes)

↓

70% alcohol (5 minutes)

↓

50% alcohol (5 minutes)

↓

30% alcohol (5 minutes)

↓

Distilled water

↓

Haematoxylin staining

↓

Running tap water (1/2 hr.)

↓

30% alcohol (5 minutes)

↓

50% alcohol (5 minutes)

↓

70% alcohol (5 minutes)

↓

Eosin staining (2-3 minutes)

↓

70% alcohol (3 minutes)

↓

90% alcohol (3 minutes)

↓

100% alcohol (3 minutes)

↓

Xylene (5 minutes)

↓

DPX mounting

↓

Drying

Brief Description of a microtome

Rotary microtomes are generally used in all laboratories. Rocking type microtomes are also used. It has a very heavy base.

Fig : 1.18 microtomes

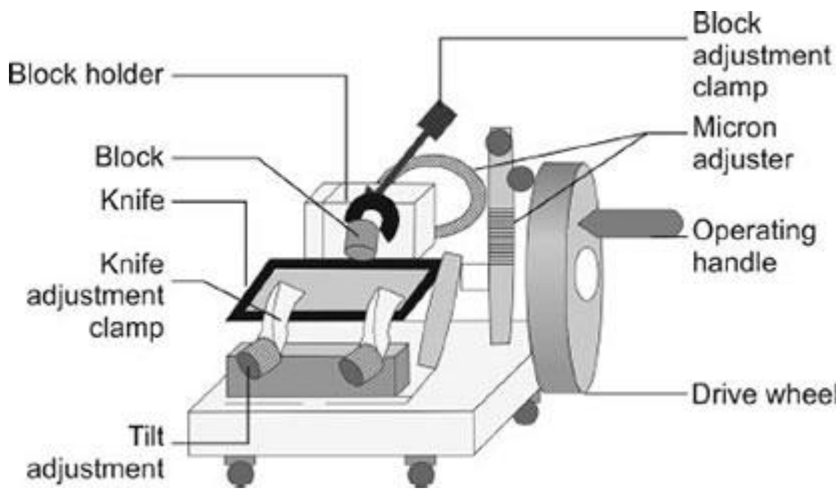


Fig:1.19 Rotary microtome

Quite a few new models of Rotary microtomes are available. A circular drive wheel is rotated which cause the movement of axle forward. As the front part which holds the block holder moves up and down, the central axle moves forward simultaneouly by the same distance. The razor is mounted on a pair of hands with a groove and adjusting screws. The razor can be moved forward and backward along the grooves so that the razor can also be brought nearer to the block if required. On a desired position it is locked with the help of levers.

1.8 Determination of pH of the gut contents of any Insect

Requirements: Insect specimen, distilled-water, microscope slide,

Principle:

Method: Remove the gut of insect, and divide the gut into main regions i.e., foregut, mid gut and hind gut. Regions from which contents were spilled during this procedure should be discarded. Then separate gut regions of 2-5 same insect specimens should be pooled in **10µ** of dust-free distilled-water on a microscope slide and broken-out with needles.

Then add five microlitres of pH indicator solutions such as (tropaeolin 0; m-cresol purple; phenolphthalein; thymol blue; cresol red; neutral red; phenol red; alizarin; bromocresol purple; litmus and bromocresol green). Confirmatory determinations should make from squash preparations using Whatman- BDH narrow-range indicator papers.

Result: In some insects, the gut pH was neutral (pH ranges from 5.5-6.2) while in some insects the pH ranges varies from fore gut to Hind gut. The pH was acidic in crop and mid gut region.

1.9 : Summary

- The basic functional unit of the nervous system is the nerve cell or neuron. Based on anatomy the insect nervous system is divided into three major parts: the central nervous system, the visceral (sympathetic or stomatogastric) nervous system and the peripheral nervous system.
- The salivary glands or labial glands are paired structure lie ventral to the foregut in the head and thorax and occasionally extend posteriorly into the abdomen.
- Haemolymph in cockroach are of two types- amoebocytes and chromophils.
- Insect mouth parts are mainly of 6 types.
- In insect, legs show of 10 types adaptation. The main parts of insect legs are coxa, trochanter, femur, tibia, tarsus, pretarsus.
- In insect, the main parts of wing are precosta, costa, subcostal, radius, media, cubitus, anal veins, jugal. 9 types of different adaptation are seen in insects.

10.1 Terminal Questions and Answers

Q1. Describe in details the nervous system of insect.

Q2. What is neuron?

Q3. Describe the main type of nervous system.

Q4. Differentiate between central, visceral and peripheral nervous system?

Q5. How many types of cell are present in haemolymph?

Q6. Describe the method of preparation of permanent slide?

Q7. Describe different types of

a) Mouth parts in insect
b) Legs in insect
c) Wings

Q8. Describe in detail the main parts of

a) Mouth parts in insect
b) Legs in insect
c) Wings

References:

- http://bugs.bio.usyd.edu.au/learning/resources/Entomology/importance/importance.html
- http://www.shivrai.co.in/elearning/lesson_1.html
- Smith, D. S., & Treherne, J. E. (1963). Functional aspects of the organization of the insect nervous system. In Advances in insect physiology (Vol. 1, pp. 401-484). Academic Press.
- Huber, F. (1978). The insect nervous system and insect behaviour. Animal behaviour.

Unit 02: Taxonomy and Biosystematics of Insects

2.1 Objectives

The main objectives of insect taxonomy are

- To catalogue the insect diversity on earth
- To differentiate the various kinds of insect and to point out their characteristics.
- To develop a set of principles in regards to the choice and relative importance of characters with ultimate aim of arranging the insect species in hierarchy.
- To estimate the morphological, physiological, genetic and phylogenetic relationship among insect species.
- To contribute towards the understanding the evolutionary process.
- To document and preserve insect specimen to provide a useful data reservoir for future biologist.
- To help in clarifying the place of systematics or taxonomy in general biology.

2.2 Introduction

The word taxonomy has been derived from two Greek words taxis=arrangement and nomos =law or study. This word was first of all coined by A.P de Candole, in hi botany treatise in 1813.

Systematic coined by Linnaeus in 4th edition of historical book Systema Naturein 1735 has been derived from Latinised Greek word "systema" applied to the systems of classification. Systematic include both taxonomy and evolution.

Stages of taxonomy:

It is now well-known that taxonomy of a given group passes through several stages. These stages are referred to as alpha (analytical phase), beta (synthetic phase), and gamma (biological phase) taxonomy.

Alpha taxonomy is the level at which the species are characterised and named.

Beta taxonomy refers to the arrangement of the species into a natural system of lower and higher categories.

Gamma taxonomy is the analysis of intraspecific variations and evolutionary studies, i.e., study of speciation.

Classification of insects: The widely accepted classification of insects was proposed by the eminent insect taxonomist A.D.Imms. In this classification insects are classified into 29 orders (Fig 10.1) as under:

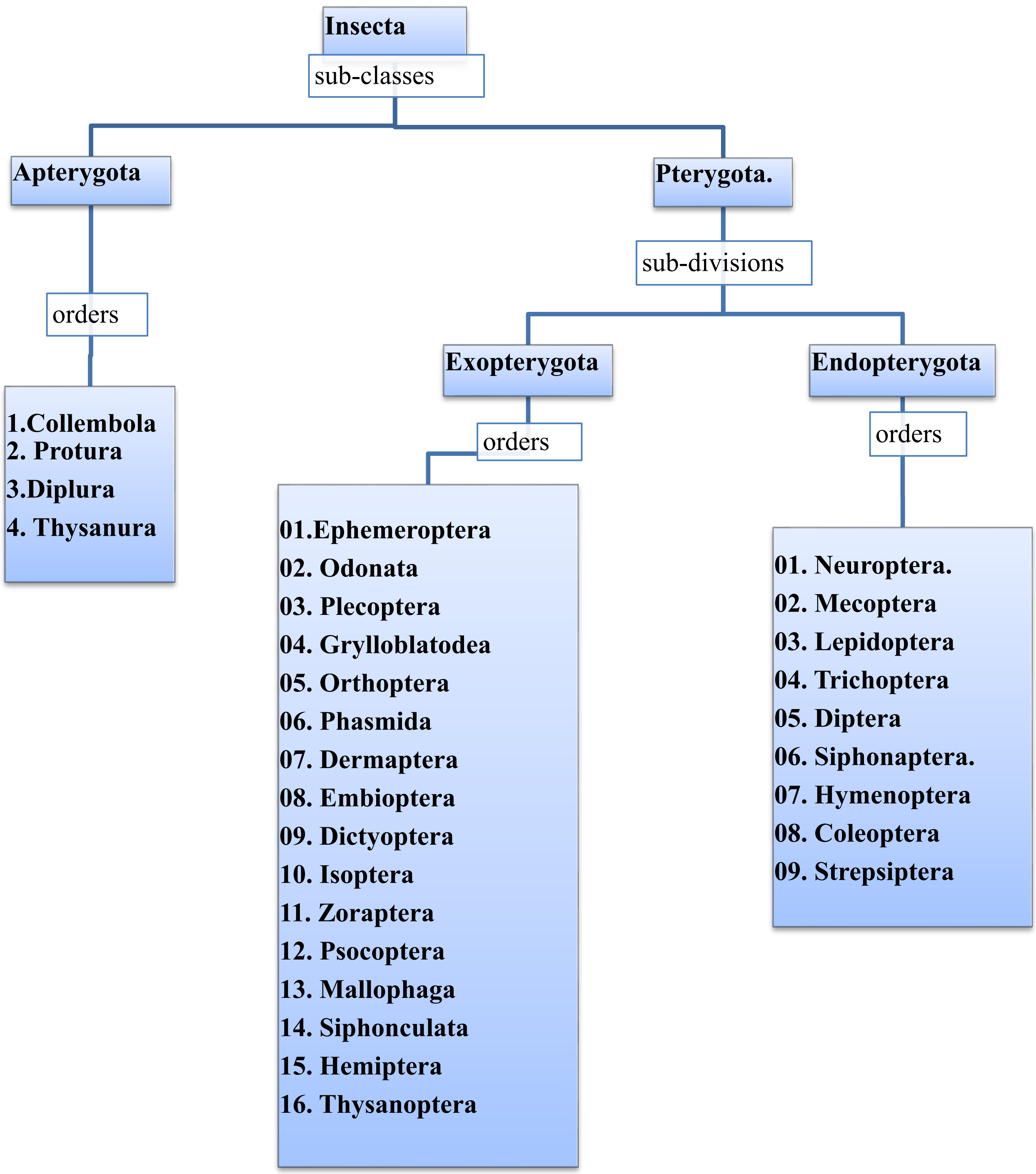


Fig. 10.1Classification of insects (A.D. Imms)

2.3 Use of dichotomous key in the Identification of Insects

"Dichotomous" means divided into two parts, hence the dichotomous keys always present two choices based on the key characteristics of the organism in each step. By correctly selecting the right choice at each stage, the user will be able to identify the name of the organism at the end. The further you divide the key, the more you learn about the specimen you are trying to identify.

DICHOTOMOUS PICTORIAL KEY TO ORDERS OF INSECTS

Usually the first question that comes up when someone encounters a question "What is an insect"? Answering this question can be difficult and simple as well. It can be difficult because insects are incredibly diverse, with nearly one million described species. To resolve this problem a pictorial identification key to the adult stages of class Insecta is developed so that most of insects could be easily identified up to order level even by an amateur person. This pictorial key is particularly useful for student and the researchers.

1. Winged forms……………………………………………………………………………………………………..2

- Wingless forms…………………………………………………………………………………………………26

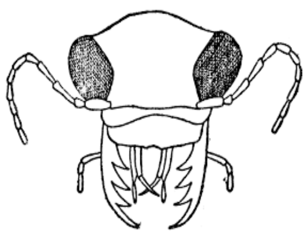
   

2. Fore wings hardened, leathery or parchment-like at least at the base……………………..3

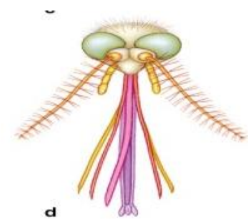
   

- Fore wings membranous or scaly……………………………………………………………………….8

3. Mouth parts chewing……………………………………………...................…….5

- Mouth parts sucking………………………..............……………………..……..……4

4. Front wings leathery at base and membranous at end……............ HETEROPTERA (True bugs)

- Front wings having uniform texture……………………………............... HOMOPTERA (Leafhoppers, Planthoppers, Cicadas, Spittlebugs)

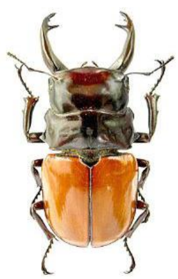
5. Abdominal tip having pincer-like cerci……………….........………DERMAPTERA

(Earwigs)


- Abdominal tip not having such pincer-like cerci…………………………………..........................…6

6. Front wings with branched veins………...................………………………….……....…7

- Front wings hard, without veins…………………...................……….COLEOPTERA
(Beetles and Weevils)


7. Hind femur enlarged, tarsi with four or fewer segments (Jumping insects).. ORTHOPTERA
(Crickets, Katydids, Grasshoppers



- Hind femur not enlarged, tarsi with five segments (Walking insects...DICTYOPTERA
(Cockroaches, Mantids, Walking sticks, Leaf insects)




8. Two winged insects………………………………………………………........................9

- Four winged insects………………………………………........…………...........….13

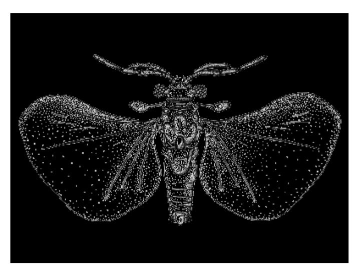
9. Pronotum extended over abdomen………………….................……ORTHOPTERA
(Pygmy grasshoppers)

- Pronotum not extended over abdomen……………………………….........................…10

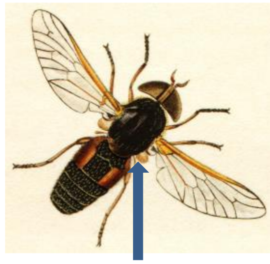
10. End of abdomen without noticeable appendages……………....................………11

- End of abdomen with style or thread-like tail…………………...................…………12

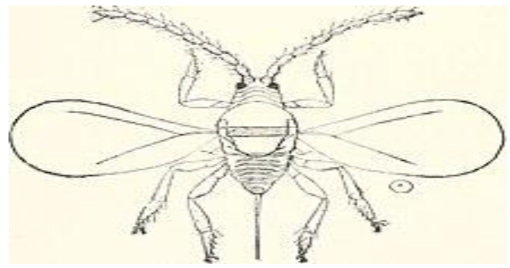
11. With haltere-like organs in front of wings……….............……..…STREPSIPTERA
(Male stylopids)

- With halteres behind the front wing…..............................…………………DIPTERA
(Flies, Mosquitoes, Midges, Gnats)

12. Style-like tail…………………………….............................…… HOMOPTERA (Male scale Insects)



- Two or three thread-like tails……………….............……………..EPHEMEROPTERA (Mayflies, mealy bugs insects)


13. Wings usually covered with scales, mouthparts consist of coiled Proboscis..LEPIDOPTERA (Moths, Butterflies, Skippers)

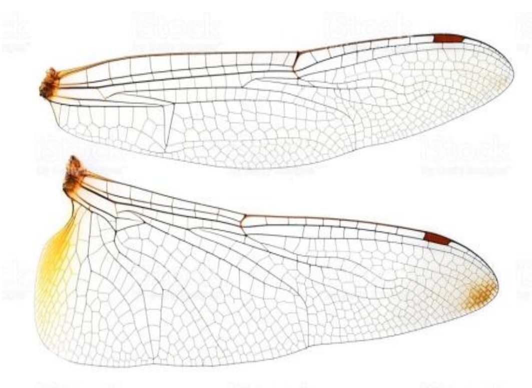



- Wings with few or no scales; without coiled proboscis……………..............……......14

14. very slender wings with fringe of hairs as long as wing is wide (minute insects)……...THYSANOPTERA (Thrips)

- No fringe of hairs, or if present, not as long as wing width……….........................……15

15. Hind wings equal to or larger than front wings……….................……………………….20



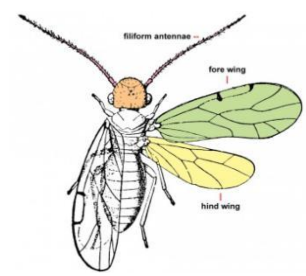
 

- Hind wings smaller than front wings…………………..................……………………….16

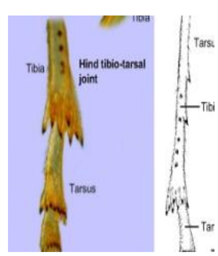
16. Abdomen with two or three thread-like tails…………................ EPHEMEROPTERA (Mayflies)

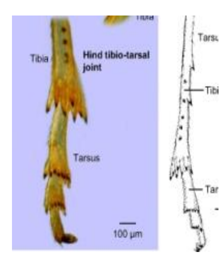
 

- No such long abdominal appendages………..........…………………………………….17



17. Tarsi two or three segmented………………………………………….....................…18



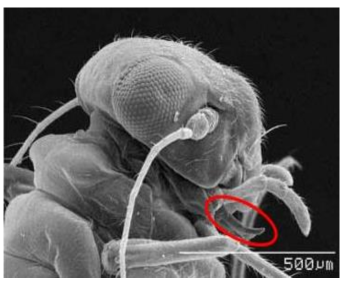


- Tarsi with more than three segments (usually five)……………………...........................…19

18. Piercing-sucking mouthparts…………...............……………………. HOMOPTERA
(Leafhoppers, Planthoppers, Cicadas, Spittlebugs)



- Mandibulate mouthparts………………………………………….…......**PSOCOPTERA**
(Barklice, Booklice)




19. Wings membranous; usually elbow shaped antennae shorter than body ………………………………………………..........................…..HYMENOPTERA
(Sawflies, Wasps, Bees, Parasitic Wasps, Ants)



- Setaceous antennae as long as body; adult resemble like moth but typically instead of scales having silky hairs on wings; *their aquatic larvae* generally live inside cases made of various materials…………..……………………................................TRICHOPTERA

(Caddishflies)

20. Mouth parts comparatively close to eye ……………………………….......………21

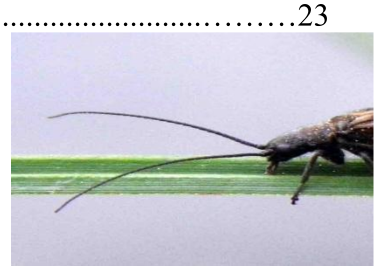
- Mouth parts at end of beak-like structure, situated some distance from eye………..MECOPTERA (Scorpionflies)

21. Wings never held flat over abdomen or making roof like structure over abdomen ………………………………………………….…………………………........…….22

- Wings held flat over abdomen…………………………………......…………………24

22. Bristle-like inconspicuous antennae………………….....................………**ODONATA**
(Dragonflies, Damselflies)

- Antennae apparently with several segments………………….........................………23



23. Hind wings with enlarged anal area folded fan-like; wings tend to curl around the body lengthwise…………………….. ……..**MEGALOPTERA**
(Dobsonflies, Fishflies, Alderflies)

- Hind wings without enlarged anal area folded fan-like; wings do not tend to curl around the body lengthwise………… ………………..**NEUROPTERA**
(Lacewings, Mantispids, Owlflies, Antlions, Spoonwings)

Typical stalked eggs of a neuropteran

24. All legs of walking type…………………..................……………………………….25

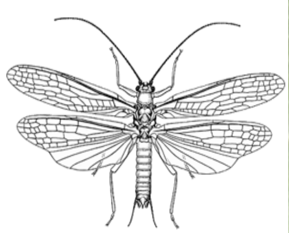
- Hind legs modified for jumping……………………..….................….. **ORTHOPTERA**

(Tree crickets)

25. Cerci usually long; more than eight segments……….............................**PLECOPTERA**

(Stoneflies)

- Cerci short; with two to eight segments…………….........…….................... **ISOPTERA**

(Termites)


26. Antennae present………………………………………….................................…29

- Antennae absent…………………………...……………..27

27. Legs present………………………………….............……………………**DIPTERA**

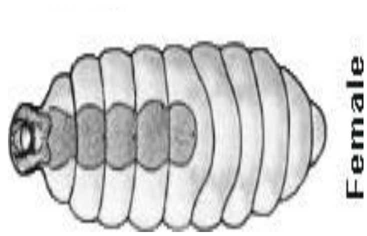
(Louse flies, Bat flies)

- Legs absent………………………………………………..…28

28. Head & thorax distinct and not fused……………….........…………………Homoptera

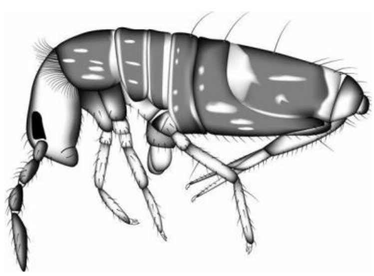
(Scale insects)

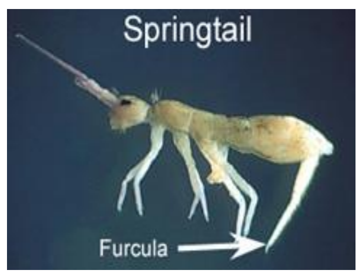
- Head & thorax fused; females are endoparasitc in a variety of insects...**STREPSIPTERA**
(Female stylopid)



29. Collophore (glue peg) present; spring-like organ (furcula) usually present; microscopic insects having six segmented abdomen………….……….. ……..........**COLLEMBOLA**
(Springtails)

-





- Both collophore and spring-like organ absent…………………..........................……...30

30. Three tail-like appendages present…………….............................……… **THYSANURA**
(Silverfish)

- Such long tail-like appendages absent……………….……………...…................……31

31. Body not compressed laterally or dorsoventrally ……………………….…….................32



- Body compressed laterally or dorsoventrally………...........………………………..43

32. Abdomen and thorax broadly joined together……...............................………………33

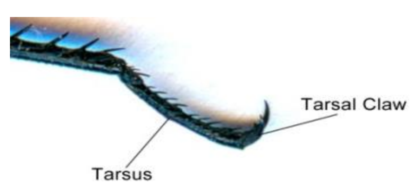
- Abdomen and thorax narrowly joined together……........................…...HYMENOPTERA (Ants)

33. Body covered with scales……………………........................………LEPIDOPTERA (Wingless Moths: Female Cankerworms)

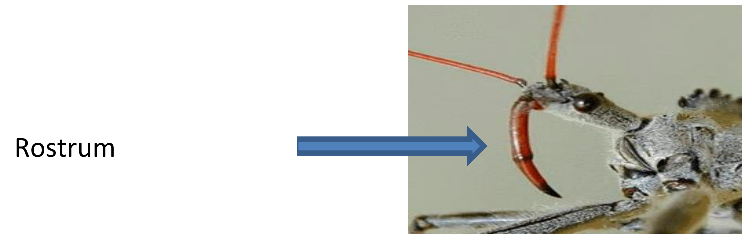
- Body not covered with scales………………...................................…………………..34

34. Legs at end having a bladder-like organ not a typical tarsal claw.....THYSANOPTERA (Thrips)

- Tarsal claws present at the end of leg……………………………………….........……..35



35. Piercing-sucking (rostrum) mouthparts..….......................36



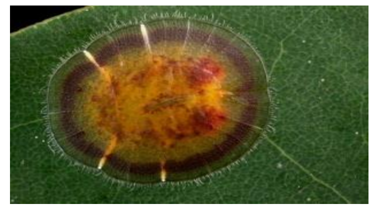
- Chewing mouthparts…………………………………….................................……..38

36. Abdomen without cornicles……………………………………………………….......…37

- Cornicles usually present……………………………………..............… HOMOPTERA (Aphids)

37. With distinct head and eyes…………………………………........ ……HETEROPTERA (Bed bugs)

- Without distinct head and eyes……………………………….............. ..HOMOPTERA (Female scale insects)



38. Abdominal forceps present; entire body rather hard and brown coloured...DERMAPTERA (Earwigs)

- Abdominal forceps absent……………………………………...........……...………….39

39. Mouthparts at end of beak-like structure some distance from eye…………..MECOPTERA (Scorpionflies)

- Mouthparts not elongated, close to eyes…………………...........……………….……..40

40. Cerci present……......……………….…………….…………………………………..41

- Cerci absent…………………………………………......…………………………..42

41. Body leathery and usually grey or dark coloured……………….............**ORTHOPTERA**

(Crickets/Wetas)

- Body soft and pale coloured; three to five tarsal segments; basal segment of front tarsi about same size as ones immediately following...ISOPTERA

(Termites)

42. Antennae longer than one-third of body length………........…....………...PSOCOPTERA

(Booklice, Barklice)

- Antennae shorter than one-fourth of body length………..…..…............ STREPSIPTERA

(Female stylopids)

43. Body compressed dorsoventrally…………………………...........................………..44

- Body compressed laterally……………………….........................…..**SIPHONAPTERA** (Fleas)

44. Sucking mouthparts externally visible……………...............................……………..45

- No sucking mouthparts externally visible……………………......................................…46

45. Antennae longer than head...…................**HETEROPTERA** (True bugs)

- Antennae shorter than head………….............................……….……………… **DIPTERA** (Louse flies and Bat flies)

46. Antennae longer than head…………..………………………47

- Antennae shorter than head…………………………...…..48

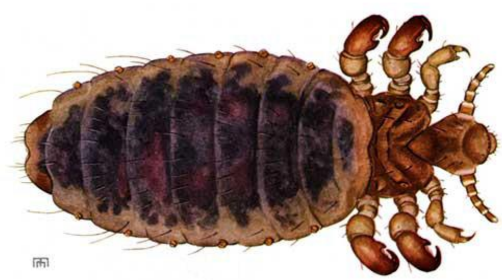
47. Tiny insects; tarsi with two or three segments……….........................… PSOCOPTERA (Barklice, Booklice)

- Large insects; tarsi with five segments……………..................……..... DICTYOPTERA (Cockroaches, Mantids, Walking sticks)

48. Head wider than thorax at point of attachment to thorax………………….. **MALLOPHAGA** (Biting lice)

- Head narrower than thorax at point of attachment to thorax……..........….. **ANOPLURA**
(Sucking lice)



2.4 Identification of insects up to Family of the Orders

2.4.1 Thysanura (Machilidae, Lepismatidae)

- Soft, elongate body tapering towards the abdomen and covered with silvery-grey scales
- 3 long abdominal cerci of similar length with the outer 2 pointing away from the body
- Apterygote (primitively wingless)
- Body relatively flat, tapered and often covered with scales
- Compound eyes small or absent
- Ectognathous mouthparts, adapted for biting.
- Antennae long, thread-like, and multisegmented
- Abdomen with ten complete segments
- Eleventh abdominal segment elongated to form a median caudal filament
- Cerci present, nearly as long as median caudal filament
- Styliform appendages located on abdominal segments 7-9.

- Metamorphosis slight or wanting.

Family: Machilidae

Body somewhat cylindrical, with thorax arched; ocelli present; Compound eyes large, usually contiguous. Compound eyes small and widely separated, or absent. E.g. Jumping bristle

Family Lepismatidae: Body somewhat flattened dorso-ventrally, thorax not arched; Compound eyes small and widely separated; body always covered with scales; widely distributed Tarsi 3- or 4-segmented; ocelli absent; body usually covered with scales. E.g. Silverfish and Fire brat.

Usually they are found hidden in cracks and crevices in the buildings, beneath the stones, in decomposed wood. They are active in dark places. They manoeuvre with an undulating movement.

Economic Importance: It is often a pest in home and libraries. *Ctenolepisma* sp. is the common household silverfish. It feeds and destroys paper, book bindings and starched clothing. It can be collected from amongst old books, behind calendar, photo frames, etc.

2.4.2 Collembola

- Collembolans, or “springtails,” are the primitive Apterygote (wingless) insects.
- Collembola comes from the Greek words kolla, which means glue, and embolon, which means peg. Because they possess a tube-like structure, called the collophore, on the ventral side.
- wingless
- soft-bodied
- possess a forked springing organ, called the furculum, on the ventral side.
- six or fewer abdominal segments
- It can be collected from moist places in soil.

Importance: *Sminthurus viridis* is a pest on alfalfa. They are also found in mushroom houses as a pest.

2.4.3 Isoptera

Members of order Isoptera can be distinguished by the following features:

- Termites are also colloquially known as 'white ants'. However, these insects are very different from those in the order Hymenoptera to which ants belong.
- They are ancient polymorphic, social insects living in colonies.
- Termites are Pale, elongate bodied, small to medium sized insects ranging from 3-20 millimetres in body length.
- These insects are not often seen although evidence of their presence is observable in the large mounds they construct or the damage they do to wood products and structures.

- Termites are medium-sized, cellulose-eating social insects making up the order Isoptera, a relatively small group of insects, consisting of approximately 1900 species worldwide.
- Termites are social insects and live in colonies consisting of a queen, sterile workers and soldiers and winged reproductive males and females known as alates.
- They live in highly organized and integrated societies, or colonies, with the individuals differentiated morphologically into distinct forms or castes-reproductives, workers, and soldiers-that perform different biological functions.
- The sterile castes (workers and soldiers) in termites are made up of both sexes, and reproductives and sterile castes develop from fertilized eggs. In ants, the sterile castes are made up of females only, and all females, sterile and reproductive, develop from fertilized eggs, whereas the reproductive males develop from unfertilized eggs.

- 2 pairs of membranous wings of equal length and identical venation. Wings are present in reproductive castes only and wings shed after mating by means of basal or humeral fractures.

- Mouthparts mandibulate
- Compound eyes are present in alate forms and usually absent in apterous forms.
- Abdomen is broadly jointed to the thorax without constriction.

- Antennae are short and moniliform
- Soil inhabiting termites construct earthern mounds called termitaria.
- Rectum is distended forming rectal pouch to accommodate large number of intestinal symbionts. They have evolved complex relationships with other organisms like bacteria, protozoa and fungi which help them in the digestion of wood.
- The cellulose in a termite's food is digested by myriads of flagellate protists living in the termite's digestive tract. Termites engage in a unique form of anal liquid exchange (trophallaxis), and this is how intestinal microorganisms are transmitted from one individual to another.

Economic Importance: Termites hold two positions from the economic point of view. On the one hand, they may be very destructive, because they feed on and often destroy various structures or materials that people use: wooden portions of buildings, furniture, books, utility poles, fence posts, many fabrics, and the like. Worldwide they account for a high amount of atmospheric methane. On the other hand, they help convert dead trees and other plant products to substances that plants can use.

2.4.4 Phithioptera (Phithiraptera) (Anoplura and Mallophaga)

Characteristics

Lice are small, wingless insects that are parasites of birds and mammals. They are usually less than 10 millimetres in length and are rarely seen without the aid of a microscope or magnifying glass. Lice are short lived and usually host specific. Lice can be recognised by the following features:

- Small, flattened body
- Wingless and colourless
- Short, stubby antennae
- Legs with hooked tarsi adapted to gripping their hosts
- Chewing or biting mouthparts (biting lice) or piercing and sucking mouthparts (sucking lice)

A few species of lice have adapted to live and feed on humans, such as the head louse *Pediculus capitis*, the eggs of which are commonly called nits and the body louse *Pediculus humanus*.

Anoplura

- Completely wingless (secondarily wingless) insects living ectoparasite of mammals.
- Mouthparts are piercing and sucking type and entognathous.

- Claws specialized for grasping hairs.
- Antennae are short.
- They are ectoparasite of man and mammals.
- The eggs are laid in clothing or attached to hairs.
- They suck blood of man or other mammals.

Economic importance

- Pediculus transmits dreaded typhus fever in man. Other diseases transmitted by the human louse are trench fever and relapsing fever.

Mallophaga

- Wingless ectoparasite of birds.
- Head broader than or same as abdomen, meso and meta-thorax separated from prothorax.
- Mouthparts biting type.
- Antennae short incospicuous. Eyes reduced.
- Cerci absent
- Legs are adapted for clinging.

- Commonly called bird lice. They are entirely ectoparasitic on warm blooded animals specially bird.
- They feed upon feathers, epidermal scales, dried blood collecting form wound, hairs etc.

Economic importance

- They cause intense irritation to the host and when present in large numbers often leads to its death by nervous break down.
- 2. They are injurious to poultry (genus -*Menopan*) genus *Lipeurus* on domestic fowl.
- Some species also cause loss to wool and live stock.

2.4.5 Orthoptera (Acrididae, Tettigoniidae and Gryllidae)

- They are medium to large sized insects commonly known as Grasshoppers, Locust, Katydid, Cricket, Mole cricket.

- Usually antenna is filiform.
- Mouthparts are mandibulate.
- Prothorax is large. Pronotum is curved, ventrally covering the pleural region.
- Hindlegs are adapted for jumping (saltatorial type).
- Forewings are leathery, thickened and known as tegmina.
- Hindwings are membranous with large anal area. They are folded by longitudinal pleats between veins and kept beneath the tegmina.
- Cerci are short and unsegmented.
- Ovipositor is well developed.
- Specialized stridulatory (sound-producing) and auditory (hearing) organs are present.
- This order is sub divided into two suborders, viz., **Caelifera** (Short horned grasshoppers) and **Ensifera** (long horned grasshoppers).

Family Acrididae:

This family includes Short horned grasshoppers and locusts. The main character of this family include

- Antenna are short
- Tarsus three segmented
- Ovipositor short and horny
- Tympanum located one on either side of the first abdominal segment.
- Sound is produced by femoro-alary mechanism. A row of peg like projections found on the innerside of each hindfemur is rubbed against the hard radial vein of the closed tegmen.
- Locusts are a serious threat to tropical agriculture. They swarm under favourable conditions and mainly feed on grasses, cereals etc.
- Grasshoppers and Locusts are herbivorous and found in tropical parts of the world.

Economic importance:

Acrididae family possess economic importance due to their intensive damage to agricultural crops and are considered as major pest of plants. These plants are significant for their production rate and nutritional values. Grasshoppers and Locusts invaded many crops in the past and caused destructive damage to them.

Tettigoniidae:

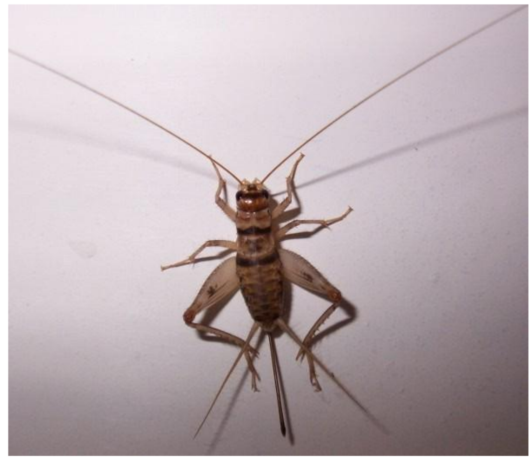
This family includes Katydids, Long horned grasshoppers. The characters of this family are

- Antenna long and slender as long as or longer than the body.
- Tarsus four segmented.
- Ovipositor sword like.
- Auditory organs are found on the fore-tibiae.
- In each fore-tibia a pair of tympanum is present. The outer tympanum is larger than the inner.
- They are maily nocturnal in habit with strident mating calls. Many species of this family exhibit mimicry and camouflage, commonly with the shapes and/or colors similar to leaves.

Economic importance:

The diet of most of the tettigoniids comprises bark, flowers, seeds, and leaves but many of the species are entirely predatory feeding up on other insects, snails etc. Some of the tettigoniids are also considered pests of commercial crop.

Gryllidae:



- Antennae are long.
- Tarsus four segmented.
- Ovipositor is slender and needle like.
- Forewings are abruptly bent down to cover the sides of the body.
- Hindwings are acuminate. They are produced into a pair of long processes which project beyond the abdomen.
- Cerci are long and unsegmented
- Auditory organs and stridulatory organs are similar to long horned grasshopper. Males stridulate during night. They produce a shrill chirping noise. Gryllus sp. It is household pest.
- They are nocturnal in habit, known for musical, monotonous chirpings. They are both herbivorous and carnivorous. Sometimes they show cannibalism when in hunger and captivity.

Economic importance:

Both nymphs and adults damage clothes, starchy material and pollute the food stuffs in the kitchens. They sometimes chew the skin and hairs of babies and infants.

2.4.6 Heteroptera (Pentatomidae, Pyrrhocoridae, Coreidae, Reduviidae, Nepidae, and Belostomatidae)

- Head is porrect or horizontal
- Bases of the forelegs do not touch the head
- Beak arises from the anterior part of the head

- Gular region of the head (midventral sclerotised defined part between labium and foramen magnum) well defined.
- Pronotum usually greatly small
- Scutellum (triangular plate found between the wing bases) well developed
- Forewings heavily sclerotized at the base and the apical half is membranous (Hemelytra) harder than hind pair.
- Wings are held flat over the back at rest and the left and right side overlap on the abdomen.
- Honey dew secretion uncommon
- Herbivorous, predaceous or blood sucking.
- Both terrestrial and aquatic.

IMPORTANT FAMILIES OF HETEROPTERA:

Pentatomidae (Stink bugs or Shield bugs):

- Antenna is five segmented.
- Scutellum is prominent and shield like.
- Adults and nymphs produce a disagreeable odour from stink glands located in metathorax and abdomen respectively.

Economic importance:

Some are phytophagous and some are predaceous. e.g. Green stink bug Nezara viridula is a pest on millets.

Pyrrhocoridae (Red bugs or Stainers):

- Brightly coloured with red or black markings, elongate or oval in shape
- Antennae 4 segmented and rostrum 4 segmented Ocelli absent
- Membrane of hemielytra with 5 unbranched veins

- Coxa is rotatory and tarsi 3 segmented
- Ex: Red cotton bug, *Dysdercus cingulatus*

Economic importance:

It is a serious pest of cotton aand other plants of Malvaceae like Bhindi. It feeds on cotton bolls a nd stain the lint thereby causing a serious loss.

Coreidae: (Squash bugs or leaf footed bugs)

- Dull coloured brownish bugs
- Body oval to elongate with narrow head
- Antennae 4 segmented situated well on the sides of head
- Both hind femora and tibia have conspicuous enlargement or leaf lik the name leaf footed bugs
- Produce pungent smell
- Membrane of hemielytra with 5 unbranched veins Ex: Rice gundhi bug, *Leptocorisa varicornis*

Economic importance:

They feed by inserting their needle like mouthparts into new leaves, tender stems and developing grains. When injuries accumulate, the plant becomes stressed, which can lead to growth retardation of the grains and some grain and plant deformation. Excessive feeding can cause yellow spots on the leaves.

Reduviidae (Assassin bugs, Kissing bugs or cone nose bugs)

- Brown to black, medium sized insects
- Rostrum 3 segmented, curved and its tip fits in a posterior groove
- Fore legs bear adhesive pads on tibia
- Metathoracic scent glands absent
- Most of these are predacious and some are blood

sucking

- Ex: *Rhodnius prolixus*

Economic importance:

Many are predaceous on other isects. eg. *Platymeris leavicollis* is a predator on coconut rhinoceros beetle. *Triatoma* sp and *Rhodnius prolixus* are the vectors of chagas disease caused by *Trypanasoma cruzi* which causes human trypanasomiasis.

Nepidae: (Water scorpions)

- Forelegs are raptorial and suited for prey catching.
- Middle and hindlegs are suited for walking.
- A long caudal breathing tube formed by the cerci is present at the apex of the abdomen.
- They inflict a painful bite when handled.

Belostomatidae: (Giant water bugs or electric light bugs)

- They are large sized insects.
- Eyes are bead like.
- Antennae concealed in ear-like pockets.
- Forelegs raptorial and suited for capturing prey. Posterior legs are adapted for swimming.
- Tibia and tarsus are flattened and fringed with hairs.
- Abdomen with two short retractile apical appendages forming a terminal breathing tube.
- Dorsum of the abdomen is concave forming an air reservoir under the wings.
- They are positively phototropic. They are excellent fliers and swimmers.
- In some species eggs are laid on the back of the male.
- They suck the blood from toads, frogs, fishes and even human beings.
- They are aquatic and usually attracted to light. They feed upon insect, fish, snail.

Economic importance:

Sometimes they bite the swimmers. Their claws are sharp and able to cause painful punctures

2.4.7 Homoptera (Fulgoridae, Membracidae, Cicadidae, Aphididae, Coccidae)

1. Two pairs of wings are usually similar in texture and each wing is practically same in thickness throughout.
2. Excretion of honey dew is a unique feature in many members of this suborder.
3. Metamorphosis is usually gradual type.
4. Mouth parts are adapted for Piercing and sucking type.

Fulgoridae (Lophopidae): (Sugarcane Pyrilla, *Pyrilla perpusilla)*

- Head is produced into a snout.
- Hind trochanter is directed backward
- Hind basitarsus is moderately long. e.g. Sugarcane leaf hopper Pyrilla perpusilla nymphs and adults suck the sap and reduce the quality and quantity of cane juice.

Economic importance:

The planthopper feeds on its host by inserting its stylet into a leaf or stem and sucking out the phloem sap. Excess fluid are excreted as honeydew and sooty mould grows on it. The plant's vigour is reduced through the loss of sap and the reduction in photosynthesis resulting from the sooty mould.

Membracidae: (Tree hoppers or Cowbugs)

- They are structurally modified to resemble thorns or other plant parts.
- Pronotum is enlarge and it covers the head.
- It is also extended backward over the abdomen.
- Wings are concealed by pronotum
- Pronotal process is either partially developed or absent in nymphs.
- Nymphs and adults suck tree sap and are commonly attended by ants for their honey dew.

Economic importance:

Several treehopper species are minor pests, particularly of tropical fruit trees such as papaya, cacao and palm.

Cicadidae: (Cicadas)

- Males have sound producing organs at the base of the abdomen. Sound producing organs consist of a pair of large plates, the opercula covering the cavity containing structures producing sound. In the anterior part of the cavity benath each operculum is a yellowish membrane. A shinning mirror is located in the posterior part of the cavity. In the lateral wall of the cavity is an oval shaped ribbed structure, the tymbal. These are vibrated by strong muscles to produce sound. Each species has a characteristic song. Tympanum is present in both in sexes.
- Wings are transparent.
- Eggs are inserted into the tree twigs by the female.
- Nymphs drop to the ground, enter the soil and feed on root sap.
- Anterior femora of the nymph are thickened with spines beneath and are suited for digging the soil.
- Life cycle of periodical cicada lasts for 13-17 years.

Economic importance:

Cicadas are a valuable food source for birds and other predators. Cicadas can aerate lawns and improve water filtration into the ground. Cicadas add nutrients to the soil as they decompose.

Aphididae: Aphids green flies or plant lice.

- Small soft bodied, pear shaped insects with a pair of cornicles on 5 or 6 the abdominal segment

- Antennae long, tapering distally
- Polymorphic alate forms with 2 pairs of transparent membranous wings.
- Tarsus 3 segmented with a pair of claws.
- They excrete honey due to which ants are attracted Ex: Groundnut aphid, *Aphis croccivora*

Economic importance:

Aphids are pests of economic importance throughout the world. Along with transmitting plant viruses, aphids are capable of inflicting severe crop production losses. They also excrete honeydew that favours the growth of sooty mold which reduces the quality of vegetables and fruits and hence their market values.

Coccidae: (Mealy bugs and scale insects)

- Minute, inconspicuous and highly specialized insects.
- Body is coverd with waxy or powdery coating.
- Females apterous, degenerate larviform, scale like with functional mouth par Males are active, first pair of wings well developed, second pair reduced to halteres
- Tarsi 1 segmented with a single claw
- Reproduction bisexual or parthenogenesis
- Ex: Coffee green scale, *Coccus viridis*

Economic importance:

The coccids of economic importance recorded on horticultural crops in the Republic are reviewed, together with control measures, mainly biological.

2.4.8 Coleoptera (Hydrophilidae, Meloidae, Coccinellidae, Curculionidae, Scarabaeidae, Chrysomelidae, Cerambycidae)

Some of the distinguishing characteristics of insect order Coleoptera are

- Coleoptera means "sheath wings," a reference to the hardened forewings which cover the insect's body
- Highly sclerotized endopterygote insect order with leathery elytra, biting and chewing type of mouth parts and compodeiform and eruciform larvae

- Coleoptera constitute the largest and most diverse order of insects on earth, making up about 30% of all animals Head is strongly sclerotized pro or hypognathous
- Antennae is 11 segmented and present in a variety of forms • Compound eyes in a variety of sizes and shapes like acone, eucone and pseudocone
- Prothorax is large and mobile whereas, mesothorax is reduced Mouth parts are biting and chewing type. Mandibles are well developed. Legs are variously modified for swimming, running, jumping, walking and fossorial Forewings hardened, hind wings are membranous used for flight. Hind wings folded under elytra, with reduced venation Genitalia is concealed and retracted into abdomen
- Metamorphosis is holometabolous, larvae generally appear grub-like with a well defined head capsule and highly sclerotized. Pupa is adecticous and exarate Coleoptera is divided into four suborders, Adephaga and Polyphaga, Myxophaga and Archostemata

> Suborders of Coleoptera

1. **Polyphaga:** It is by far the largest suborder, containing 85 % of the known species, including rove beetles, scarabs, stag beetles, metallic wood-boring beetles, click beetles, fireflies, blister beetles, mealworms, ladybirds, leaf beetles, longhorn beetles, and weevils. Many are phytophagous.
2. **Adephaga:** It includes ground beetles, tiger beetles, predacious diving beetles, and whirligig beetles; most adephagans are predacious.
3. **Myxophaga:** It is a small suborder, members are small or minute, and associated with hygropetric habitats, drift material, or interstitial habitats among sand grains.
4. **Archostemata:** It contains several families of beetles, most associated with wood and these are not known to occur in India so far.

Some of the important families of Coleoptera are under:

Hydrophilidae: (Water scavenger beetles)

- They are black or dull coloured.

- Body is convex above and flattened below.
- Antenna is clubbed and kept beneath the prothorax.
- Maxillary palps are long and look like antennae.
- Legs are evenly placed in the anterior part of the body.
- Middle legs are flattened and suited for swimming.
- Metasternum is produced into a spine posteriorly.
- Air is stored beneath the elytra and over the undersurface of the body.
- Adults and larvae feed on decomposing vegetable matter.

Economic importance:

Meloidae: (Blister beetles, Oil beetles)

- They are cylindrical, soft bodied beetles.
- Head is connected to thorax by a distinct neck.
- Legs are heteromerous with a tarsal formula of 5-5-4.
- Claws show longitudinal splitting.
- Forewings are soft and leathery.
- They give off a fluid containing the oily principle catharidin, when disturbed which causes blisters.
- Development involves hypermetamorphosis. Eggs hatch into active triungulin larvae which may feed on eggs of grasshoppers.
- Adults feed on foliage and flowers.

Economic importance:

Blister beetles, pose a major health and economic problem in agriculture. Adults of Meloidae family are destructive phytophagous pests of a wide variety of ornamental flowers and agricultural crops. All the blister beetle yield a pharmaceutical product, oily in

nature called as cantharidin. It is regarded as hair restorer. Powder of dried blister beetle is used to extract cantharidin .

Coccinellidae: (Lady bird beetles)

- They are hemispherical. The body is convex above and flat below.
- Their body appearance resembles a split pea.
- Head is small, turned downward and received into a prominent notch of prothorax.
- Elytra is strongly convex, brightly coloured and variously spotted.
- Grubs are compodeiform and spiny.
- The last larval skin either cover the pupa or gets attached to the anal end of the pupa.

Economic importance:

Except the genus *Epilachna*, others are predators on aphids, scales, mites and whiteflies. Both larva and adult are potent natural biological control agent.

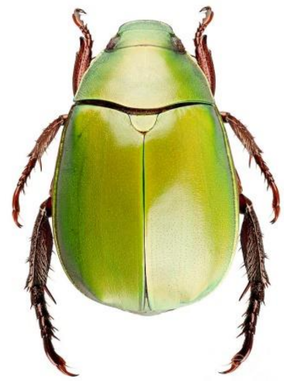
Curculionidae: (Weevils, snout beetles)

- Minute to large sized insects.
- Frons and vertex of the head are produced into snout. It is cylindrical and in some species larger than the beetle itself.
- Mouthparts (Mandibles and maxillae) are present at the tip of the snout. It is useful to feed on internal tissues of the plant and provide a place for egg laying.
- Antenna is geniculate and found usually in the middle of the snout.
- Grubs are apodous and eucephalous.
- Weevils are important crop pests occuring both in field and storage.
- Coconut red palm weevil: *Rhynchophorus ferrugineus*.

Economic importance:

Members of Curculionidae are extremely important economically, containing many pest species (and some beneficials).

Scarabaeidae: (Scarabs, Dung beetles)



- Head is broad and flat.
- Mandibles are membranous and incapable of chewing.
- Many have spines and horns on head and prothorax.
- Forelegs are fossorial.
- Middle legs are widely separated
- Adults and larvae are scavengers. They feed upon the droppings of animals and human excreta. They role on the dung into balls and bury them in underground chambers. They use their head and forelegs for handling dung and digging pits in the soil. Head is used as an excavator and fore-tibia as shovel. They show remarkable parental care.
- Common Indian dung beetle: *Anomala dimidiata*

Economic importance:

The beetle family Scarabaeidae has a high diversity of species, some of them have become important pests. Some species of this family have become international pests due to human transport to new habitats. Scarab pests cause damage to the roots of plant through larval feeding or adult feeding on the aerial parts of plants. The pests from this are difficult to control due to the cryptic position of the larvae in the soil and the usually nocturnal activity of the adults. However, light traps are considered as the best way to control the pest form this family.

Chrysomelidae: (Flea beetle)

- Adults are oval and convex, with metallic colouration
- Antennae widely separated at the base

- Prothorax is laterally marginated and narrow
- Legs are well adapted for running and jumping
- Elytra covers entire body, pygidium not exposed beyond elytra
- Third tarsal segment is bilobed
- Ex: Rice hispa, *Dicladispa armigera*

Cerambycidae: (Longicorn beetles)

- Body is cylindrical.
- Compound eyes are notched.
- Antenna is as long or longer than the beetle itself. Antenna can be flexed backwards. It is surrounded at the base by compound eye.
- Pronotum is with one to three laterally located spines.
- Grubs are called round headed borers. They are apodous but have psuedopods both on dorsal and ventral side. They are wood borers. They develop beneath the bark and tunnel into the branches or main stem.
- Example: Mango stem borer : *Batocera rufomaculata*

Economic importance:

Cerambycidae is economically one of the most important wood boring insect. Members of this family interferes and causes damages to forests, forest products, fruit and nut trees, vegetable and field crops, seeds, orchids, and flowers.

2.4.9 Lepidoptera (Noctuidae, Sphingidae, Bombycidae, Nymphalidae, Pieridae, Papilionidae, Pyralididae and Saturniidae)

The characteristics which distinguish the order Lepidoptera from other insect orders are

- The name Lepidoptera means "scale wings." Body, wings and appendages covered with scales
- Head is hypognathous

- Antennae are of various types, clavate, pectinate, plumose. They also have a Johnston's organ, on the pedicle
- Compound eyes are well developed
- Mouth parts are siphoning type. Mandibles are vestigeal. Long coiled probocis is formed by galeae of maxillae, labial palpi well developed
- Prothorax in most species is reduced. Mesothorax is large and distinct
- Wings are two pairs, large and covered by scales. Microtrichia are present
- Wings are floded vertically upward in butterflies and these are held roof like in moths at rest
- Abdomen is slender or tubular. The posterior abdominal segments are modified extensively for reproduction. Cerci are absent. Tympanal organas are present at the base of abdomen
- Genetalia: 9th and 10th segments form telescopic oviopositor
- Larva The larvae are eruciform with well-developed head and mandibles. They have 0 to 10 prolegs, usually 8. Prolegs armed with crochets. The larvae are commonly called caterpillars
- Pupa: The pupae in most species are adecticous and obtect, while they are decticous in others. Pupae of moths are called cocoons and of butterflies called chrysalis

Some of the important families of Lepidoptera are described below:

Noctuidae: (Army worms, borers and cut warms)

They are medium sized, stoutly built moths.

- They are nocturnal and attracted to light.
- Labial palp is well developed.
- Crochets on the larval prolegs are all of one size and arranged in semi-circle.
- Some larvae are semiloopers. They have either three or four pairs of prolegs.
- Example: Tobocco cut worm, *Spodoptera litura*

Economic importance:

Larvae attack the plants during night. Larvae of some species remain concealed beneath the surface of the ground or litter on the surface during day and feed on plants during night. They often cut small seedlings close to the ground and hence they are called cut worms.

Sphingidae: (Hawk moths, Sphinx moths, Horn worms)

- They are large sized stoutly built moths.
- Antenna is thick towards middle and hooked at the tip.
- Proboscis is very long.
- Forewings are elongated and pointed with very oblique outer margin.
- Hindwings are reduced in width fitting into the indendted margin of forewings. They are powerful fliers.
- Larva is smooth with a middorsal horn (anal horn) on the eighth abdominal segment.
- Pupation takes place in earthern cells. In many species the proboscis is enclosed in a separate sheath.
- Example Death's head moth, *Acherontia styx* is a defoliator on gingelly. Markings present on the thorax of the adult moth resemble human skull.

Economic importance:

Bombycidae: (Silk worm moths)

- Antenna is bipectinate.
- Larvae is either with tuft of hairs or glabrous with medio dorsal horn on the eighth abdominal segment.
- Pupation occurs in dense silken cocoon.
- Example Mulberry silk worm, *Bombyx mori* an important source of natural silk.

Economic importance:

Silkworm is *B. mori* “economically important” due to its use in silk industry to maximize silk fibre productivity.

Nymphalidae: (Brush footed or four footed butterflies)

- Forelegs are short, functionless, hairy and folded on thorax.
- Foretibia is short and covered with long hairs.
- Larva is with many processes or spines on the body.

Example: Chocolate pansy, *Junonia iphita*

Economic importance:

Castor butterfly : *Ergolis merione*. It is a defoliator.

Pieridae: (Cabbage butterfly)

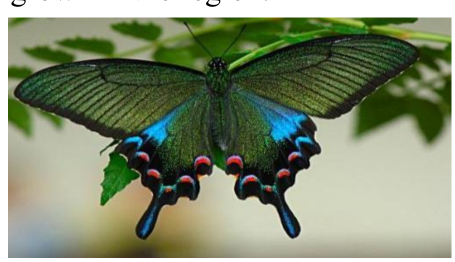
- They are white or yellow or orange coloured with black markings.
- Larva is green, elongate and covered with find hairs.
- Larval body segments have annulets.

  Example: Cabbage butterfly, *Pieris brassicae*

  Economic importance:

  Cabbage butterfly is serious pest of various crops grown in the region.

Papilionidae: (Swallow tails)



- They are often large and brightly coloured.
- Prothoracic legs have tibial epiphysis.
- In ma ny species hindwings has tail like prolongation.

- Amplexiform type of wing coupling is present.
- Larval body is either smooth or with tubercles.
- Retractile osmeteria are present on the prothoracic tergum of the caterpillar
  Example: Chinese peacock, *Papilio bianor* (State butterfly of Uttarakhand).

Economic importance:

Pyralidae (Syn-Pyralididae): (Snout moth)

- Small delicate moths with labial palpi projecting forward into a snout like structure
- Fore wings are elongate or triangular
- Cu_2 absent in forewing and present in hind wing
- Legs are slender and long
- Tympanum present at the base of the abdomen
- Adult females provided with a tuft of hairs at the caudal extremity
- Ex: Indian meal moth, *Plodia interpunctella*

Economic importance:

Saturniidae: (Moon months, giant silk worm moths)

- They are large sized moths.
- Antenna is bipectinate.
- Transparent eye spots are present near the centre of each wing. The spots are either circular or crescent shaped.
- Larva is stout and smooth with scoli.
- Cocoon is dense and firm.
- Example: Tussor silk worm, Antherea

Economic importance:

2 .4.10 Hymenoptera (Ichneumonidae, Chalcididae, Braconidae, Vespidae, Apidae, Formicidae)

- The characteristics which distinguish the order Hymeoptera from other insect orders are . Many species have highly developed social life
- Head is hypognathous
- Antennae is genicultae, clavate, filiform or pectinate
- Eyes are well developed except in some ants
- Mouthparts are biting and chewing type in Symphyta, lapping and sucking in bees •
- Mesothorax is large. First abdominal segment is fused with meta notum forming propodeum. Rest of the abdomen forms gaster or metasoma. First segment is modified into petiole
- Forewings are large and hind wings are small. During flight forewings are interlocked with hind wings with a row of hooks called hamuli Legs are variously modified. Trochanter along with trochantellus present
- Ovipositor is well developed, secondarily modified for sawing, boring, stinging and piercing
- Metamorphosis is holometabolous. Larvae is apodous with well developed head, pupae exarate and pupates in cocoon

Order Hymenoptera is divided into two sub orders

- Symphyta Primitive Hymenoptera (sawflies)
- Apocrita Highly evolved Hymenoptera (wasps, ants and bees)

Some of the important families of order Hymenoptera are under:

Ichneumonidae: (Ichneumon flies)

- Adults are diurnal and visit flowers.
- Trochanter is two segmented. Hind femur is with trochantellus
- Forewing has two recurrent veins.
- Petiole is curved and expanded at the apex.

- Sternites of the gaster are membranous
- Ovipositor is arising anterior to the tip of abdomen. It is often longer than the body and exerted out permanently.

Economic importance:

Larvae are mostly parasites and less frequently hyperparasites. They are solitary parasites. They spin cocoons in or outside the host. *Eriborus trochanteratus* is an exotic larval parasite of coconut black headed caterpillar.

Chalcididae:

- They are small to medium sized insects.
- Hind coxae are five to six times larger than forecoxae.
- Hind tibial spurs are larger than mid tibial spurs.
- Hind femora are larger with a row of short-teeth beneath.

- Wing venation is reduced to a single anterior vein.
- Ovipositor is short and straight.

Economic importance:

Brachymeria sp. is a pupal parasite on coconut black headed caterpillar.

Braconidae: (Braconid wasps)

- They are small, stout bodied insects
- Forewing has one recurrent vein.
- Petiole is neither curved nor expanded at the apex.
- Gaster is sessile or subsessile.
- Sternites of the gaster are partly membranous.
- Abdomen is as long as the head and thorax together
- They parasitize lepidopteran larvae commonly.
- They are gregarious parasites.

- In many species polyembryony is observed.
- Pupation occurs in silken cocoons either externally on the host or away from the host in groups. *Bracon brevicornis* is mass multiplied and released for the control of coconut black headed caterpillar.

Economic importance:

Vespidae: (Yellow jackets, Hornets)

- Lateral extensions of the pronotum reach the point of insertion of wings and do not form rounded lobes.
- Abdomen is conical
- They construct nest with `wasp paper', a substance made from fragments of chewed wood mixed with saliva.
- They are either solitary or social wasps.

  Example: *Vespa velutina*

Economic importance:

They are generally predaceous on Lepidopteran caterpillars. Many paralysed caterpillars are stored in the cells of their nests. Eggs are suspended by a filament from the top of the nest and the cell is sealed. *Vespa velutina* and *V. mandarinia* is a bee enemy.

Apidae: (Honey bees)

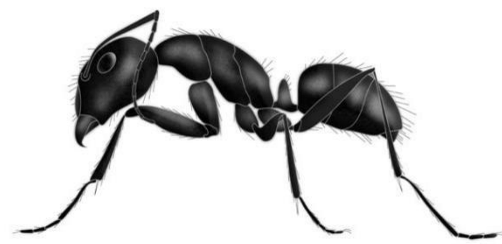
- Body is covered with branching or plumose hairs.
- Mouthparts are chewing and lapping type. Mandibles are suited for crushing and shaping wax for building combs.
- Legs are specialized for pollen collection. Scopa (pollen basket) is present on hind tibia.
- They are social insects with three castes viz., queen, drone and workers. Temporal separation of duties is noticed among workers.

- Example: Indian honey bee, *Apis indica*

Economic importance:

They are highly beneficial to insect as they help in pollination. Additionally they produce honey, wax, royal jelly, propolis, pollen, bee venom etc.

Formicidae: (Ants)



- They are common widespread insects.
- Antennae are geniculate.
- Mandibles are well developed.
- Wings are present only in sexually mature forms.
- Petiole may have one or two spines.
- They are social insects with three castes viz., queen, males and workers. Workers are sterile females and they form the bulk of the colony. Many species have established symbiotic relationship with homopteran insects.

Economic importance:

The economic importance of the Formicidae (ants) in agriculture is mainly due to their interactions with honeydew-producing insect Hemipterans, which reduce the abundance of beneficial arthropods in the canopies, thus hindering the biological control of pests.

2.4.11 Diptera (Tipulidae, Chironomidae, Culicidae, Muscidae, Tabanidae, Tachinidae, Drosophilidae, and Bombyliidae)

The characteristics which distinguish the order Diptera from other insect orders are Endopterygote insect order with a pair of forewings, extremely reduced thread like hind wings (halters), suctorial proboscis and apodous larvae (maggots)

- Head is prognathous, eyes are large and holoptic in males and dichoptic in females. Ocelli are 3, arrangesd in triangle

- Antennae in Nematocera is filiform in females and plumose in males, Brachycera it is stylet and in Cyclorrhapa it is aristate type
- Mouth parts are piercing and sucking type in blood sucking insects and sponging in non-blood sucking Cyclorrhapa
- Meso thorax is well developed, pro and meta thorax greatly reduced Only one pair of forewings, hind wings are extremely reduced (halters)
- Legs are well developed for clinging, tarsi 5 segmented, paired claws, with empodium and pulvilli
- Undergo complete metamorphosis- larvae apodous, pupa is either free or enclosed in puparium
- Order Diptera is divided into 3 sub orders namely Nematocera, Brachycera and Cyclorrhapa

Some of the important families of order Diptera are under:

Tipulidae: (Crane fly)

- Tipulidae are medium to large-sized flies (7–35 mm, 1⁄4–1+1⁄2 in) with elongated legs, wings, and abdomen.
- Their colour is yellow, brown or grey.
- Ocelli are absent.
- The rostrum (a snout) is short to very short with a beak-like point called the nasus (rarely absent).

Economic Importance:

Chironomidae: (Non-biting midges)

- Chironomidae are the Diptera belonging to the morphologically to the Culiciforma, so their general appearance look like amosquito.

- They are Nematoceran and as such, they are characterized by long antennae (more or less as long as the head).

Economic importance:

Culicidae: (Mosquitoes)

- They are delicate, fragile, slender insects
- Females have piercing and sucking type of mouthparts with six stylets.
- Antenna is plumose (bushy) in male and pilose (less hairy) in female.
- Legs are slender, delicate and long.
- Wings are fringed with hairs and scales on hind margin and on some veins.
- Males are short lived and feed on nectar or decaying fruits.
- Females live long and are blood feeders.
- Larvae are called wrigglers. Larval head is large with chewing mouthparts and mouth brush aiding in filter feeding. Thorax is large without legs. Respiratory siphon is located in the penultimate abdominal segment. Anal gills are present at the terminal end of the abdomen.
- Pupa is known as tumbler. It is very active. It has a pair of prothoracic horns which houses the anterior pair of spiracles. A pair of anal paddles is present at the terminal end aids in swimming.

Example: *Anopheles* sp.

Economic importance:

Anopheles sp. is responsible for transmitting malaria.

Muscidae: (House fly)

- Antennal arista is plumose.

- Mouthparts are sponging type. Labium is distally modifed into a pair of oval shaped fleshy lobes called labella.
- Pretarsus consits of two claws and two adhesive pads.
- First abdominal segment is yellow in colour. Terminal abdominal segments are telescopic forming a pseudo ovipositor. Abdomen is not bristly on basal part.
- Maggots are scavengers. Adults carry certain disease causing microbes on its legs, body hairs and mouthparts.

Example: Housefly, *Musca domestica*

Economic importance:

Tabanidae: (Horse flies)

- Body is stout
- Head is large. Eyes are large and often brilliantely coloured. In male eyes are holoptic (contiguous) and in female dichoptic (seperate). The third antennal segment is annulated. The proboscis is strong and pointing downwards.
- They are swift fliers.
- Male feeds on nectar. Female sucks blood from cattle and horses. They spread anthrax.

Economic importance:

Tachinidae: (Tachinid flies)

- Arista is completely bare.
- Abdomen is stout with several noticeable bristles.

Economic importance:

They are nonspecific endoparasites on the larvae and pupae of Orthoptera, Hemiptera, Lepidoptera and Coleoptera.

Drosophilidae: (Vinegar gnats, Pomace flies)

- Eyes are usually red.
- They are attracted to rotting vegetables and fruits.
- Larvae feed on yeast and products of fermentation.
- Life cycle is very short (7 days).

Economic importance:

Drosophila melanogaster, They are extensively used in the study of animal genetics.

Bombyliidae:

- The Bombyliidae are a family of dipteran flies.
- Their common name is bee flies.
- Adults mainly feed on the nectar and pollen. Some of them are important pollinators.
- Larvae generally are parasitoids of other insects.

Economic importance:

10.5 Study of the different types of adaptation found in insects

Adaptation is basically an artefact of natural selection acting on populations. Natural selection means differential reproduction i.e. some members of population have traits which enable them to grow up and reproduce at a high rate and leave the more offsprings in the next generations than others. Generally those individuals which are best adapted to the environment have a greater number of surviving young ones.

Some of adaptations found in insect are under:

1. **Migration:**

   All insect moves to some extent from one place to another. The range of movement can vary from few centimetres e.g., sucking insects and wingless aphids to thousands of kilometres e.g., locusts, butterflies and dragonflies.

2. **Hibernation:**

   Ladybird beetles are known to hibernate in big colonies under the loose bark of trees, and in buildings. House flies, and the blow flies known as Bluebottles and Green bottles, winter in cellars, attics and the crevices of buildings. If the temperature rises above 50 degrees, they will crawl or fly aimlessly.

   The May beetle or June bug burrows down below the frost line. The young queen bumblebees lie dormant in burrows well below the ground surface. Some beetles, for instance, get ready for hibernation by storing up fat, like bears.

3. **Sounding scary:**

   Many insects, such as some shield bugs, dung beetles, longhorn beetles, ants and tiger moths produce rasping, buzzing or hissing sounds when disturbed or handled. In most of the cases by rubbing or vibrating one part of the body against another part (a mechanism called stridulation).

4. **Shooting spray:**

   A foul smell or a bad taste is often enough to discourage a potential predator. Shield bugs have specialized glands located in the thorax or abdomen that produce foul-smelling hydrocarbons. These chemicals accumulate in a small reservoir adjacent to the gland and are released onto the body surface only as needed. The larvae of certain swallowtail butterflies have eversible glands called osmeteria, located just behind the head. When a caterpillar is disturbed, it rears up everts the osmeteria to release a repellent vapour and waves its body back and forth to ward off intruders.

5. **Thanatosis (feigning death):**

Death feigning as a defensive response is very widespread in insects. A remarkable example of intraspecific death feigning comes from the fire ants. Red flour beetles (*Tribolium castaneum*) feign death upon encountering a predator such as a jumping spider.

6. **Mimicry:**

Mimicry is the adaptive resemblance in signal between several species in a locality. The most spectacular and intriguing cases are of course those of accurate resemblance between distantly related species, such as spiders mimicking ants. Mimicry typically involves three players: two senders and one receiver. For mimicry to evolve it is essential that both senders benefit from eliciting the same response from the receiver. This provides the incentive for looking alike. Two situations can occur depending on whether it pays the receiver to react with a favored response towards only one of the senders or to both.

In Batesian mimicry, one of the sender species the mimic, sends a dishonest signal to deceive the receiver e.g., a predator. It is thought that deception is possible only if the receiver has previously inherited or acquired knowledge about this signal. The most famous Batesian mimic is probably the viceroy butterfly (*Limenitis archippus*) which mimics the monarch (*Danaus plexippus*).

Müllerian mimicry, a form of biological resemblance in which two or more unrelated noxious, or dangerous, organisms exhibit closely similar warning systems, such as the same pattern of bright colours. Mullerian mimicry occurs when the mimic is also well-defended. An example of Mullerian mimicry is the distasteful queen butterfly that is orange and black like the equally unpalat able monarch.

7. **Camouflage:**

Camouflage is a protective strategy occurring in invertebrate lineages as diverse as sea urchins, gastropods, crabs and insects. Insects that look like their environment won't be seen by predators such as birds and lizards. Some insects look like sticks, leaves, and thorns. This type of adaptation helps insect survive by blending in with their surroundings so they aren't eaten or so that prey doesn't see them hidin

2.6 Summary

- Class insecta are divided into two sub-classes. Total 29 order are there in class insecta.
- Dichotomous key always present two characteristic of organism in each step, with right choice one is able to identify insect species.
- Insects are known to exhibit migration, hibernation, producing scary sounds, produces foul smell, thanotosis, mimicry, camouflage etc. to protect itself from predator and harsh conditions.

2.7 Terminal Questions and Answers

Q1. Describe in detail three stages of taxonomy?

Q2. How many sub-classes are there in class insecta?

Q3. Describe in detail the classification of insecta.

Q4. What are the main features of Dichotomous keys?

Q5. Describe different types of adaptation in insects?

Q6. What is Thanatosis?

Q7. Differentiate between Batesian and Müllerian mimicry?

Q8. What is camouflage?

References:

- Mani, M. S. (1974). Modern classification of insects. Modern classification of insects.
- Sunaullah Bhat, Sandeep Kumar, Vishal Kumar, Sangeeta Rawat & Puja Pant (Kumaun University, S.S.J. Campus, Almora) & G.C.S. Negi & Ravindra Joshi (G. B. Pant National Institute of Himalayan Environment) (2020). Insect Diversity in Surya-Kung (Contribution to Nature Interpretation and Learning-V). GBPNIHE, Kosi- Katarmal, Almora, Uttarakhand, India

Unit 03: Applied entomology exercise

3.1 Objectives

- To learn about the pest of various fruits, vegetables and Stored grains.
- To learn about the damaged caused by various pest.
- To learn about the life cycle of major pest.
- To learn about honey bee and bee hive.
- To learn about the pollination provided by various insects.

3.2 Introduction

Insect are one of the most versatile and fascinating groups among all the animals. Insects have lived on earth for about 350 million years, compared with less than 2 million for human. They have dominated the earth and excel all other animals in both diversity and magnitude. Entomology as applied science has its own importance both in plant protection and getting benefit for mankind from the useful role played by insects. Scientific entomology is over a century old in India and a firm foundation of economic entomology has been laid by scientists like Lefroy, Fletcher, Ramkrishnan Ayyar and Ramchandra Rao in India. Till absent 1930, the subject was morphological all over the world.

This study yielded considerable information on Taxonomy, insect pests and control. Towards the later period, applied entomology developed a fundamental basis for pest study and methods of pest control including biological and legal control formed the major activity in this branch of science. Recognizing the usefulness of insect as an experimental animal Wigglesworth showed that physiology of insect is a fascinating field of study, and he established insect physiology as a separate discipline in 1930-38; in later period the same was extended into field of insect control also. In 1950-60 entomology emerged as a biological science encompassing morphology, ecology, physiology, phenology, pestology, biochemistry and ethiology (behaviour).

Entomology can generate employment up to certain extent e.g. production of parasites/ predators, honey bee, lac culture, diseases causing agents. This job one can do by taking short training and can earn money as well as can help the farmer in adoption heap and non-polluted plant protection.

3.3 Pests of fruits, Vegetables & Stored grains:

Fruit production in India is largely dominated by tropical and sub-tropical fruits. About 39.5% of the world's mangoes and 11% of the world's banana are produced in India. Some of the important pests of fruits are discussed as under:

Insect pest name	Scientific name	Damage symptom	Specific management practices
Mango hoppers	*Idioscopus* spp., *Amritodus arkinsoni* (Cicadellidae: Hemiptera)	• Drying of inflorescence. with large scale withering planting and shedding of mango • Development of sooty mould due to honey dew secretion	• Avoid frequent irrigation flowers • Avoid high density and split doses of nitrogen fertilizers • Avoid water logging • Need based spray of carbaryl or malathion
Mango stem borer,	*Batocera rufomaculata* (Cerambycidae: Coleoptera)	• Bore holes on mango stemm with protrusion of branches	• Cut and destroy the infested branches • Injectin methyl parathion into bore holes and plug with mud
Mango mealy bug.	*Drosicha mangiferae* (Margarodidae: Hemiptera)	• Large number of mealy bugs are seen on the stalks and fruits effecting the quality and quantity of fruit. • Nymphs and adult suck plant juice and the leaves	• Banding of trees with sticky alkathene or plastic sheets • De-weeding • Deep summer ploughing • Release of predator like Crytolaemus montrouzieri

		dry up.	• Need based sprad of methyl parathion
Mango fruit fly	*Bactrocera dorsalis* (Tephritidae: Diptera)	• Magots feeds on the pulp pf fruit and the affected portion rot and the fruit drops off.	• Deep summer ploughing to kill pupae • Removal and destruction of infested fruits • Setting up pheromone traps like methyl eugnol or curlure
Pests of citrus fruit:			
Citrus sucking moth	*Othreis fulonica, O. maternal, O. ancilla* (Noctuidae: Lepidoptera)	• Adult sucks the juice from ripening fruits resulting in fruit dropping. • Shedding of fruits with fedding punctures	• Destruction of weed hosts • Smoking below the tree to scare away adult. • Bagging of fruits with polythene or paper cover to avoid damage by adult • Setting up of light traps
Lemon butterfly	*Papilio demoleus* (Papilionidae: Lepidoptera)	• The caterpillar varaciously feeds on tender leaves • In case of serve infestation entire tree gets defoliated.	• Hand picking of various stage of pest. • Use of natural enemies like *Trichogramme* sp. • Needs based spray of quinalphos or carbaryl

Cirtus leaf minor	*Phyllocnistic Citrella* (psyllidae: Hemiptera)	• Both adult and nymphs sucks sap from the plant. • Nymph injects toxins into plant as a result affected parts dry up • Excrete honeydew resulting in growth of sooty moulds • Psylla transmits the Greening virus.	• Destruction of infested brances • Use of natural predator like lady bird beetle • Need based spray of monocrotophos.
Pest of Guava:			
Guava tea mosquito bug	*Helopeltis antonii* (Miridae: Hemiptera)	• Corky out growth or scab formation. • Drying of shoots, inflorescence and dropping of flowers and young fruits.	• Destruction of infested plant part. • Need based spray of carbaryl
Spiraling whitefly	*Aleurodicus disperses* (Aleyrodidae: Hemiptera)	• Yellowing of leaves and development of sooty mould.	• Clean cultivation • Removal of weeds as well as alternative host of the pest • Release of predators like *Chrysoperla* sp. • Need based spray of metasystox or monocrotophos.

Fruit borer	*Conoganthes punctiferalis* (Pyralidae: Lepidoptera)	• Caterpillar feeds on the fruits and dropiing of fruits	• Infested fruits should be collected and destroyed. • Need based spray of carbaryl
Pests of Banana:			
Rhizome weevil	*Cosmoplities sordidus* (Curculionidae: Coleoptea)	• Grubs bore into pseudostem and rhizome making tunnels by feeding • Adult bore and kill the central stem	• Drenching of soil chloropyrofos before palnting • Clean cultivation • Trimming og rhizome • Trapping adult using yellow traps • Use of carbofuran or phorate granules.
Banana rusty thrips	*Chaetonphosthrips Signipennis* (Thripidae:Thysanoptera)	• Red discolouration between individual fingers • The skin becomes reddish brown, roughed	• Using only clean corms • Release of natural predators like *Chrysoperla* and lady bird beetles • Need based spray of metasystox
Pests of grapes:			

Grapevine flea beetle	*Scelodonta strigicolla* (Chrysomelidae: Coleoptera)	• Grubs feeds on roots and adult on tender leaves and buds resulting in shoot holes	• Removal of loose bark at the time pruning prenvents egg laying by flea beetle • Mass collection and destruction of adult • Need based spray of chlorpyriphos
Grapevine mealy bug	*Maconellicoccus hirisutus, Ferrisia virgate* (Pseudococcidae: Hemiptera)	• Sticky, shrivelled grapes • Berries with sooty mould	• Destruction of affected parts • Removal of weeds and alternate hosts • Release of natural predators like *Chrysoperla* and coccinellid beetles. • Needs based spray of metyl parathion
Insect pest of Pomegranate			
Anar butterfly/fruit borer	*Virachola Isocrates* (Lycaenidae: Lepidoptera)	• Bore hole on pomegranate fruits surrounded by faecal material and feed on the inner content • Infested fruits are attacked by bacteria, fungi and rot	• Bagging og fruit with polythene cover • Collection and destruction of fallen infested fruits • Need based sprad of monocrotophos
Insect pest of Apple, Pear, peach and Plum			

Apple wooly aphid	*Eriosoma lonigera* (Aphididae: Hemiptera)	• Aphids suck sap from twings and from the roots • Ashy coat is noticed on apple tree stem with galled roots.	• Use of resistant root stocks such as golden delicious and Northern spy varieties. • Release of parasitiods, like *Aphelimus mali* • Need based spray of diazinon or oxydemeton methyl
San Jose scale	*Quadraspidiotus perniciosus* (Diaspididae: Hemiptera)	• Nymphs and adult female ucks sap from twings, branches, and fruits • The infested region on bark turns into pink colour • Pink colour encrustation on apple apple fruits	• Infested pruned material should be collected and burnt • Augmentation and inoculative release of parasitoids, *Encarsia perniciosi* and *Aphytis* sp. • Need based spray of diazinon or oxydemeton methyl
Apple stem borer	*Apriona cinerea* (Cerambycidae: Coleptera)	• Grubs make acircular hole bores into stem and in severe cases the brance dry and wilts.	• Pruning and burning of infested shoot • Injection of carbon disulphide or chloroform into hole • Placing of Aluminium phosphide tablets inside the hole and then plugging with moist soil. • Need based spray of dimethorate

Insect pest Vegetables			
Insect pest of Brinjal:			
Spotted beetle	*Henosepilochna viginitoctopunctata* (Coccincllidae: Coleoptera)	• Grubs and adults feed on the upper surface of the leaves • Skeletanization of leaves and lace like appearance • Infested leaves dry up and fall	• Collection and destruction of masses and skeletonised leaves with adults and grubs • Hand picking of grubs and collection of beetles hand nets • Need based spray of carbaryl or malathion
Shoot and fruit borer,	*Leucinodes orbonalis* (Pyraustidae: Lepidoptera)	• Larva bores into tender shoot resulting in drying of the tips • It bores into developing fruits and plugged with excreta	• Cultivation of resistant varieties such Pusa purple round and Punjab Neelam • Installation of pheromones traps for adult. • Avoid monoculture • Need based application of indoxacarb or caarbaryl

White fly	*Bemisia tabaci* (Aleyrodidae: Hemiptera)	• nymph and adults sucks sap from the under surface of leaf and excrete honey dew • leaves appear sickly and get coated with sooty mold • it transmit yellow vein mosaic virus	• setting of yellow trap coated with grease/ oily material is the only effective way to control white fly
Insect pest of Tomato:			
Fruit borer	*Helicoverpa armigera* (Noctuidae: Lepidoptera)	• Caterpillar in the initial stages feeds on tender leaves and later on bores into fruit	• Grow resistant varieties like Avinash-2 • Growing of African Marigold as trap crop • Use of pheromone and light trap • Release parasitoid like Trichogramma spp., Bracon spp. And Campoletis spp.
Serpentine leaf minor	*Liriomyza trifolii* (Agromyzidae: Lepidoptera)	• Larva mines into the leaves. In severe cases the leaves dry up.	• Destruction of affected plant and plant part. • Spray of neem oil

Fruit borer	*Spodoptera litura* (Noctuidae: Lepidoptera)	• caterpillar initially causes defloration • once the fruit is formed it bore into fruit making it unpleasant for use.	• Growing castor as trap crop • Deep ploughing to exposure pupae to high temperature • Manual collection and mass destruction eggs and caterpillar. • Need based spray of emamectin benzoate
American pinworm	*Tuta absoluta* (Gelechiidae: Lepiddoptera)	• The larva feeds voraciously upon tomato plants, producing large galleries in leaves, burrowing in stalks, and consuming apical buds and green and ripe fruits. • It is capable of causing a yield loss of 100% in case of protected cultivation	• Spray of spinosad, imidacloprid • *Bacillus thuringiensis* spray • Setting up of pheromones traps
White fly	*Bemisia tabaci* (Aleyrodidae: Hemiptera)	• nymph and adults sucks sap from the under surface of leaf and excrete honey dew • leaves appear sickly and get coated with sooty	• setting of yellow trap coated with grease/ oily material is the only effective way to control white fly

		mold • it transmit yellow vein mosaic virus	
Pest of potato:			
Potato tuber moth	*Phthorimaea operculella* (Gelechiidae: Lepidoptera)	• Mines on the leaves and bores holes on tender shoot and tubers.	• Earthing up of tuber crop • Removal and destruction of effected crop. • Release of *Bracon gelichiae* • Need based spray of malathion
Potato black cut worm	*Agrotis ipsilon* (Noctuidae: Lepidoptera)	• Caterpillar feeds on young leaves and also cut tender stem at ground level	• Deep summer ploughing • Collection and destruction of caterpillar • Setting up of light traps • Need based spray of carbaryl
Pest of Okra:			
Fruit borer	*Earias vittela* (Noctuidae: Lepidoptera)	• Larva bores into terminal shoot of the young plant leading to death of plant • Larva bores into fruit resulting in fruit sheeding	• Growing cotton as trap crop • Deep ploughing • Avoid mono cropping

Leaf hopper	*Amrasca biguttela* (Cicadellidae: Hemiptera)	• damaged caused sucking sap of the plant • hopper lead to curling and crinkling of leaves	• growing of tolerant varieties • release of predators such as *Chrysoperla,* lady bird beetle • seed treatment with imiadacloprid
Fruit borer	*Spodoptera litura* (Noctuidae: Lepidoptera)	• caterpillar initially causes defloration • once the fruit is formed it bore into fruit making it unpleasant for use.	• Growing castor as trap crop • Deep ploughing to exposure pupae to high temperature • Manual collection and mass destruction eggs and caterpillar. • Need based spray of emamectin benzoate
White fly	*Bemisia tabaci* (Aleyrodidae: Hemiptera)	• nymph and adults sucks sap from the under surface of leaf and excrete honey dew • leaves appear sickly and get coated with sooty mold • it transmit yellow vein mosaic virus	• setting of yellow trap coated with grease/ oily material is the only effective way to control white fly
Pest of Green chilli:			

Fruit borer	*Spodoptera litura* (Noctuidae: Lepidoptera)	• caterpillar initially causes defloration • once the fruit is formed it bore into fruit making it unpleasant for use.	• Growing castor as trap crop • Deep ploughing to exposure pupae to high temperature • Manual collection and mass destruction eggs and caterpillar. • Need based spray of emamectin benzoate
Thrips	*Scirtothrips dorsalis* (Thripidae: Thysanoptera)	• Adult and nymphs lacerate the leaf tissue and suck the sap • Upward curling of leaf • Victim plants are stunted, leaves droped, fresh buds become brittle and drop dwon	• Destruction of affected plant part • Release of predators like *Chrysoperla* and lady bird beetles • Need based spray of Acephate or fipronil
Mite	*Polyphagotarsonemus latus* (Tarsonemidae: Acarina)	• Nymph and adult feeds exclusively on lower leaf • Leaf curl downwards along the margin and attain inverted boat shape	• Destruction of affactd plant • Release of natural predator like *Chrysoperla* or lady bird beetle. • Need based spray of omite/sulphur or dicofol
Pests of Cruciferous crops:			

Diamond back moth	*Plutella xylostella* (Pluttellidae: Lepidoptera)	• Mining and skeltanization of cabbage leaves • Larva feed on cabbage	• Growing bold seeded mustard as trap crop. • Use of pheromones traps • Release of parastoids like *Apanteles plutellae* • Need based spray of quinalphos
Cabbage butterfly	*Pieris brassicae* (Pieridae:Lepidoptera)	• Caterpillar scrape the leaves and eat up leaving only main vain. • Defliation of the plant	• Mass collection of caterpillar followed by killing them • Need baed spray of malathion/ deltamethrin
Cabbage Aphids	• *Brevicoryne brassicae* • *Myzus persicae* (Aphididae: Hemiptera)	• The adult and young one suck sap from plant resulting in growth retardation and development of sooty mould	• Setting of yellow sticky traps • Growing resistant varieties of cabbage • Release of natural predator like *Chrysoperla* or lady bird beetle • Need based spray of dimethoate or Imidacloprid
Panited bug	***Bagrada cruciferarum* (Pentatomidae: Hemiptera)**	• Both nymph and adult suck the sap from leaves • Due to feeding the vigour of the crop is reduced	• Clean cultivation • Need based spray of malathion/ deltamethrin.

Insect pest of Cucurbitaceous Crop:			
Red pumpkin beetle	*Aulacophora foveicollis* (Chrysomelidae: Coleptera)	• Irregular holes on the leaves • Grubs bore into the roots and underground stem	• Avoid early sowing • Deep ploughing • Need based spray of carbaryl
Cucurbit fruit flies	*Bactrocera cucurbitae* (Tephritridae: Diptera)	• Maggots feeds on the pulp and seeds inside the fruit • The affectd fruits may fall prematurely • Infested fruits become soft and rotten	• Deep ploughing for killing of papae • Removal and destruction of infested fruits • Setting of baits mixed with insecticide • Pheromone trap like cur lure or methyl eugonal
Insect pest of Storage Grains			
Internal feeders			
Rice weevil	*Sitophilus oryzae* (Curculionidae: Coleptera)	Grubs and adults feeds inside the grain and pupates inside, emerges by making irregular hole through the grain	
Pulse beetle	*Callosobruchus chinensis* (Bruchidae: Coleoptera)	Adult lay individual eggs on pulse beetle and the grub emerge feeds on the inner content of the pulse and pupate inside the pulse.	
External feeders			
Rust red flour beetle,	*Tribolium castaneum, T. confusum* (Tenebrionidae: Coleptera)	Grub and adult feeds from outside and they are serious pest of the procedded food like flour, grains, dry fruits. They feeds on broken grains	

Khapra beetle	*Trogoderma granarium* (Tenebrionidae: Lepidoptera)	Grubs mainly attack stored wheat and other grains. Grubs eat near the embryo region of the grains. They usaually remain in the top layers of the heap.
Rice moth	*Corcyra cephalonica* (Galleridae: Lepidoptera)	Larva web together the grains and feed inside. Development of foul odour and grain become unfit for consumption. It also attack broken grains and milled products.
Secondary pests:		
Saw toothed grin beetle	*Oryzaephilus suriamensis* (cucjidae: Coleptera)	Grubs and adults feeds grains which are already damaged by other insects Feeding consists of scarring the roughing of the surface of the grains

3 .4 Study of the structure of Beehive

Bee keeping in gaining popularity now a days. It is done in artificial frame hives. Frame hives are fitted with movable frames on which the bees are persuaded to build their combs. They are usually composed of several boxes one on top of other in which are suspended hive frames. A movable frame hive, Langstroth is composed of the following parts.

1. Hive stand-The upper hive components rests on this providing a landing board for the bees and helping to protect the Bottom Board. It is 6-10 inch high from the surface of earth. It is usually made from iron.

2. Floor board-It is a tray with all its four sides raised by side runners. This has an entrance for the bees to get into the hive.

3. Brood box (chamber)-It is a rectangular box. The number of brood box can be increased when the colony enlarges. It is part of bee hive where queen lay eggs.

4. Hive frames- They are wooden or plastic frames with wax or plastic sheets with honey comb impression. It is where the bee build wax comb. They are spaced apart to leave the bee space.

5. **Queen excluder-**it is necessary to separate the broad chamber from the supers chamber where honey is stores. This is accomplished by wire frame which allows the workers to pass through it but not the queen.

6. Honey Super-Usually shorter than the brood box, but is upper-most box (s) where honey is stored.

7. Inner Cover: Provides separation from outer cover and can be used as a shelf for feeding or other purposes.

8. Outer Cover: Provides weather protection for the hive.

Fig 3.1: Bee Hive

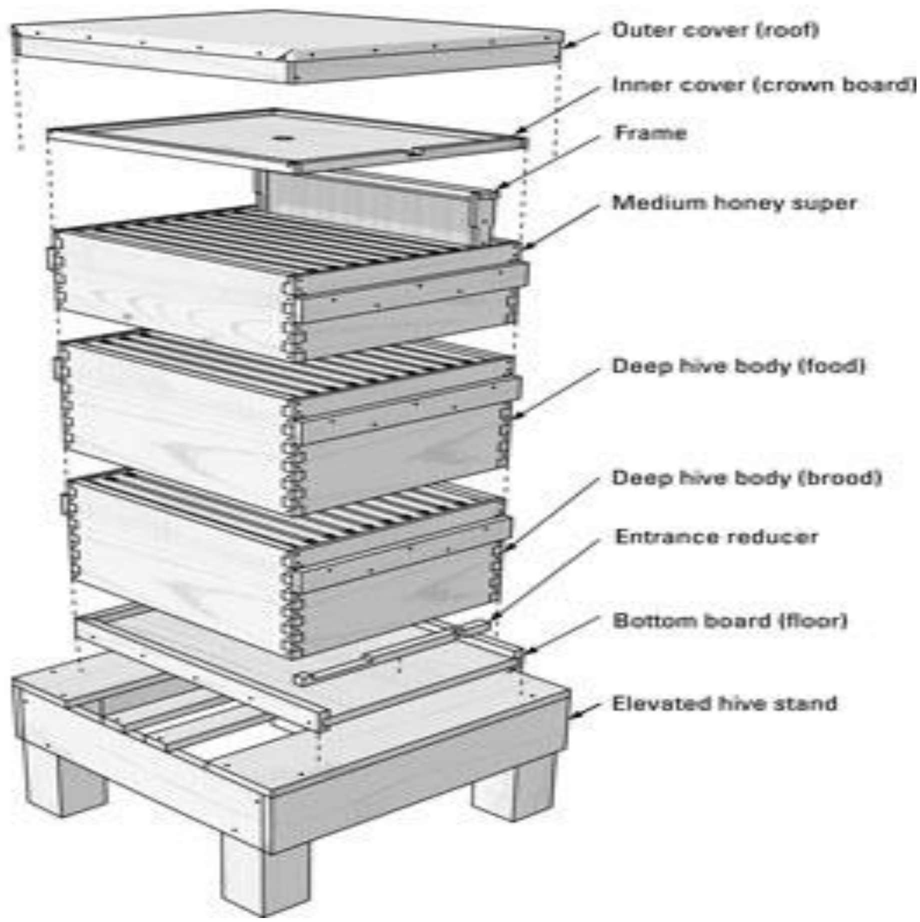


Fig 3.2: Structure of Bee hive and its various parts

3.5 Bioassay studies on Insects using some Contact Poisons

To determine the LC_{50} of contact insecticide e.g., Deltamethrin

Requirement: Live insect (e.g., *Helicoverpa armigera* larva), insecticide (e.g., Deltamethrin), beaker, petri dishes, diet of insect (e.g., green leaves or artificial diet for *H. armigera*), forceps

Pricnicple:

LC50 is the concentration of a substance that is lethal to 50 percent of the organisms in a toxicity test. LC50 can be determined for any exposure time, but the most common exposure period is 96 hours. Other common durations are 24, 48, and 72 hours. As a general rule, the longer the exposure, the lower the LC50.

Procedure:

Take 6 beakers filled with 25 ml of water and arranged them in a line. Mark them with label from 1-6. 6th one will be control. Make desired concentration of pesticide (Using the formula $N_1V_1=N_2V_2$). From example the concentration maybe 0.5 ppm, 1 ppm, 1.5 ppm, 2ppm and 2.5 ppm. In control open no pesticide will be added. Now dip the diet e.g. Green leaves in each of the concentration for at least 1 minute. Then air dry the leaves for 5 minutes and put the leaves and larva in petri dishes.

Record the mortality rate after 24 h, 48 h respectively.

Observation:

S.no	Number of larva	Pesticide concentration	Mortality duration			
			24 h		48 h	
			Number	%age	Number	%age
1.	10	0.5 ppm	0	0	1	10
2.	10	1 ppm	3	30	4	40
3.	10	1.5 ppm	4	40	6	60
4.	10	2 ppm	7	70	9	90
5.	10	2.5 ppm	10	100	10	100
6.	10	Control	0	0	0	0

Note: these data are completely hypothetical. They have been put just for understanding.

Result:

Determination of LC_{50} by interpolation invlovess plotting the data on semi lorrithmic coordinates graphs paper showing concentration of toxicant on sub ordinate axis (y-axis) and percentage mortality on abscissa (x-axis).

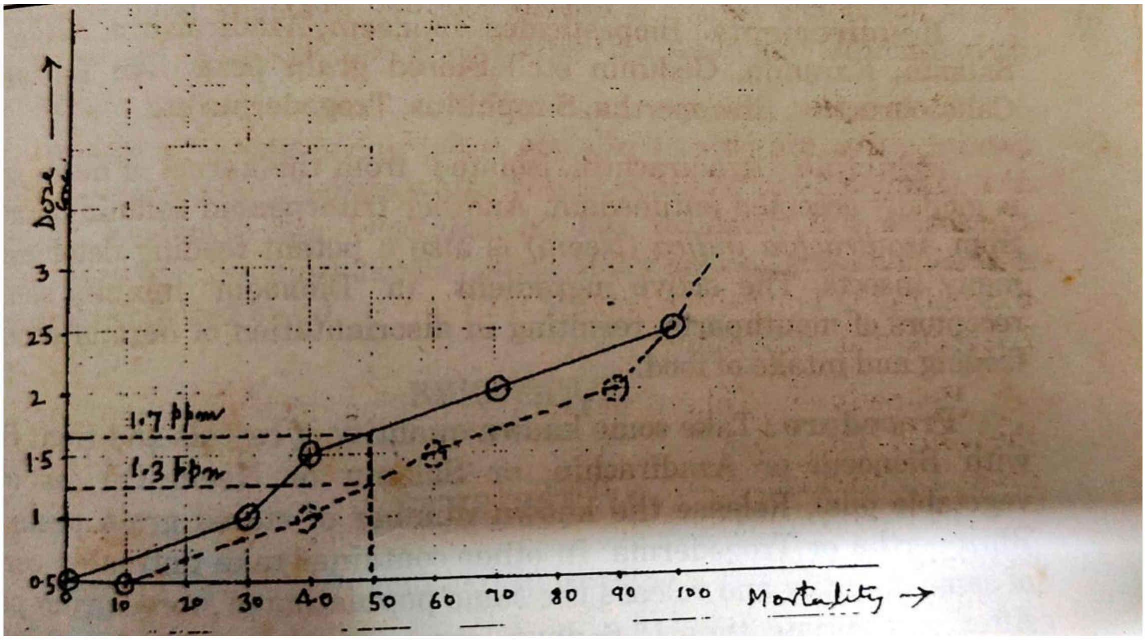


Fig 11.3: LC $_{50}$ value of Deltamethrin

Thus, plot the percentage of mortality observed in each replica. Draw a straight line between two points representing mortality for two successive concentrations. The concentration at which this line crosses 50% lethality line will be the LC_{50} value. This method is straight line interpolation.

LC_{50} for 24 hrs in this case is 1.7 ppm and for 48 hrs is 1.3 ppm.

3 .6 Study of the Life Cycles of some important Insect Pests

1) The Fall Armyworm (*Spodoptera frugiperda,* (J. E. Smith) Noctuidae: Lepidoptera)

It is an invasive insect pest known as the fall armyworm (FAW) causes significant harm to maize at all phases of its development. It was introduced in India, May 2018.

- The egg masses are laid by the female moths on the upper or lower surface of the leaf and are covered with tan scales. 50–150 eggs are included in each egg mass. The time of incubation ranges from 4-5 days.

- The smooth-skinned larvae have three creamy yellow dorsal and lateral lines on their bodies, and their colours range from light tan or green to dull grey. The head of the larva is reddish brown with a white, inverted Y-shaped suture predominating between the eyes. The larva has six instars, with a range of 15 to 18 days between each instar. Four big spots are grouped in a square pattern on the eighth abdominal segment and a trapezoid pattern on the ninth abdominal segment of the body.
- The hue of the pupa is reddish brown.
- Adults emerge from pupae in 7-9 days. While mature female moths are less obviously marked, varying from uniform greyish brown to a faint mottling of grey and brown, adult male moths have a fawn coloured spot and a white patch at the apical margin of the wing.
- The entire lifetime is completed in between 30 and 35 days, depending on the climate. Adult life expectancy ranges from 4 to 7 days. Before oviposition, the adult moth can fly up to 500 miles.

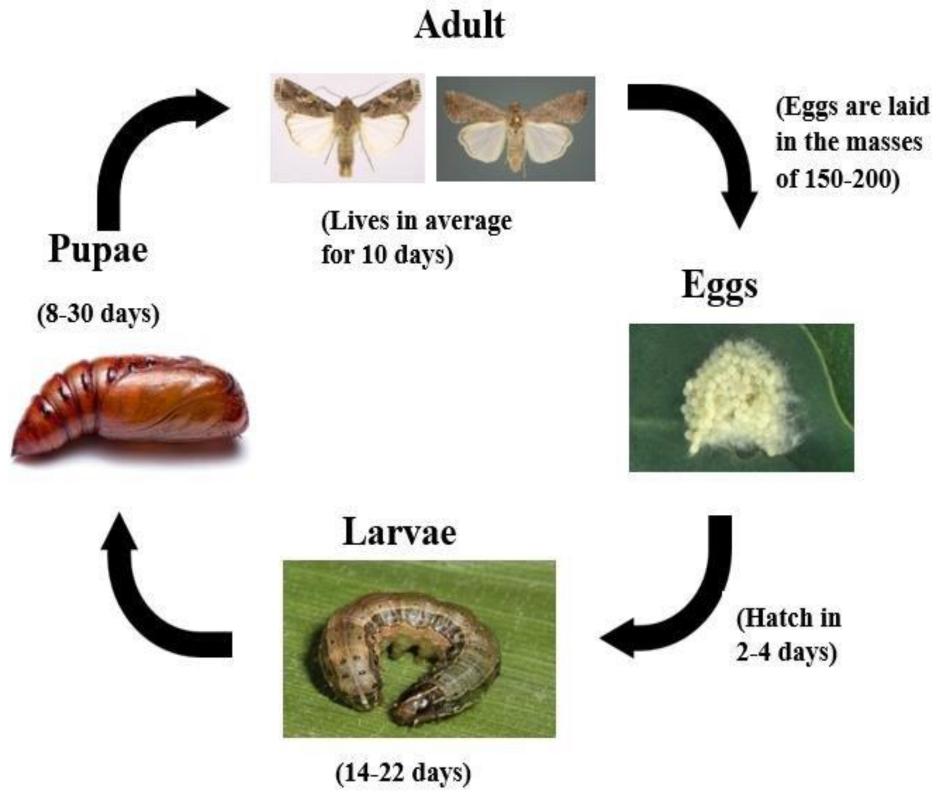


Fig 3.4: Life cycle of The Fall Armyworm (Spodoptera frugiperda)

2) Oriental fruit fly, (*Bactrocera dorsalis,* (Hendel) Tephritidae: Lepidpptera)

The Oriental fruit fly or mango fruit fly, in the most serious of all fruit-flies and is widely distributed in India and South-east Asia. The adult is stout, a little larger than the house fly, is brown and has transparent wings and yellow legs and dark rust-red and black patterns on the thorax. It measures 1.4 cm across the wings and 0.7 mm in body length. The legless maggots are yellow and opaque; when full-grown, measure 8-9 mm long and 1.5 mm across the posterior end.

- The adult flies emerge in April and start laying eggs under the rind of the ripening fruits and vegetables of the season (such as guava, loquat, apricot, plum, brinjal, etc.) and later shift to mango. They lay 2-15 eggs at a time in clusters. A female lays, on an average, 50 eggs but under favourable conditions, 150-200 eggs are laid in one month. The eggs hatch in 2-3 days in March-April and 1-1.5 days in the summer, and 10 days during winter.

Fig 3.5: life cycle of ***Oriental fruit fly, (Bactrocera dorsalis)***

- As the maggots develop they pass through 3 stages in the ripening pulp and are full-grown in 6-29 days. They leave the fruit and move away by jumping in little hops.
- On reaching a suitable place, they bury themselves into the soil and pupate 8-13 cm below the surface. In 6-44 days, they emerge as flies and reach the ripe fruit for further multiplication.
- The life-cycle is completed in 2-13 weeks and many generations are completed in a year. Host plants. Apart from mango, the pest also feeds on guava, peach, apricot, cherry pear, chiku, ber, citrus and other plants, totalling more than 250 hosts.

3) Gram pod borer (*Helicoverpa armigera*, Noctuidae: Lepidoptera)

It is cosmopolitan in distribution being widely distributed in India. The moth is stoutly built and is yellowish brown. There is a dark speck and a dark area near the outer margin of each fore wing. The fore wings are marked with greyish wavy lines and black spots of varying size on the upper side and a black kidney shaped mark and a round spot on the underside. The hind wings are whitish and lighter in colour with a broad blackish band along the outer margin. The caterpillars when full-grown, are 3.5 cm in length, being greenish with dark broken grey lines along the sides of the body.

- The females lay eggs singly on tender parts of the plants. A single female may lay as many as 741 eggs in 4 days. The eggs are shining greenish yellow and are round.
- They hatch in 2-4 days in April to October and 6 days in February and the young larvae feed on the foliage for some time and later bore into the pods and feed on the developing grains, with their bodies hanging outside. They move from pod to pod and are full-fed in 13-19 days and measure 35 mm in the last instar. The full-grown larvae come out of the pod and pupate in the soil.
- In the active season, the pupal period lasts 8-15 days, but in winter the duration is prolonged, particularly in northern India.
- Some of the pupae remain in a facultative diapause during November-April in northern India. There may be as many as 8 overlapping generations in a year.

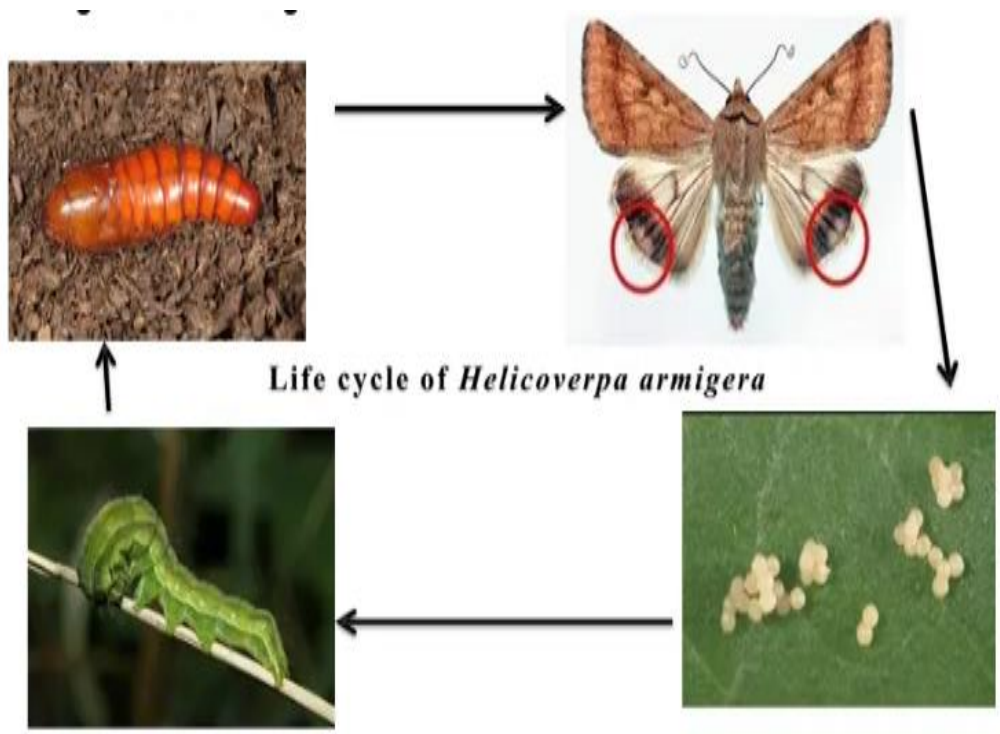


Fig 3.6: Life cycle of Helicoverpa armigera

3.7 Study of Pollinators Insect Species and their Host Plant

Most flowering plants (75%) require an animal pollinator. There are over 200,000 species of animal pollinators and the vast majority of these are insects. Insect pollinators include beetles, flies, ants, moths, butterflies, bumble bees, honey bees, solitary bees, and wasps.

Butterflies and moths are important pollinators of flowering plants in wild ecosystems and managed systems such as parks and yards. Butterflies and moths have different niches; butterflies are active during the day while moths are active in the evening and at night.

The pollination by insect types are classified based on the insect group that pollinate the crops and are listed below

Insect group	Pollination type
Bees	Mellitophily

Syrphids and Bombylid flies	Myophily
Butterflies	Psychophily
Small moths	Phaleophily
Hawk moth	Sphinophily
Beetles	Cantharophily
Carrion flies	Saprophily

Some of the major pollinators of various plants are under:

Crop	**Insect species**	**Family: Order**
Mango	• *Meliopona sp.* • *Syrphus sp.* • *Musa domestica*	• Apidae: Hymenoptera • Syrphidae: Diptera • Muscidae: Diptera
Coconut	• *Apis mellifera* • *Apis cerana* • *Augochlora sp*	• Apidae: Hymenoptera • Apidae: Hymenoptera • Halictidae: Hymenoptera
Sunflower, cotton, tobacco, alfa alfa, *Brassica* crop, cucurbitious crops, clove	• Honey bee	• Apidae: Hymenoptera
Oil palm	• Weevil *Elaeidobius kamerunicus*	Curculionidae: Coleoptera
Carrot, Bhindi, and pulses	• Hover flies and syrphid flies	Syrphidae: Diptera
Fig	• Fig wasp: *Blastophaga psenes*	Aganonidae: Hymenoptera

Some of the important non-Apis bee pollinators are under:

Fig 3.7: Important non-Apis bees pollinators

3.8 Identification and study of Taxonomic Status of Insect and their Host Plant used in various economic practices: Apiculture, Sericulture and Lac culture

Apiculture:

Honey bee species:

Indian honey bees, *Apis cerana*: (Family: Apidae Subfamily: Apinae)

In physical characteristics, *Apis cerana* (Indian honey bee) individuals are very much similar to those of other species in the genus *Apis*. The individuals in this genus are defined by long, erect plumose hairs that cover the body and assist in pollen collection, strongly convex scutellum, and a jugal lobe in the hind wing.

Adult *Apis cerana* are black in color, with four yellow abdominal stripes. The honey bee show a perfect division of labour where every individual performs the assigned work. The colony is divided into three castes viz., worker, drone and the queen bee. There are also distinctions between worker bees, queen, and drones. Worker bees are characterized by a pollen pockets on the hind leg to transport pollen, as well as a sting apparatus which is modified ovipositor used to defend the colony.

Fig 3.8: Apis cerana

Queens, which are the reproductive females, are typically larger than worker bees due to their enlarged reproductive organs. Drones, which are the males of the species, are defined by larger eyes, lack of a sting apparatus, and a blunter abdominal shape. The sole work is to mate with the queen bee during nuptial flight.

European Honey bee, *Apis mellifera* **(Family: Apidae Subfamily: Apinae)**

This exotic bee was successfully introduced in India form itayl in 1962 at Nagrota in Himachal Pradesh. Generally, *Apis mellifera* are greyish /brown with yellow abdomen having black bands. They have more plumose hair on head thorax and less hair on abdomen (gaster). They also have a pollen basket on their hind legs. The legs of Italian Honeybee are mostly dark brown/black.

Like other honey bee the colony is differentiated into three castes viz., worker bees, drone bees and queen bee. There are two castes of females, sterile workers are smaller (adults 10-15 mm long), fertile queens are larger (18-20 mm). Males, called drones, are 15-17 mm long at maturity.

The honey bee show a perfect division of labour where every individual performs the assinged work. The colony is divided into three castes viz., worker, drone and the queen bee. Worker bees are characterized by a pollen pockets on the hind leg to transport pollen, as well as a sting apparatus which is modified ovipositor used to defend the colony and individual bee when a danger is sited.

Fig 3.9: Apis mellifera

Queens, which are the reproductive females, are typically larger than worker bees due to their enlarged reproductive organs. Drones, which are the males of the species, are defined by larger eyes, lack of a sting apparatus, and a blunter abdominal shape. The sole work is to mate with the queen bee during nuptial flight. Honeybees are endothermic. They can warm their bodies and the temperature in their hive by moving their flight muscles.

Dwarf bee, *Apis florea:* (Family: Apidae Subfamily: Apinae)

A. florea also known as dwarf honey bee due to its small size compared to other honeybee's species. A worker is typically 7–10 mm in body length, the forewing length is between 6.0–6.9 mm and its overall coloration is red-brown. Like other honey bee the colony comprised 3 castes viz. workers, drones and the queen.

Fig 3.10: Apis florea

Dwarf honey bees are characterized by their external cryptic nesting habits and their single comb. Dwarf honey bee nests consist of a small single comb (usually less than 25 cm across) nest that is built around a small branch. This small nest contains a crown above the branch for honey storage, as well as being used by the bees as a platform for the foragers leaving and arriving at the nest. The brood comb is suspended below the supporting branch in a single comb. The curtain of bees for a large dwarf honey bee colony is usually 3–4 bees thick. On either side of the nest on the branch, the honey bees commonly place a propolis barrier on the branch which acts as a sticky and repellent barrier to protect the nest from attack by other insects, such as ants.

Rock bee: *A. dorsata* (Family: Apidae Subfamily: Apinae)

Apis dorsata is largest species of among the honey bees (17–20 mm in body length and forewing length of 12–15 mm). *A. dorsata* is highly variable in coloration depending on the race, which is also associated with the distribution.

Head, thorax, legs and apical three segments of the abdomen are black, more or less pale and fuscous on the hinder part of the thorax and on the abdomen. The basal three segments of the abdomen honey yellow; pubescence fuscous on the head, thorax in front, legs above and apical segments of the abdomen, pale ochraceous yellow.

Apis dorsata is remarkable for having a well-organized mass defense reaction, where once an intruder is marked by being stung, it can be followed kilometers away. In addition, a single colony of *A. dorsata* can migrate between 100–200 km every year, and it is dependent on the dry and rainy seasons.

Fig 3.11: Apis dorsata

Nests of *A. dorsata* are typically constructed in open or exposed and conspicuous areas (tall trees, rock cliffs, over hanged tanks or even buildings). Usually the nests are aggregated (although they can also be single), and it is not uncommon to find 10–25 nests in the same area or even on a single tree (also known as bee trees). Their nests are normally at heights of around 6 m above ground, however, some nests can be found as low as 3 m and as high as 25 m. In terms of their architecture, nests are composed of a single comb built below rocks or tree branches (undersurface of its support), and their organization is similar to that of other species of honey bees: honey storage is at the top, followed by pollen storage, worker brood, and drone brood. The lower part of the nest is the active area or "mouth" where workers take off and land and where dances are performed by scouts. Dances take place on the vertical surface of the comb.

Sericulture:

1. **Mulberry silkworm, *Bombyx mori* Linnaeus. (Bombycidae: Lepidoptea)-** It is the most important worm as far as sericulture is concerned and reared extensively in various part of India. Its caterpillar feeds on mulberry leaves. The cocoons are white in colour from which best quality of silk is obtained. There are several races of the mulberry silkworm which may be grouped into two categories, univoltine and multivoltine. The univoltine has an annual life cycle while multivoltine race passes through many generations in a year. The multivoltine race produces inferior quality of silk and is reared in West Bengal, Assam and Karnataka.

Fig 3.12: ***Mulberry silkworm, Bombyx mori***

2. **Tasar silkworm, *Antheraea paphia* Linnaeus.** (**Saturniidae: Lepidoptera**)-It is generally found in the forests of West Bengal, Assam and Uttar Pradesh and is not domesticated. The host trees of this silkworm are sal (*Shorea robusta*), ber (*Ziziphus mauritiana*), Asans (*Terminalia tomentosa*), and Arjun (*Terminalia arjuna*). The cocoons are hard light brown to dark in colour and have to be collected from the jungle. They are reeled and pierced are spun.

Fig 3.13: Tasar silkworm, Antheraea paphia

3. **Eri silkworm, *Samia cynthia ricini* Boisduval. (Saturnidae: Lepidoptera)-**This silkworm was mainly found in the forests of Assam but now found in West Bengal, Bihar, UP, Orissa an Tamil Nadu. As its scientific name indicates, it feeds on castor (*Ricinus comman* leaves and is domesticated all over the country where castor is grown. Its cocoons which are white in colour cannot be reeled and have to be spun.

Fig 3.14: Eri silkworm, Samia cynthia ricini Boisduval.

4. **Muga silkworm, *Antheraea assamensis* Helfer. (Saturnidae: Lepidoptera)-**This silkworm is found in Bihar, West Bengal, Orissa and Assam, and it cannot be domesticated. The caterpillars feed on the leaves of cinnamon and machilis plants. The cocoons are reeled and are of brilliant yellow colour from which silk of golden yellow colour is obtained.

Fig 3.15: Muga silkworm, Antheraea assamensis Helfer.

Host plant of mulberry sericulture:

The cultivation of mulberry plant is known as moriculture. The name is derived from the family Moraceace to which mulberry plant belongs. Among 20 different species of mulberry, the most common is *Morus alba*, *M. indica*, *M. serrate* and *M. latifolia* while the local *M. indica* offers certain good features (like quick growing, hardiness, remaining in flush throughout the year. Certain high yielding varieties have been developed suiting for various regions, viz. Northern and Eastern States (Punjab, J&K, UP and West Bengal): S-162, S-519 and 8-623, and Southern States (Karnataka, Andhra Pradesh and Tamil Nadu): Kanva-2, S-30 and S-54.

The pencil-thick cuttings (22-25 cm long with 3-4 buds each) of mulberry are planted according to two systems. In the pit system, pits (45 cm wide and 45 cm deep) are due prior to monsoon (June), filled with compost and cuttings planted after the first rainfall. The distance between the rows and plants is maintained at 95 and 45 cm, respectively In the row system, cuttings are planted on the two margins of 60 x 30 cm ridges, keeping the distance between rows and plants at 45 and 10 cm, respectively. In each case, the plants are kept alive by pot-watering until they have taken roots and become strong Subsequently, recommended agronomic practices are followed till good flush of leaves

Fig 3.16: Mulberry tree

The leaves are harvested for larval feeding in three ways:

(i) Leaf picking method. Individual leaves are hand picked, tender leaves for younger larvae and mature leaves for older larval instars.

(ii) Branch cutting method. The entire branch with leaves is cut and offered to third instar larvae.

(iii) Top shoot harvesting method. The tops of the shoots are clipped and giver to fourth and fifth instars larvae.

Lac culture:

The lac insect or scale insect *Laccifer lacca* (Lacciferidae: Homoptera) secretes a resinous by product which is marketed as shellac.

Life cycle: The female lays bout 300-500 eggs in the brood cells. The eggs hatch with few hours into tiny red colour first instar nymphs (crawlers). The emergence of nymphs is called swarming. The nymphs crawl to reach soft succulent twigs and start sucking the plant sap voraciously and start secreting resinous secretions over the body.

Lac is secreted by the dermal glands spread all over the body except moth parts, two breathing pores and anus. They moult thrice so that the 3 instar nymph develops into the adult. After the first moult both males and females nymphs lose their legs antennae and eyes and become degenerate. The females stay as degenerate form and continue feeding, growing in size and secreting resin. The male is slipper like with an operculum at the rear end and female is globular. After the final moult males emerge as winged or wingless adults which mate with females and they die afterwards.

Fig 3.17: Lac tubes created by Laccifer lacca

Lac strains

They are two strains of lac insects grown in India. The Kusumi strain grown on kusum plants (*Schleichera oleon*) and Rangeeni strain grown on host plants other than kusum. The common host plant for Rangeeni strain are *Butea*, *Ziziphus* and *Shorea*

Both strains have two generations per year.

Kusumi: Jethwi (June/July to Jan/Feb) and Agani (Jan/Feb to June/July), each six months duration.

Rangeeni: Katki (Jun/July to Oct/Nov) and Baisakhi (Oct/Nov to Jun/July) four months and 8 months duration respectively. Agani and Baisaki are main crops contributing to 90% of the lac production and lac obtained from Kusumi is considered superior because of light colour.

3.9 Summary:

- Important pest of fruits, vegetables and stored grained producted were learnt in detail
- Structure of bee hive consist of hive stand, floor board, brood chamber, super chamber, queen excluder, inner cover and outer cover
- Bioassay using contact insecticide were learnt
- Life cycle of important pest like *Spodoptera frugiperda*, *Bactocera doesalis* and *Helicoverpa armigera* were described.
- Pollination by different insect and pollinators of various important plant were learnt
- Sericulture and lac culture were also learnt

3.10 Terminal Questions and Answers

Q1. Describe in details various pest of vegetable?

Q2. *Helicoverpa armigera* is an important pest of which crop.

Q3. Describe in details the various pest of fruits and stored grain products?

Q4. What are secondary pest?

Q5. Describe in details important pollinators of mango plant and brassica crop?

Q6. Various kind of bee species found in India are?

Q7.Various kinds of silk wrom moth in India are?

Q8. Lac insect belongs to the family? What are main stain s of lac produced in India?

References:

- Alexander, V. N. (2002). Nabokov, teleology, and insect mimicry. Nabokov Studies, 7(1), 177-213.
- Begon, M., Harper, J. L., & Townsend, C. R. (1986). Ecology. Individuals, populations and communities. Blackwell scientific publications.
- Stevens, M., & Ruxton, G. D. (2012). Linking the evolution and form of warning coloration in nature. Proceedings of the Royal Society B: Biological Sciences, 279(1728), 417-426.
- Tullberg, B. S., Merilaita, S., & Wiklund, C. (2005). Aposematism and crypsis combined as a result of distance dependence: functional versatility of the colour pattern in the swallowtail butterfly larva. Proceedings of the Royal Society B: Biological Sciences, 272(1570), 1315-1321.
- Wang, I. J., & Shaffer, H. B. (2008). Rapid color evolution in an aposematic species: A phylogenetic analysis of color variation in the strikingly polymorphic strawberry poison-dart frog. Evolution: International Journal of Organic Evolution, 62(11), 2742-2759.
- Williams, K. S., Smith, K. G., & Stephen, F. M. (1993). Emergence of 13-Yr periodical cicadas (Cicadidae: Magicicada): phenology, mortality, and predators satiation. Ecology, 74(4), 1143-1152.
- Wilson, J. S., Jahner, J. P., Williams, K. A., & Forister, M. L. (2013). Ecological and evolutionary processes drive the origin and maintenance of imperfect mimicry. PloS one, 8(4), e61610.

Unit 04: Insect Ecology Exercise

4.1 Objectives

- To learn about the insect behaviour
- Response of insect towards different things
- Interaction of insect
- Effect of biotic and abiotic factors on insect assemblage

4.2 Introduction

Ecology as a science has emerged as one of the distinct discipline by the end 19th Century and became prominent in the second half of the 20th Century. Ernst Haeckel, was an eminent German biologist and naturalist who described this term very first time. As far as insect ecology is concerned, it is the scientific study of how the insects live individually or as a community, their interaction with the surrounding environment or the ecosystem. In a broader perspective the ecology is a study of the structure and function of nature as proposed by some earlier ecologists. Ecology the study of organism in relation to their environment has developed in recent years from the descriptive attempt to describe nature, the natural history of yesterday.

Ecosystem, the basic functional unit of ecology, is composed of abiotic (non-living) components of the environment and biotic (living) community both interacting with each other. Insect being the member of biotic community have interaction with both living and the non-living (abiotic) factors of the environment. The outcome of these interactions is in the positive or negative growth of the population. Insects are the dominant group of living organisms on this earth, both in term of taxonomic diversity as well as ecological function. Insects play significant roles in the ecology of the world due to their vast diversity of form, function and life-style; their considerable biomass; and their interaction with plant life, other organisms and the environment. Since they are the major contributor to biodiversity in the majority of habitats, except in the sea, they accordingly play a variety of extremely important ecological roles in the many functions of an eco-system. Insects are important part of food chain, specially for the entomophagous vertebrates like many amphibians, reptiles, birds, and mammals. Insects play important role in maintaining community structure and composition. From an anthropocentric point of view, insects (insect pests) compete with humans, they consume almost 10% of the food produced.

4.3 Exercises on Insect Behaviours

1. **Thigmotaxis:**

Experiment: To study thigmotaxis in insect

Requirements: Earwigs (living), Houseflies, Ants, Beetles (Scarabeidae).

Principle: Response of an insect to touch is called thigmotaxis. When insects prefer to remain in contact with some surface all round. its body is called positive thigmotaxis and when it prefers to remain in open is called negative thigmotaxis. Stimulus of touch tends to affect the behaviour of insects.

Procedure: Take a clean and dry beaker (capacity 500 ml) and release a few beetles. They tend to set at bottom and remains there.

Repeat the exercise with earwigs, they also remains at the bottom and becomes immobilized. Now light on the lamp. Still they remain there otherwise earwigs run away from the light source and bury themselves in the soil. Repeat the exercise with ants and house flies also. They roam around the beaker and try to come out.

Result: The earwigs and beetles exhibit positive thigmotoxis and ants, and house flies negative thigmotaxis.

2. **Chemotaxis**

To study chemotactic response in insects.

Requirement: Drosophila flies, T-tube, Glass tubes, fruits and cotton

Principle: Olfactory sense is developed in most of the insect. It helps in locating the food and recognition of the mate. The organs which detect chemical sense are located on antennae, mouthparts legs.

Procedure: Take a T tube as shown in the Figure 7.9. Plug cotton to each open ends. Take 10 living Drosophila flies in base arm of T tube. Take out the cotton plugs from the arm of T tube inserting two glass tubes containing inert sand in one and fruit pulp in the other s that the Drosophila do not escape

Result: As the smell of the fruit pulp reaches to the flies in basal arm, they move towards the smell. Some flies also ventures in the tube containing inert sand but soon comes out of it and enters to the pulp containing tube.

Note: Carrion eating Beetles are also attracted to the smell of ammonia.

3. **Thanatosis:**

To study katelepsy or thanatosis in insects.

Requirements: Living insects (Beetles, Bug, Stick Insect), Stop watch, Glass rod, Beaker, Petridish, Muslin cloth, Rubber band, Brush, Forceps etc.

Principle: Various protective phenomenon are exhibited by the insects. Death pretending is one of them and is displayed on mechanical stimulus or on approach of predator. Beetles and various other insects become motionless on touch stimuli, others roll into a ball (cuckoo wasp), others assumed bizzare postures and yet others becomes immobilized. This is commonly called Katelapsy or thanatosis.

Procedure: Take a *Rhinoceros* beetle and allow it to move normally. Now tap it with the help of glass rod and note the reaction of beetle. Also repeat the exercise with other beetles like *Holotrichia* and *Lasioderma*.

Result: On tapping it becomes motionless and pretend as if dead. It retract the legs and antennae. Note down the time of termination of thanatosis when the insect start moving its antennae.

Precautions: Experimental insects should remain undisturbed for reasonable period before recording the duration of thanatosis. Pre handling of insects shortly before the stimulation to feign death' can prevent it responding to the stimulus.

Note: Repeat this exercise by dropping the beetle from a distance/height of 5 inch and record the time taken for termination of Katelapsy.

Modifications of the exercise

(a) Effect of mutilations on Thanatosis: Take 20 beetles of the same age group. Divide into 4 groups of 5 each and cut off antennae, head, legs (fore) and hind legs. Allow each batch to recover for 1-3/4 hour and induce thanatosis by tapping with rod or by dropping it from a height of 2-3 inches. Record the time taken for the termination of thanatosis in each group.

S.no	Group	Body part mutilated	Time taken for the termination

			of Thanatosis
1	I	Antennae	
2	II	Head	
3	III	Foreleg	
4	IV	Hind legs	

(b) **Effect of light:** take 5 beetles and induce Thanatosis in dark and record the termination time.

4. Antennal grooming in cockroach

To study the antennal grooming in cockroach.

Requirement: Living cockroach, Glass trough, Glass rod, Acetone, Vaseline, Acetic acid.

Principle: Insects exhibit avoidance reaction to chemical irritants'. The sensory organs for chemical irritants are "basiconic pegs" surrounded by trichogen and tormogen cells which are especially present on antennae. Each peg is associated with 4-6 neurons whose dendrites reach to the tip. They carry the chemical sensations to the central nervous system and exhibit the behavioural response under the influence of brain. As per the directions from brain, the muscles found in scape (basal part of the antennae) contracts and bring the antennae to the mouthparts for grooming.

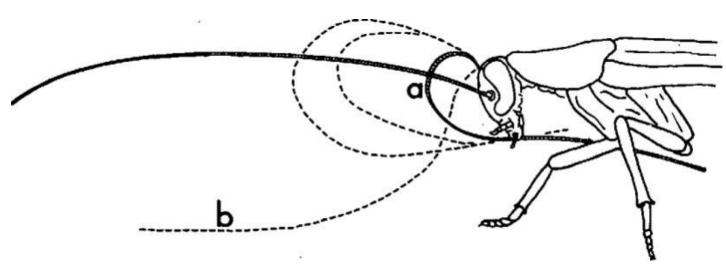


Fig:4.1 Antennal grooming in cockroach

Procedure: Release a cockroach in a glass trough. Dip the glass rod in acetone and touch it to the antennae of cockroach. Repeat the exercise with vaseline and weak acid and record your results.

Result: When the acetone dipped rod is touched to the antennae, it immediately clean it with the help of mouth parts and legs.

5. **Food preferences in Tribolium**

Object: To study the food preference in Tribolium.

Requirements: Tribolium beetles, Wheat flour, Sooji, wheat bran, Maida, Glass container, Aspirator, Brush.

Principle: Stored grain pests attack a variety of food articles and grains but much of the damage is caused to that food which is more palatable and easily available. The insect restrict their feeding activity in most palatable and preferred food.

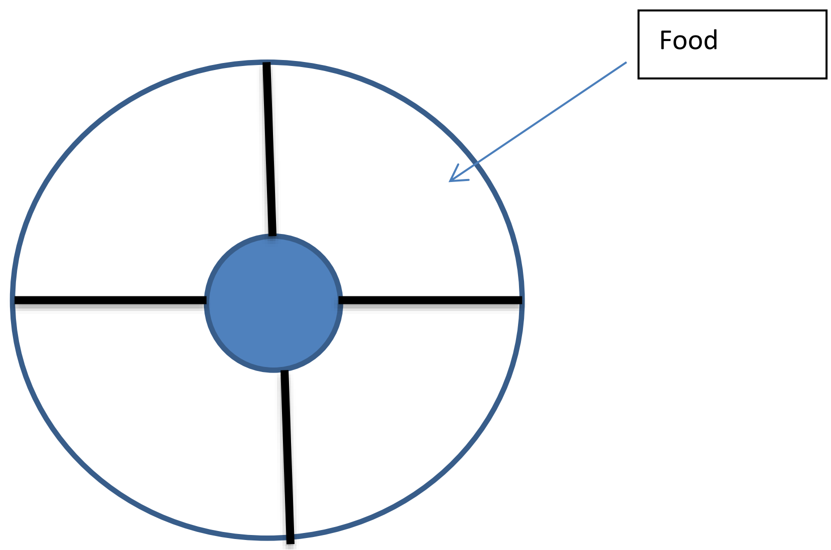


Fig4.2: Food Preference in Tribolium

Procedure: Take a round plastic box or container which is equally divided into 4-5 chambers with a circular central chamber. Fill the chamber with different eatables viz. Wheat flour, Maida, Sooji Wheat bran and coarse grains. Release 50 Red rust flour beetles (Tribolium) in the central chamber. Cover the lid and allow the insects to select their most preferred food for 24 hours and record your results. Calculate standard deviation and standard error of the mean of your results.

Take your observations on the following parameters.

a. Number of insects in each food items.

b. Mortality if any.

c. Food stuff that record the lowest number of beetles.

d. Food stuff's that record the heighest number of beetles.

Precautions: Central chamber should not be very deep otherwise the insects would not come out of it. If it is deep then make it shallow by pouring melted wax or plaster of paris.

6. **Wing cleaning**

To demonstrate the wing cleaning in Musca.

Requirements: Alive houseflies, Talcom powder, Brush, Vaseline, Beaker.

Principle: Response elicited to a particular stimulus constitute a particular behavioural activity which helps the insect in one way or other.

Procedure: Release 1 or 2 alive house flies in a beaker and cover it with muslin cloth. Now sprinkle some talcom powder on the wings of the fly. Repeat the exercise by applying vaseline on either of the wings and record your result.

Result: The fly immediately cleans the powder particles or vaseline by lowering the wings with the help of legs and it also jerks the wings.

7. **Response of house fly towards light**

To study the response of light in House flies.

Requirements: Houseflies, Jar, Black Paper.

Principle: Many insects are attracted towards light, it is called positive phototaxis and those which are repelled from light are negative phototactic.

Procedure: Take a jar and wrap black paper in the middle part of it. Release some houseflies and note the resting of houseflies in dark and light part of the jar. Repeat the exercise with *Tribolium*.

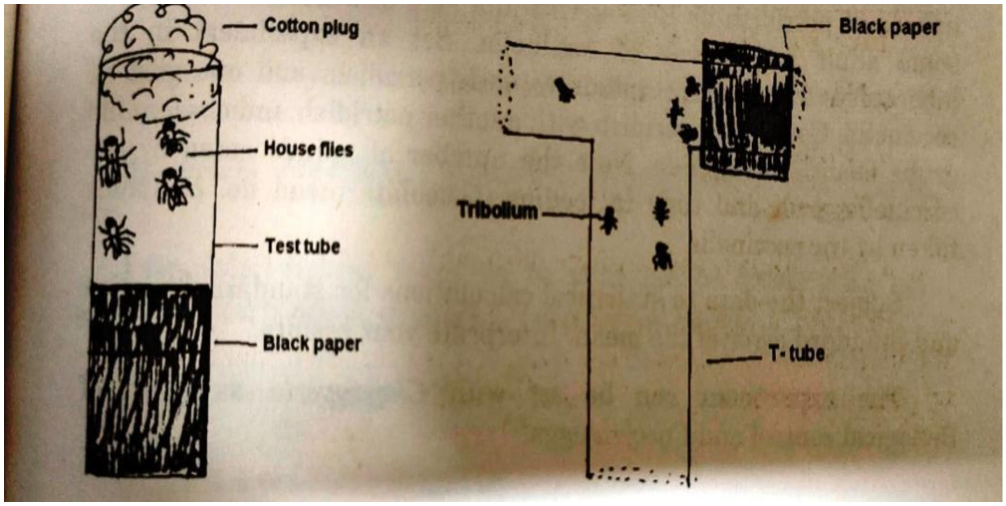


Fig:4.3 Effect of light to house flies and Tribolium

Result: Majority of houseflies prefers to sit on the lighted part of the jar which indicates the positive phototactic movement.

4.4 Insect Plant Interactions and Bee Plant of Local Area

(information about bee plant of local area is already provided in exercise no. 11.7 of Unit III)

Approximately 30 -40% of all insect species feeds on plants and the remaining ones are carnivores, parasitoids, parasites, saprophages etc. In other words plant feeders are "parasites" of plants. Plants don't move so insects have to come near plants. Insects use all parts of the plant as food but there is not a single insect species which can consume all plant parts.

Leaves

a) **Feed from/on surface:**

Leaf feeders (whole or portions of leaf)- e.g. Colorado potato beetle, grasshoppers, lepidopteran larvae, leaf feeders (skeletonizers), beetle larvae.

Sap suckers – These types of insects have a piercing and sucking type of mouth parts which help to enterinto individual cells or vascular system of plants. - aphids both direct and indirect damage. The insects can assimilate plant and spread plant diseases. Any insect that moves from plant to plant may spread disease.

b) **Feed inside**- leafminers - serpentine, blotch mines, protected by leaf tissue, implications for control. E.g. - caterpillars, fly larvae, sawflies - birch leafminers.

Stems/Stalks- Insects can cause excessive damage to stem parts of plant with limited feeding.

a) Feed from/on surface - cutworms - also feed just below soil surface and on foliage, aphids etc.

b) Feed inside -bark beetles – stem, stem or stalk borers - major pests in corn, also were in wheat.

Roots- Its usually very difficult to detect root insect infestation.

a) feed from/on surface - fly larvae - roots (cabbage maggots) also provide wounds, beetle larvae - wireworms - root damage, aphids - phylloxera.

Reproductive Tissues -Pollen feeders insects usually acts as pollinators, and seed eaters.

1. Factors which influence insect host plant interactions

a) Low nutritional quality (available nitrogen).

b) Lower protein content than animals.

c) Different ratios and proportions of amino acids, salts, etc.

d) Phytophagous insects often have low assimilation and growth efficiencies (study: 2% - 38%).

e) Assimilation and growth rates can be linked with plant nitrogen content

f) Effects of fertilizer- from increasing nitrogen content, overall many insects show "better" growth with increased nitrogen but not all.

2. Physical defences

a) hooks, spines, trichomes - sticky exudates

b) leaf toughness

c) can be age-related (of plant). e.g. pubescence may increase with age.

3. **Plant environment**
    - Plants in absence of phytophagous insects may flourish in a wide range of conditions. E.g. Klamath weed (introduced to North America). *Hypericum perforatum*
    - Widespread plant in drier sunny exposure; acceptable to beetles (beetles destroy it). Chrysolina spp found in moist, shaded area - less or barely acceptable to beetles.

4.5 : Study of habitat quality effect on Insect Assemblage

- Insect Assemblage are effected by both physical as well as biological factors. Physical factors include (abiotic factors) like light, temperature, wind, humidity and pesticides
- Biological factors or biotic factors) like other members of the same insect species, food sources, natural enemies (including predators, parasitoids and diseases) and competitors (other organisms that use the same space or food sources).
- **Abiotic factors**

  The Abiotic components of the insect environment, mainly include temperature, moisture, light, air and water currents and others. These have been found to be significant in their influence on insect. The abiotic factors like temperature, moisture and light are not uniform throughout an ecosystem. They are variable not only in different parts of ecosystem but also in different parts of a plant. And therefore, the effect of an environmental component, like temperature, may be described accurately only in terms of the temperature in a specific part of an ecosystem. This has led to develop the concept of microenvironment which implies the variation in environmental component within the ecosystem. The main abiotic factors influencing insects are temperature, moisture, light and air and water currents.

A) Temperature:

Of all the physical factors of environment, temperature is the most important .Insect maintain body temperatures within certain boundaries. Temperature acts on insects in two fold manner.

1. By acting directly on survival and development

2. Indirectly through food, humidity, rainfall, wind atmospheric pressure etc., All insects are poikilothermic i.e. their body temperatures follow more or less closely that of surrounding medium. The narrow band of temperature where physiological activities of the insect takes place is called preferred temperature or the temperature preferendum (generally 15-35 °C).

Exposure to temperatures beyond the favourable range whether low or high may result in death of the insect or may retard its growth and development. The temperature adaptation is referred to acclimation while the response of organism to it referred to as acclimatization.

Different effects of temperature are

i. Indirect effects of temperature: Temperature may also effect survival by influencing the rate utilization of food reserves. The lowest temperature at which organisms can live indefinitely is the minimum effective temperature. The lowest temperature which permits survival is the minimum survival temperature. For the same species occupying two different habitats these temperatures are different due to variation in their acclimation temperatures.

Cold hardiness: The ability of insect to withstand the lower temperatures. Some insects are able to avoid freezing because they can tolerate super cooling i.e. being cooled below the point of freezing but without freezing actually taking place. This is due to the cryoprtective compounds such as glycerol, sorbitol and erythritol. These are found in the tissues of over wintering insects to prevent tissue destructionas well as depressing the hemolymph freezing point.

ii. Lethal influence of high temperature: The temperature at which death occurs is called fatal high temperature. The death of insect is due to desiccation and increased rate of metabolism with consequent wastage of energy.

iii. Effect of fluctuating temperature: Fluctuating temperature affect the insect in the following ways

a. Fluctuating temperature makes the insect to undergo diapause.

b. Different stages of insects significantly respond to fluctuating temperature.

c. The effect of fluctuating temperature is accelerating only when one temperature is below the threshold of development but not too low to be injurious.

iv. Temperature and development: Insects complete their development more rapidly in warm weather than in cool. According to Vant Hoff's law when temperature is increased by 10°C the rate of development is doubled.

Thermal constant: The total heat energy required to complete a certain stage of development in the life cycle of a species or in the completion of physiological process is constant and called as thermal constant

Day degree: One degree of mean temperature lasting for one day

Developmental unit: The amount of development produced in given unit time by the increase of one degree centigrade

UT/nt

where U is developmental unit; T is Total development,

nt is Thermal constant

V. Temperature and fecundity: Fecundity is maximum towards moderately high temperature and declines as the upper and lower limit is reached. The fecundity may be influenced by environmental factors other than temperature, such as food, moisture, population and age of species.

vi. Temperature and dispersal: In nature dispersal of insect population does take place particularly when predators are abundant or food is sparsely distributed in its habitat. Temperature may effect the dispersal rate.

B) Moisture/humidity

A constant supply of moisture is needed for the metabolic reaction as well as the dissolution and transport of salts. The water content in insects varies from less than 50% to more than 90% of the total body weight. Soft bodied insects such as caterpillars tend to have comparatively large amount of water in the tissues, where as many insects with hard bodies tend to have somewhat lesser amounts. Active stages commonly have higher water content than dormant stage

Moisture preferendum: Insects have a tendency to congregate with in a narrow range of humidity that range is the preferred humidity or moisture preferendum. Activities of insects tend to become maximum at a specific range of humidity i.e., the optimum range. This optimum range varies from species to species even between different development stages of the same insect species.

Different effects of moisture are

i) Effect of moisture on development and fecundity: The rate of oviposition in insects increases greatly with increasing humidities. But in *Sitophilus oryzae* fecundity increases steadily up to 70% RH but there is no decline in number of eggs laid if the humidity is increased to 90%.

ii) Effect of moisture on insect coloration: Insect colouration is influenced by moisture content of the environment in some insects. In cooler areas dark colour helps to absorbs sun light which raises the body temperature and helps insects in getting rid of excessive moisture in the body. In desert insects light colour apparently helps to reflect the sun rays that saves the insect from excessive evaporation.

iii) Moisture balancing and conserving devices in insects: When the percentage of moisture content in the body of an insect is equal the RH of the atmosphere, the insect is described as being in a state of moisture equilibrium. To maintain water content with in well-defined limits, insects acquire water by drinking or by absorption from moist surface or air. The various structural devices for water conservation include: the waxy layer of the epicuticle that prevents water loss through the integument, spiracular closing mechanism that regulate moisture loss from the tracheal system and excretory organs that retain water from urine and faeces.

iv) Effect of extremes of moisture conditions: There is an optimal range of moisture in which a given species thrives. Mortality may occur under condition of excessively low environmental moisture content. The lethal influences of exceptionally low moisture condition on insects depend on the rate at which water loss is regulated by ambient temperature wind velocity or body movements. In order to escape this exceedingly low moisture condition, insects may undergo diapause or aestivation.

v) Humidity and survival: Survival is indirectly affected by extremely high humidity condition that favours the spread of viral, fungal and bacterial diseases. If excessive moisture does not kill an insect, it may seriously affect the length of its life cycle. Extremes of environmental moisture content directly influence many of the activities of insects including feeding, development and reproduction. High humidities are more favourable for embryonic stages than low humidities.

vi) Interaction of temperature and humidity: Temperature exerts a relatively greater effect on insects at the extremes of moisture condition and vice versa. High humidity proves fatal more readily than lower humidity at ordinary temperature. Most insects are capable of resisting high temperatures under high relative humidity. For each insect there are certain limits of temperature and humidity with in which they can live.

C) Light:

Light is essential ecological factor for many biological processes such as orientation or rhythmic behaviour of insects, bioluminescence, and periodicities of occurrence and periods of inactivity. Unlike temperature light is non-lethal factor. A characteristic feature of light is its quantitative shift from a minimum to a maximum and vice versa in a short time.

Influences of light on different movement of insects are

i) Phototaxis: Oriented locomotory movements towards and away from a source of light is referred to as phototaxis. It may be +ve or -ve

ii) Phototropism: Occurs in sessile insects involves light directed growth mechanisms

iii) Photo periodism: The response of insects to environmental rhythms of light and darkness is termed as photo periodism. Each daily cycle inclusive of a period of illumination followed by a period of darkness is called the photoperiod. The term photophase and scotophase are also used to denote the period of illumination and the period of darkness respectively. The photo tactic reaction of insects to light can be modified or reversed by several factors such as temperature, moisture, food and age.

iv) Effect of alternating light and darkness on insects: Some are active during the day (diurnal), some are active during night (nocturnal), Some at dawn (matinal) and still others at dusk (crepuscular). Initiation of diapause is by day length of shorter duration. Photoperiod in addition determines whether it is embryonic diapause (*Bombyx mori*), Larval diapause (*Euproctis*), pre pupal diapause (*Plodia interpunctella*), pupal diapause (*Pieris brassicae*) or imaginal diapause (*Culex* and *Anopheles*).

Many insects exhibit continuous growth under long day condition (long day forms) or become arrested in growth under going diapause (short day forms). Long day forms have the capacity to produce several generations during the growing seasons unlike as in short day forms, where there may be 2 generations in a year. Feeding, mating, oviposition as well as emergence rhythms in insects are influences by photoperiod. In Aedes aegyptil active periods of feeding appear to be during the morning or just before the sunset.

v) Bioluminescence or phosphorescence: Employment of luminescence in recognize of one sex by another. Ex: Fire flies

D) Wind and air currents: Two basic types of air currents

a. Horizontal moving convention current
b. Vertical moving convention current
Most insects will not take flight when the speed of wind exceeds the normal flight speed. Strong flying insects tend to fly with the winds during migrations and are displaced a long distance as in case of spruce budworm moths. Air movements may be directly responsible for the death of insects; first severe wind coupled with heavy rains may cause mortality.

E) Water currents: Water currents often determine which species will live in an area. The various genera of mayflies may be classified into still or rapid water forms. Caddis fly and mayfly larvae may be found under condition of relatively high oxygen concentration, midge and black fly larvae at some what lower concentration while certain mosquito at a very low concentration.

F) Edaphic factors: Edaphic factors include the structure, texture and composition of soil along with its physical and chemical characteristics. Some organisms help in maintenance of soil fertility through nitrogen fixation. Some organisms like earth worms, millipedes etc, help in humus formation. The loams soils are most preferred by insects. Well aerated soil is a prerequisite of all soil insects (White grub). Drainage and texture together exert considerable influence in the distribution of insects which pass part of their life in soil. Nitrogen deficiency lowers the productivity of some species of insects but results in out-break of others. Height of mountain chains and steepness of the slope also effect the climate of an area, thus influencing the distribution of certain insects. The mountain range and large bodies of water such as seas act as physical barriers to the spread of insects.

BIOTIC FACTORS

Under natural conditions organisms live together influencing each others life directly or indirectly for growth, nutrition and reproduction. It is of two types

Intra-specific: Between the same species.

Inter-specific: Competition between different species. Quality and quantity of food play an important role in the survival, longevity, distribution, reproduction, speed of development etc. Biotic factors deal with

1. Relationship among organisms
2. Interrelations with plants
3. Food in relation to insects

1. **Relationship among organism**

A) Intra specific interactions

The intra specific interactions are governed by

a. Aggregation of individuals of the same species
b. Concurrence
c. Cannibalism
d. Association of sexes
e. Parental care
f. Social life

a. **Aggregation:** Aggregation refers to the tendency of some insects to concentrate in number larger than found in normal distribution. In certain cases insects may become gregarious by coincidence. These modify the environment i.e. micro climate their by bringing about the changes in the morphology, physiology and ethology of aggregating members.

b. **Concurrence:** Very large numbers of insects crowd together in mass assemblage at one time for hibernating, feeding or pairing (aphids). Concurrence is disadvantageous to the species because it results in reduction of food and contamination of surroundings etc.

c. Cannibalism: The intra-specific competition takes place between members of the same species and are inversely accentuated by crowding (**Helicoverpa armigera**).

d. Association of the sexes: The sex ratio in insects plays an important part in the build up of their population at the same temperature (House fly).

e**. Parental care**: It includes care of egg and brood nests provision of larval food either on the plant itself, or providing food material from outside (Earwigs).

f. Social life: Some insects live in colonies that have a division of labour among individuals and an interchange and sharing of food and other things among members of the colony (Ants and termites).

B) Inter specific Interactions: These are of 3 types

a) Symbiosis: One or both are benefited

b) Antagonism: At least one should be harmed

e) Neutrality: Neither harmed or benefited

1. Symbiotic relations are 2 ways,

i)Positive

ii) Negative

i) Positive interactions include:

a. Commensalism: It is an unbalanced relationship in which one partner is benefited, the other remaining un benefited and unharmed. One partner is host and other is guest. Ex: Staphylinid beetle inhabit nests of social Hymenoptera as commensal and utilize their stored food. Commensalism in which the association between, two organisms is for the purpose of transport is termed phoresy or hitch hiking. Ex: *Mallophaga*

b. Cooperation: Cooperation is found in bee colonies where there is division of labour among individuals of a colony.

c. Mutualism: Insect insect mutualism: Ants feed on honey dew secreted by aphids Insect-plant mutualism: Insect that feed on pollen and nectar have a mutualistic relationship to their plant hosts

Allotrophous: They visit the flower but do not play in pollination Ex: Thrips
Hemitrophous: Some extent of pollination. Ex: Bombycidae, Syrphidae
Eutrophous: Maximum pollination. Ex: Bees

ii). Negatvie interactions.

a) **Competition:** Individuals of same species or different species compete for space, light, food etc. Competition exclusion principal: Gause principal: No two species occupy the same ecological niche. Ex: *Tribolium casteneum* and *Tribolium confurum*, below 29°C, *T. confutam* will survive

b) **Perfect competition:** In perfect competition there is elimination of species. Same species and elimination is very fast is called hyper perfect competition

c) **Imperfect competition:** It is competition between different species and there is no elimination.

d) **Parasitism:** All inter specific interactions where by species benefit at the expense of another. Host of hyper parasites is called primary parasitoids. Hyper parasitoids may be secondary, tertiary or even quaternary parasitoids.

e) **Predatism:** A predator kills but never eliminates the prey completely. An obligate predator feeds only on one species of prey. A facultative predator feeds on more than one species.

2. Insect plant relationship

Plant is less damaged due to heritable characteristic called resistance. According to R.H.Painter, resistance is of 3 types

a. Non-preference for oviposition, shelter or food
b. Antibiosis
c. Tolerant

Hairy varieties are resistant to leaf hoppers. Secondary plant substances may have toxic, repellent, deterrent or hormonal effect on insects. Substances with moulting hormone activity have been found in several ferns (Gymnosperms). These substances protect plants by interfering with insect development. Juvenile hormones are also found in plants like Balsam fir and eastern hemlock.

3. Food in relation to insects

Quantity and quality of food play an important role in its survival, longevity, distribution reproduction and speed of development.

a) Quantity of food

Absolute shortage: Food being completely destroyed.

Effective food shortage: Food shortage may occur in patches through the distribution of a given insect populations.

The causes of absolute and effective food shortages are

- Large number of the same individuals per unit quantity of food (intra-specific competition)
- More than one species consuming the same food material (inter-specific competition)

- Species that influence the food of their species with out consuming it Other environmental factors

b) Quality of food

Egg production, larval development, longevity and size of insects may be greatly influence by the quality of available food. The queen of social Hymenoptera and termites lay eggs throughout their life and hence require food constantly. The quality of ingested food in some insects influences the outcome of development. The differences between workers and queen honey bees depend entirely on the diet that each receives during larval development. After 3 day of larval development larvae destined to become workers receive a diet containing increasing amount of honey, whereas queen larvae continue to be fed on royal jelly. Changes in the quality of food likewise include the appearance of winged form anad migratory behaviour in aphids.

4..6. **Summary**

Insects are the dominant group of organisms on earth, in terms of both taxonomic diversity and ecological function. Insects play significant roles in the ecology of the world due to their vast diversity of form, function and life-style; their considerable biomass; and their interaction with plant life, other organisms and the environment. Insects form an important part of the food chain.

4.7. **Terminal Questions and Answers**

Q1. Define ecology with special reference to behaviour of insect towards touch?

Q2. Define chemotaxis? How can you demonstrate it?

Q3. What is thanotosis? Define its principle with special reference to beetles?

Q4. How can we conduct exercise to find antennal grooming in cockroach? Explain with diagram?

Q5. Conduct an exercise on food preference in *Tribolium*?

Q6. Explain in detail insect plant interaction with examples?

Q7. Name some local bee flora?

References:

- Surtees, G. (1965). Ecological significance and practical implications of behaviour patterns determining the spatial structure of insect populations in stored grain. *Bulletin of Entomological Research*, 56(1), 201-213.
- Humphreys, R. K., & Ruxton, G. D. (2018). A review of thanatosis (death feigning) as an anti-predator behaviour. *Behavioral ecology and sociobiology*, 72, 1-16.
- Felton, G. W., & Tumlinson, J. H. (2008). Plant–insect dialogs: complex interactions at the plant–insect interface. *Current opinion in plant biology*, 11(4), 457-463.
- Price, P. W., Bouton, C. E., Gross, P., McPheron, B. A., Thompson, J. N., & Weis, A. E. (1980). Interactions among three trophic levels: influence of plants on interactions between insect herbivores and natural enemies. *Annual review of Ecology and Systematics*, 11(1), 41-65.
- Tiwari, P., Tiwari, J. K., Singh, D., & Singh, D. (2013). Traditional beekeeping with the Indian honey bee (Apis cerana F.) in District Chamoli, Uttarakhand, India. *Studies (IJRS)*, *20*(1).
- Tan, S. W., Yap, K. L., & Lee, H. L. (1997). Mechanical transport of rotavirus by the legs and wings of Musca domestica (Diptera: Muscidae). *Journal of Medical Entomology*, 34(5), 527-531.