LECTURE 1.

Definition of entomology and importance of insects. Introduction to Phyllum Arthropoda

Definition of 'Entomology' and importance of insects

The term entomology is derived from two Greek words. *Entomon* means an insect and logos means to study. The term 'insect' is derived from the Latin word *insectum* which means 'cut into'.

Insects came into earth 480 million years ago. Man came to mother earth only one million years ago. Out of 17 lakh living species on earth, 9.5 lakh species are insects, 2.5 lakh species are plants and 0.45 lakh species alone are vertebrates.

Insects are harmful to man as pests of cultivated crops, animals, stored products, carries of human diseases and pests of household and industrial articles. They are also helpful as producers of honey, lac, silk, dyes, etc., pollinators of crops and as natural enemies of crop pests. They also serve as important link in the food-web of biological cycle in ecosystem.

Insects are grouped with other animals with similar characteristics in the Phyllum Arthropoda.

Introduction To Phylum Arthropoda

There are about 1-2 million species of animals in the world and more than 70 per cent of these are insects. These animals are assigned to 29 phyla. Of these only nine phyla are large, and their representatives are common and familiar to us. These are called the major phyla. The other phyla are small and their representatives are uncommon and of uncertain relationships.

Position of insects in animal kingdom and their relationship with other Arthropods

Insects are invertebrates grouped in the phylum **Arthropoda** (Arthro-joint, poda-foot) and subphylum Uniramia. Characters of the Phylum Arthropoda are

1. Segmented body
2. Segments grouped into 2 or 3 regions (tagma) known as Tagmosis.
3. Renewable chitinous exoskeleton
4. Grow by molting.
5. Bilateral symmetry of body.
6. Body cavity filled with blood and called as haemocoel.
7. Tubular alimentary canal with mouth and anus at anterior and posterior ends.
8. Dorsal heart with valve like ostia.
9. Dorsal brain with ventral nerve cord.
10. Striated muscles (with dark and light bands).
11. No cilia (hair like vibratile structure on the surface of the cell).

12. Paired, segmented appendages.

Phylum Arthropoda is Classified in to 7 classes.

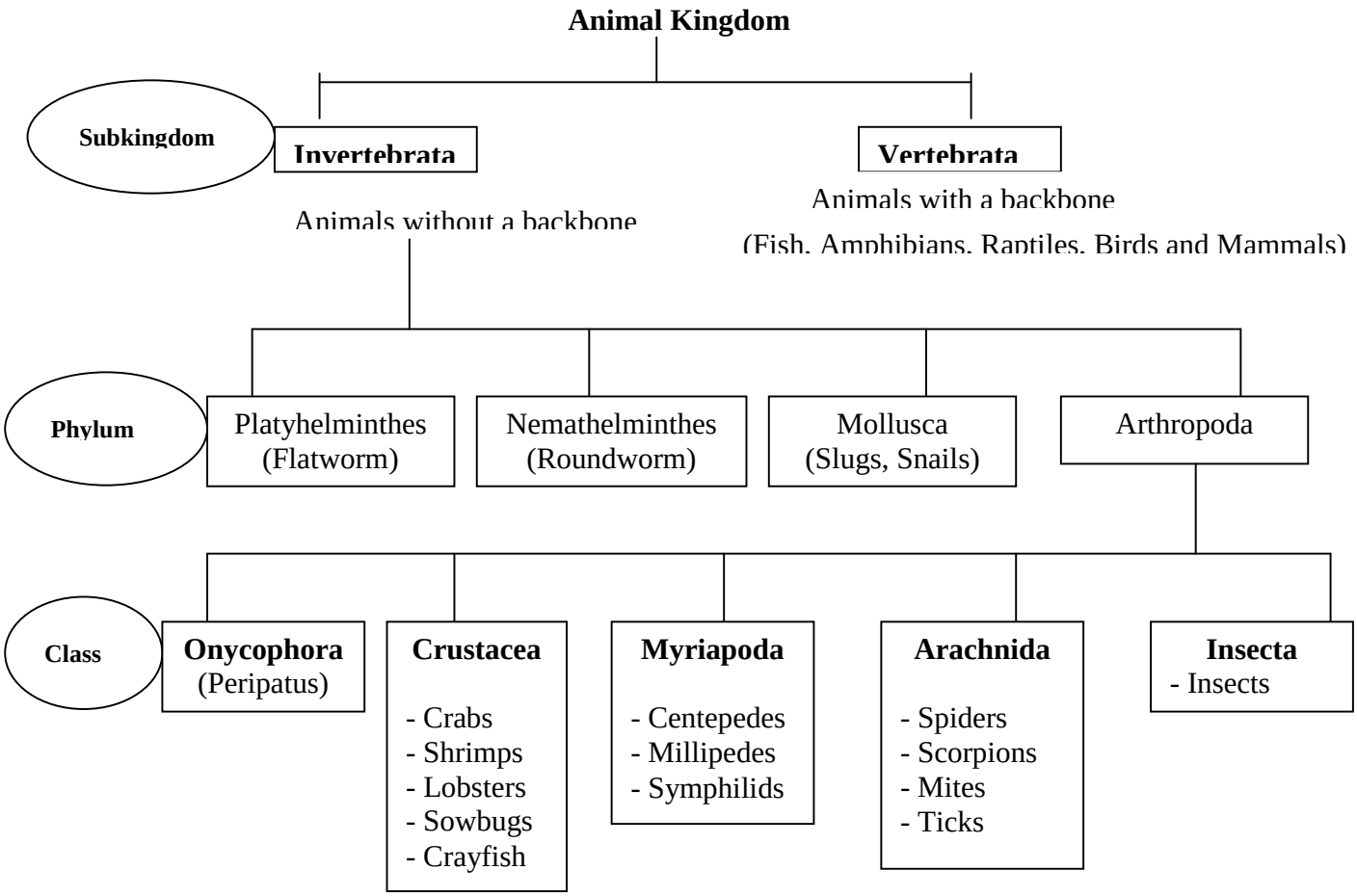
1. Onychophora (claw bearing) e.g. Peripatus
2. Crustacea (Crusta - shell) e.g. Prawn, crab, wood louse
3. Arachnida (Arachne - spider) e.g. Scorpion, spider, tick, mite
4. Chilopoda (Chilo - lip; poda - appendage) e.g. Centipedes
5. Diplopoda (Diplo - two; poda- appendage) e.g. Millipede
6. Trilobita (an extinct group)
7. Hexapoda (Hexa- six; poda-legs) or Insecta (In- internal; sect – cut) e.g. Insects.

MAJOR PHYLA OF ANIMALS

Sl. No.	**Phylum**	**Approximate known species**	**Examples**
1	**Porifera**	4500	Sponges
2	**Platyhelminthes**	12, 700	Flatworms: Planaria, tapeworm
3	**Nematoda**	12, 000	Roundworms
4	**Mollusca**	1, 00,000	Snails, octopus, oysters
5	**Annelida**	7,000	earthworms, leech
6	**Arthropoda**	1,000,000	Crabs, ticks, mites, shrimps, scorpions, spiders and insects
7	**Echinodermata**	6500	Starfishes, sea urchins, sand dollars
8	**Chordata**	43000	Fishes, amphibians, reptiles, birds and mammals
9	**Coelenterata**	80,000	Corals, Jellyfish, hydra

LECTURE 2. Introduction to Class Insecta. Insect dominance

The relationship between insects and other major groups in the animal kingdom

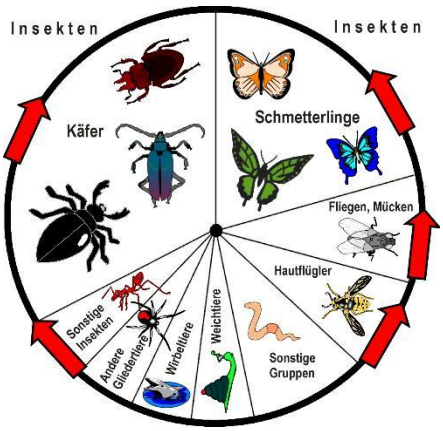


Character	Crustacea	Arachnida	Chilopoda	Diplopoda	Onychopoda	Insecta
Habitat	Aquatic and terrestrial	Terrestrial	Terrestrial	Terrestrial	Terrestrial	Many terrestrial and few aquatic
Body regions	Two – cephalothorax and abdomen	Three- Pro, meso and meta soma	Two- head and multi segmented trunk	Two- head and multi segmented trunk	Worm like- unsegmented in adults	Three: Head, thorax and abdomen
Antennae	Two pair	No antenna	One pair	One pair	One pair	One pair
Visual organs	One pair of stalked compound eyes	One pair of simple eyes	One pair of simple eyes	One pair of simple eyes	Simple eyes	Both simple (3 no.) and two compound eyes
Locomotor organs	Five pairs of biramous legs	Four pairs	One pair/segment	Two pairs/ segment	Many bilateral lobe like legs	3 pairs of legs on 3 thoracic segments and 2 pair of wings on meso and meta thorax
Respiration	Gill breathing	Book lungs tracheal	Tracheal	Tracheal	Tracheal	Tracheal
Habit	Herbivores, carnivores	Phytophagous and predators	Carnivorous	Herbivorous	Organic matter	Phytophagous, predators and parasitoids
Examples	Crayfish, crabs, wood lice and lobster	Spiders, scorpions, mites and ticks	Centipedes	Millipedes	*Peripatus* sp.	Insects

Insect dominance

Insects are the most dominant species on the earth as they originated on earth 480 million years ago. Among 1.7 million living species, 0.95 million species are insects.

Insect Order	Number of species
Coleoptera (Beetles and weevils)	3,50,000
Lepidoptera (Butterflies and moths)	1,60,000
Hymenoptera (Bees, wasps and ants)	1,20,000
Diptera (Flies and mosquitoes)	1,20,000
Hemiptera (Bugs)	98,000
Orthoptera (Grasshoppers, crickets and locust)	20,000



Measures of dominance:

1. More number of species
2. Large number of individuals in a single species: e.g. Locust swarm comprising of 10^9 number of individuals, occupying large area.
3. Great variety of habitats
4. Long geological history

Reasons for dominance:

There are several structural, morphological and physiological factors responsible for insect dominance. They are:

1. Capacity for flight

2. More adaptability or universality

3. Smaller size: Majority of insects are small in their size conferring the following physiological and ecological advantages.

4. Presence of exoskeleton: Insect body is covered with an outer cuticle called exoskeleton which is made up of a cuticular protein called **Chitin**. This is light in weight and gives strength, rigidity and flexibility to the insect body.

5. Resistance to desiccation: Insects minimise the water loss from their body surface through prevention of water loss (wax layer of epicuticle, closable spiracles, egg shell) conservation of water (capable of utilizing metabolic water, resorption of water from fecal matter, use less quantity of water to remove the nitrogenous waste)

6. Tracheal system of respiration: This ensures direct transfer of adequate oxygen to actively breathing tissues. Spiracles through their closing mechanism admit air and restrict water loss.

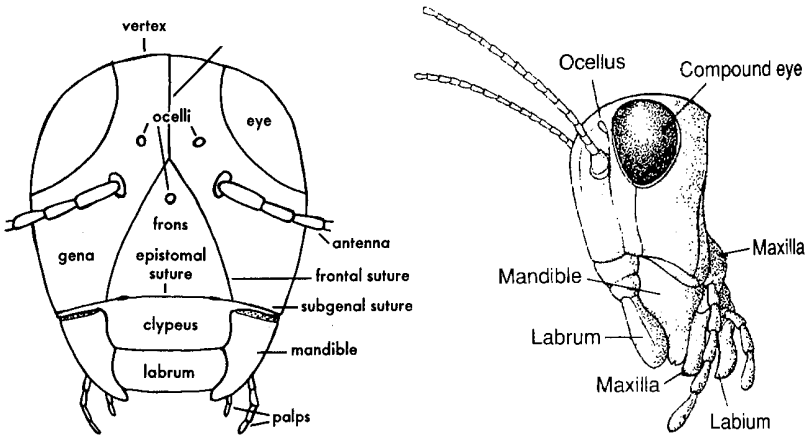
7. Higher reproductive potential: Reproductive potential of insect is high

eg. Egg laying capacity (fecundity) of queen termite is 6000 - 7000 eggs per day for 15 long years. Short development period e.g., Corn aphid produces 16 nymphs per female which reaches the adulthood within 16 days. Presence of special types of reproduction other than oviparity and viviparity like Polyembryony, Parthenogenesis and Paedogenesis

LECTURE 3. Comparative account of insect external morphology: Head, Antenna

HEAD

The head of an insect is composed of a series of segments, which are specialized for food gathering and manipulation, sensory perception, and neural integration. The head bears the eyes (compound eyes and ocelli), antennae, and mouthparts. The anterior part of the head is the **frons**. The anterior area below the dorsum of the head, between and behind the eyes is the **vertex**. The area below the compound eye, on the side of the head, is the **gena**. The liplike sclerite is the **clypeus**.



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

1. Hypognathous: (Hypo-below ; gnathous-jaw)

This type is called orthopteroid type. The long axis of the head is vertical, it is at right angles to the long axis of the body. Mouth parts are ventrally placed and project downwards. E.g. grasshopper, cockroach.

2. Prognathous: (Pro-infront ; ganthous-jaw)

This type is also called coleopteroid type. The long axis of the head is horizontal. It is in line with the long axis of the body. Mouth parts are directed forward. e.g. ground beetle.

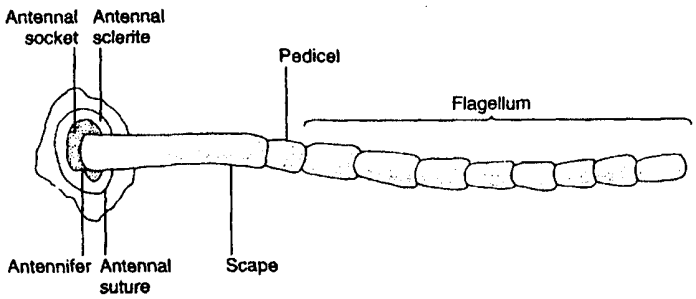
3. **Opisthognathuos**: (Opistho-benind; gnathuos-jaw)

This is also called hemipteroid type or opisthorhynchous type. Head is deflexed. Mouthparts are directed backwards and held in between the forelegs. e.g. stink bug.

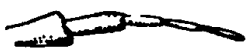
Structure of insect antenna: Antennae are also called feelers. They are paired, highly mobile and segmented. Antennae are located between or behind the compound eyes. All insects except protura have a pair of antennae. Antennae are well developed in adults and poorly developed in immature stages. The antenna is set in a socket of the cranium called antennal socket. The base of the antenna is connected to the edge of the socket by an articulatory membrane. This permits free movement of antennae. The basal segment is

called **scape**. It is conspicuously larger than succeeding segments. The second antennal segment is called **pedicle** whcih immediately follow the scape. A mass of sence cells called **Johnston's organ** is present in the pedicel, which is used as a chordatonal organ in some of the insects like mosquitoes. Both scape and pedicel are provided with intrinsic muscles. The remaining annuli or flagellomeres are known as **flagellum** or **clavola** which lack individual muscle. Surface of the flagellum is supplied with many sensory receptors that are innervated by the duetocerebrum of brain. Flagellum may very in size and form.
Function: Antenna is useful to detect chemicals including food and pheromones (chemicals secreted into air by opposite sex). It perceives smell, humidity changes, variation in temperature, vibration, wind velocity and direction. Antenna is useful to perceive the forward environment and detect danger. It is useful for hearing in mosquitoes and communication in ants. Rarely it is also useful to clasp the mate (e.g. Flea) and grasp the prey.

Antennae vary greatly among insects, but all follow a basic plan: segments 1 and 2 are termed the scape and pedicel, respectively. The remaining antennal segments (flagellomeres) are jointly called the flagellum.



Antennae function almost exclusively in sensory perception. Some of the information that can be detected by insect antennae includes: **<u>motion and orientation, odor, sound, humidity, and a variety of chemical cues.</u>** Some of the most common types of insect antennae with which you should be familiar are illustrated below:



(e.g., Odonata)

(e.g., Coleoptera)

(e.g., Lepidoptera)

(e.g., Diptera)

Types of antennae:

1. Setaceous: (Bristle like) Size of the segments decreases from base to apex. e.g. Leafhopper, Dragonfly, Damselfly.

2. Filiform: (Thread like) Segments are usually cylindrical. Thickness of segments remains same throughout. e.g. Grasshopper.

3. Moniliform: (Beaded) Segments are either globular or spherical with prominent constriction in between e.g. Termite.

4. Serrate: (Saw like) Segments have short triangular projections on one side. e.g. Longicorn bettle

5. Unipectinate: (Comb like) Segments with long slender processes on one side e.g. Sawfly

6. Bipectinate: (Double comb like) Segments with long slender lateral processes on both the sides e.g. Silkworm moth

7. Clavate: (Clubbed) Antenna enlarges gradually towards the tip. e.g. Blister beetle

8.Capitate: (Knobbed) Terminal segments become enlarged suddenly e.g. butterfly

9. Lamellate: (Plate like) Antennal tip is expanded laterally on one side to form flat plates e.g. lamellicorn beetle

10. Aristate: The terminal segment is enlarged. It bears a conspicuous dorsal bristle called arista e.g. House fly

11. Stylate: Terminal segment bear a style like process eg. Horse fly, Robber fly.

12. Plumose: (Feathery) Segments with long whorls of hairs e.g. male mosquito **13. Pilose**: (Hairy) Antenna is less feathery with few hairs at the junction of flagellomeres. e.g. Female mosquito.

14. Geniculate: (Elbowed) Scape is long remaining segments are small and are arranged at an angle to the first resembling an elbow joint. e.g. Ant, weevil and honey bee.

LECTURE 4. Insect mouth part and types of mouth parts

MOUTHPARTS

Just as insects take on many different forms, they also possess a variety of different mouth types, each of which can be grouped under one of two main categories: chewing (mandibulate) and sucking (haustellate).

Mandibulate mouthparts, like the ones illustrated below, are believed to be the most primitive. All others, including those categorized as haustellate, are presumed to have evolved as modifications of this basic type.

The five primary parts of the insect "mouth" are:

1) The clypeus

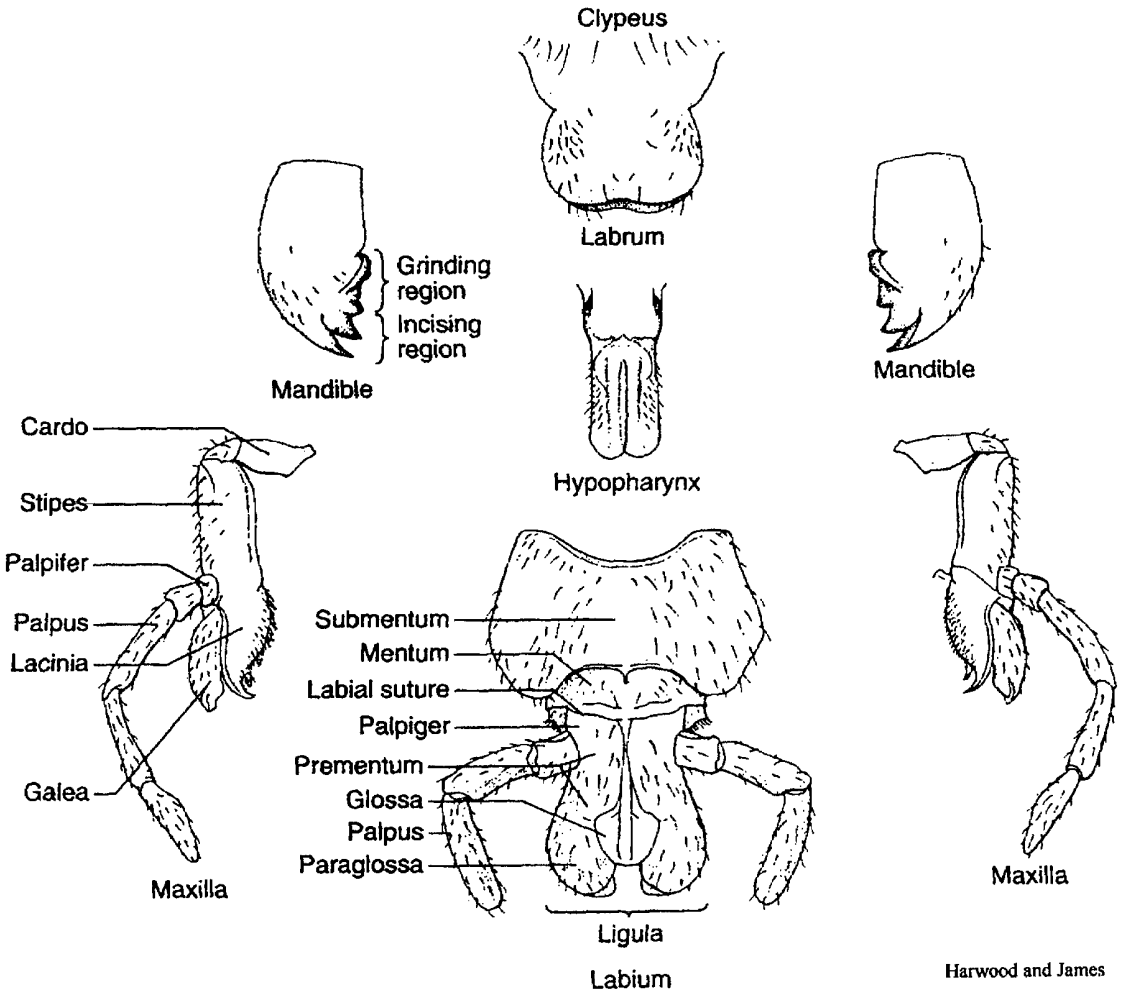
2) The "upper lip", or labrum

3) Two "jaw-like structures", or mandibles

4) The maxillae (sing. maxilla)

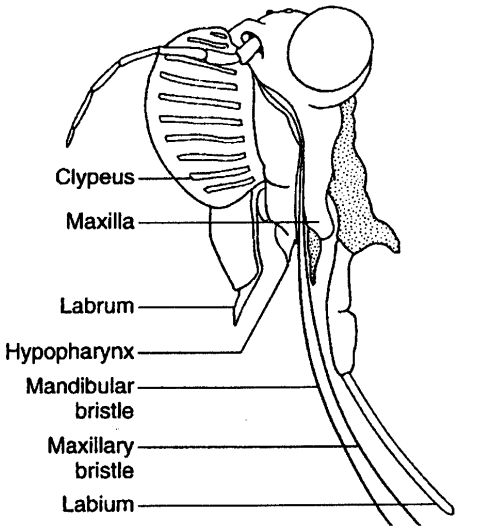
5) The "lower lip", or labium

The maxillae and labium are divided into various substructures, which include the galea, paraglossa, glossa, and the maxillary and labial palps.



Harwood and James

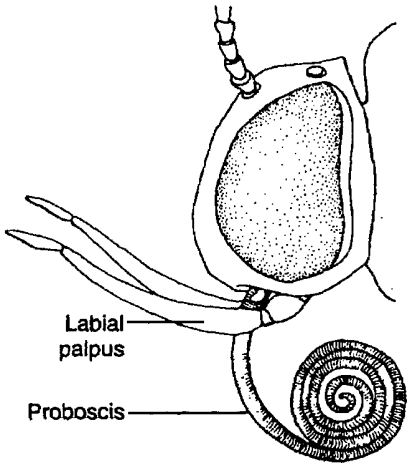
Haustellate mouthparts are primarily used for "sucking up" liquids, and can be broken down into two subgroups: those that possess stylets and those that do not. **Stylets** are needle-like projections used to penetrate plant and animal tissue. Examples of insects with stylets include Hemiptera (true bugs), Diptera (flies), and Siphonaptera (fleas).



Drawings Smithsonian Institution Press.

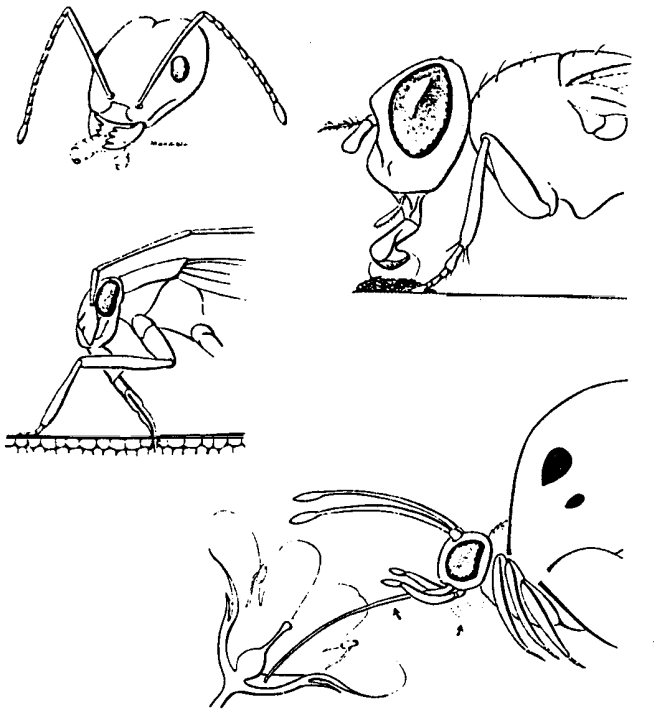
Order Hemiptera

Some haustellate mouthparts lack stylets. Unable to pierce tissues, these insects must rely on easily accessible food sources such as nectar at the base of a flower. One example of nonstylate mouthparts is the long siphoning proboscis of butterflies and moths (Order Lepidoptera). Although the method of liquid transport differs from that of the butterfly's proboscis, the rasping-sucking rostrum of some flies is also considered to be haustellate without stylets.



Moth (Order Lepidoptera)

ADAPTATIONS OF THE MOUTHPARTS



Insect Mouthparts: Top left, chewing, top right, sponging; center, piercing-sucking; bottom, siphoning. (F. W. Zettler, Cornell)

Types of insect mouthparts

Mouthparts of insects vary to a great extend among insects of different groups depending upon their feeding habits. They are mainly of two types viz., Mandibulate (feeding mainly on solid food) and haustellate (feeding mainly on liquid food).

1. **Biting and chewing type**: e.g. Cockroach & grasshopper. It is the primitive type of mouth part and consists of the following parts.

i. **Labrum** : (Upper lip) It is flap like, bilobed and attached to the clypeus by an articular membrane. It is movable. It covers the mouth cavity from above. It helps to pull the food into the mouth. It holds the food in position so that mandibles can act on it. It forms the roof of the pre oral food cavity.

ii. **Labrum-epipharynx**: Inner surface of the labrum is referred to as epipharynx. It is frequently membranous and continuous with the dorsal wall of pharnyx. It is an organ of taste.

iii. **Mandibles**: There is a pair of mandibles. They are the first pair of jaws. They are also called as primary jaws or true jaws. Mandibles articulate with the cranium at two points. They are heavily sclerotised. They are toothed on their inner border. There are two types of teeth. Distal are sharply pointed and are called incisor or cutting teeth and proximal teeth are called molar or grinding teeth. They act transversely to bite and grind the food into small fragments.

iv. Maxillae: They are paired and more complicated than mandibles. They are called secondary jaws or accessory jaws. At proximal end the first sclerite **cardo** joins the maxilla to head. The second sclerite is called **stipes** which articulates with cardo. Stipes carries a lateral sclerite called **palpifer** which bears a five segmented antenna like **maxillary palp**. On the distal end of the stipes, there are two lobes. The outer lobe is called **galea** and inner lobe is **lacinia** which is toothed. Maxille direct the food into the mouth. They hold the food in place when the mandibles are in action. They act as auxillary jaws and assist in mastication of food. Sense organs connected with the perception of touch, smell and taste are abundantly found in palpi.

v. Hypopharynx : It is a tongue like organ. It is located centrally in the preoral cavity. Salivary gland duct opens through it.

vi. **Labium /lower lip:** It is a composite structure formed by the fusion of two primitive segmented appendages. It bounds the mouth cavity from below or behind. It forms the base of the preoral cavity. It consists of three median sclerites *viz*., **submentum** (large basalsclerite), **mentum** (middle sclerite) and **prementum** (apical sclerite). On the lateral side of the prementum there are two small lateral sclerites called **palpiger** bearing three segmented **labial palpi.** Distally prementum bears two pairs of lobes. The other pair of lobes is called **paraglossae** and inner pair of lobes, **glossae**. Both pairs when fused are called **ligula**.

2**. Piercing and sucking / hemipterous / bug type** e.g. Plant bugs.

Labium projects downwards from the anterior part of the head like a beak. Beak is four segmented and grooved throughout its entire length. At the base of the labium there is a triangular flap like structure called labrum. Labium is neither involved in piercing nor sucking. It functions as a protective covering for the four **stylets** (fascicle) found with in the groove. Both mandibles and maxillae are modified into long slender sclerotized hair like structure called stylets. They are lying close together and suited for piercing and sucking. The tips of the stylets may have minute teeth for piercing the plant tissue. The inner maxillary stylets are doubly grooved on their inner faces. When these are closely opposed they form two canals viz., food canal and salivary canal through sap and saliva are conducted respectively. Saliva contains enzymes or toxins that can distort plant cell wall to permit the stylets to penetrate down and reach phloem for suking the sap. Both palps are absent.

3. Piercing and sucking / dipterous / mosquito type : e.g. Female mosquito

Mouthparts of female mosquito consists of an elongate labium which is grooved forming a gutter which encloses six stylets. The stylets are composed of labrum - epipharynx (enclosing the food canal), the hyphophrynx (containing the salivary canal), two maxillae and two mandibles. Both the ends of maxillary stylets and mandibular stylets are saw like and suited piercing flesh. The stylets are inserted into host's skin by a strong downward and forward thrust of body. Both mandibles and maxillae are reduced in male and they feed on plant nectar and juices of decaying fruits. Female pierces the skin of human beings into which it injects saliva containing an anticoagulant (to keep

The blood flowing without clotting) and an anesthetic (to keep the victim unaware of the bite) and sucks up the blood. Labium does not pierce but folds up or back as stylets pierce. Maxillary palpi are present.

4. **Chewing and lapping type** : e.g. honey bee.

Labrum and mandibles are as in biting and chewing type of mouth parts. But mandibles are blunt and not toothed. They are useful to crush and shape wax for comb building; ingest pollen grains and other manipulative functions. Maxillolabial structures are modified to form the lapping tongue. The tongue unit consists of two galea of maxillae, two labial palpi and elongated flexible hairy glossa of labium. The glossa terminates into a small circular spoon shaped lobe called spoon or bouton or flabellum which is useful to lick the nectar.

5. **Rasping and sucking** : e.g. Thrips

Mouth cone consists of labrum, labium and maxillae. There are three stylets derived from two maxillae and left mandible. Right mandible is absent. Stylets are useful to lacerate the plant tissue and the oozing sap is sucked up by the mouth cone. Both maxillary palpi and labial palpi are present.

6. **Mandibulosuctorial type** : e.g. grub of antlion

Mandibles are elongate sickle shaped and grooved on the inner surface. Each maxilla is elongated and fits against the mandibular groove to from a closed food canal. The body of the insect victim is pierced by the opposing mandibles and fluids are extracted.

7. **Sponging type** : e.g. House fly

The proboscis is fleshy, elbowed, retractile and projects downwards from head. The proboscis can be differentiated into basal rostrum and distal haustellum. The proboscis consists of labium which is grooved on its anterior surface. Within this groove lie the labrum-epiphraynx (enclosing the food canal) and slender hypopharynx (containing the salivary canal). Mandibles are absent. Maxillae are represented by single segmented maxillary palpi. The end of the proboscis is enlarged, sponge like and two lobed which acts as suction pads.

They are called oral discs or labella. The surfaces of labella are transvered by capillary canals called pseudotracheae which collect the liquid food and convey it to the canal. Labella function as sponging organs and are capable of taking exposed fluids. These insects often spit enzyme containing saliva onto solid foods to liquify them.

8. **Siphoning type** : e.g. Moths and butterflies

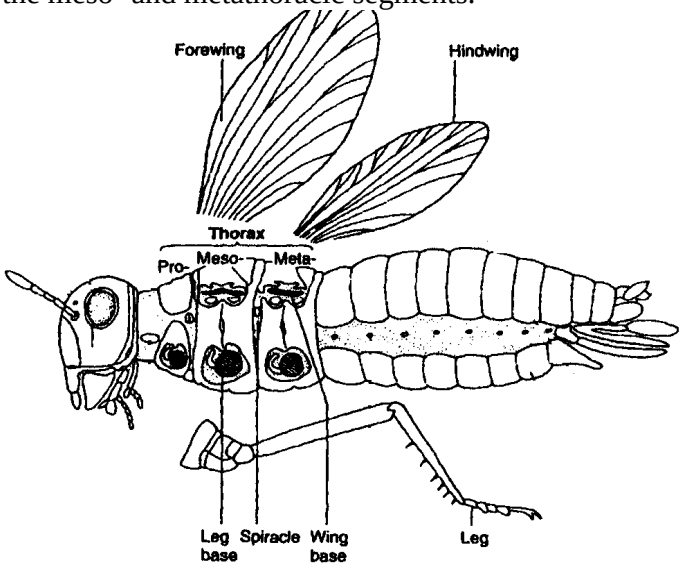
Mouth parts consists of elongate sucking tube or proboscis. It is formed by two greatly elongated galeae of maxillae which are zippered together by interlocking spines and hooks. Galeae are grooved on their inner surface and when they are fitting together closely they form a suctorial food canal through which the nectar is sucked up. The proboscis is coiled up like watch spring and kept beneath the head when it is not in use. By pumping of blood into galeae, the proboscis is extended. The other mouth parts are reduced or absent except the labial palpi and smaller maxillary palpi.

LECTURE 5. Insect thorax: segmentation of thorax. Leg structure and its modifications

THORAX

The insect thorax is divided into three parts: the prothorax (pro=first), mesothorax (meso=middle), and metathorax (meta=last). Each segment consists of hardened plates, or sclerites. Dorsal sclerites are called nota (sing. notum), lateral sclerites are called pleura (sing. pleuron), and ventral sclerites are called sterna (sing. sternum).

Each of the three thoracic segments contains one pair of legs. Wings are found only on the meso- and metathoracic segments.



LEGS

The **fore-legs** are located on the prothorax, the **mid-legs** on the mesothorax, and **the hind legs** on the metathorax. Each leg has six major components, listed here from proximal to distal: **coxa** (p1. coxae), **trochanter**, **femur** (p1. femora),**tibia**(p1.tibiae),**tarsus** (p1. tarsi), **pretarsus**.

The femur and tibia may be modified with spines. The tarsus appears to be divided into one to five "pseudosegments" called **tarsomeres**.

Structure:
In almost all insects all the three thoracic segments *viz*., pro-, meso- and metathorax bear a pair of segmented legs. Each leg consists of five segments viz., coxa, trochanter, femur, tibia and tarsus.

Coxa : (Pl. coxae) It is the first or proximal leg segment. It articulates with the cup like depression on the thoracic pleuron. It is generally freely movable.

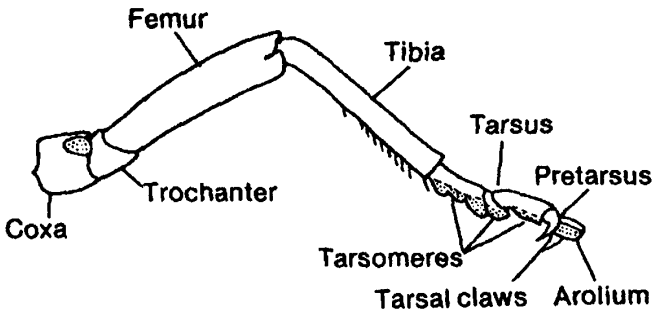
Trochanter: It is the second leg segment. It is usually small and single segmented. Trochanter seems to be two segmented in dragonfly, dameselfy and ichneumonid wasp. The apparent second trochanter is in fact a part of femur, which is called trochantellus.

Femur: (Pl. femora) It is the largest and stoutest part of the leg and is closely attached to the trochanter.

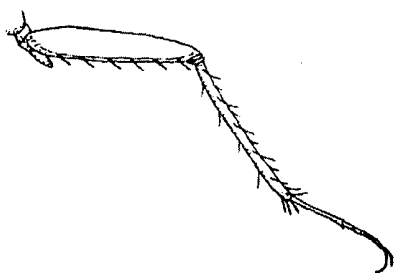
Tibia: (Pl. tibiae) It is usually long and provided with downward projecting spines which aid in climbing and footing. Tibia of many insects is armed with large movable spur near the apex.

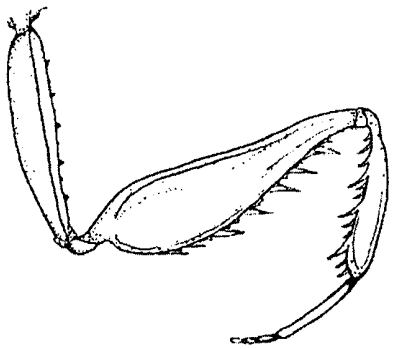
Tarsus: (Pl. tarsi) It is further sub-divided. The sub segment of the tarsus is called tarsomere. The number of tarsomeres vary from one to five. The basal tarsal segment is often larger than others and is named as basitarsus.

Pretarsus: Beyound the tarsus there are several structure collectively known as pretarsus. Tarsus terminates in a pair of strongly curved claws with one or two pads of cushions at their base between them. A median pad between the claws is usually known as arolium and a pair of pads, at their base are called pulvilli (Pulvillus-singular). Leg pads are useful while walking on smooth surface and claws give needed grip while walking on rough surface. When one structure is used, the other is bent upwards.



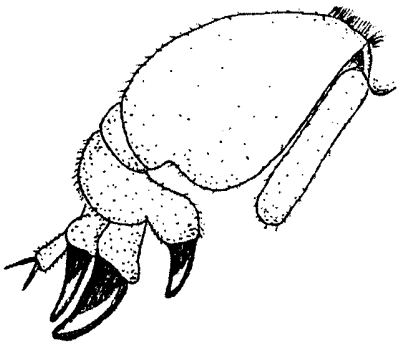
LEG TYPES AND FUNCTION

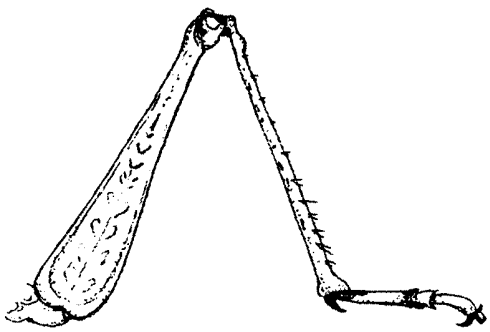




Cursorial: Used for walking/ running. Some textbooks distinguish the two by calling walking legs ambulatory or gressorial, but the leg structure is basically the same.

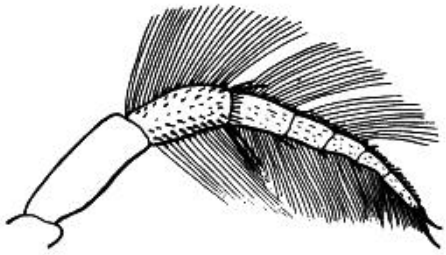
Raptorial: Fore legs modified for grasping. These are often associated with Preying Mantids.





Fossorial: Fore legs and tibiae specialized for digging; common in ground-dwelling insects.

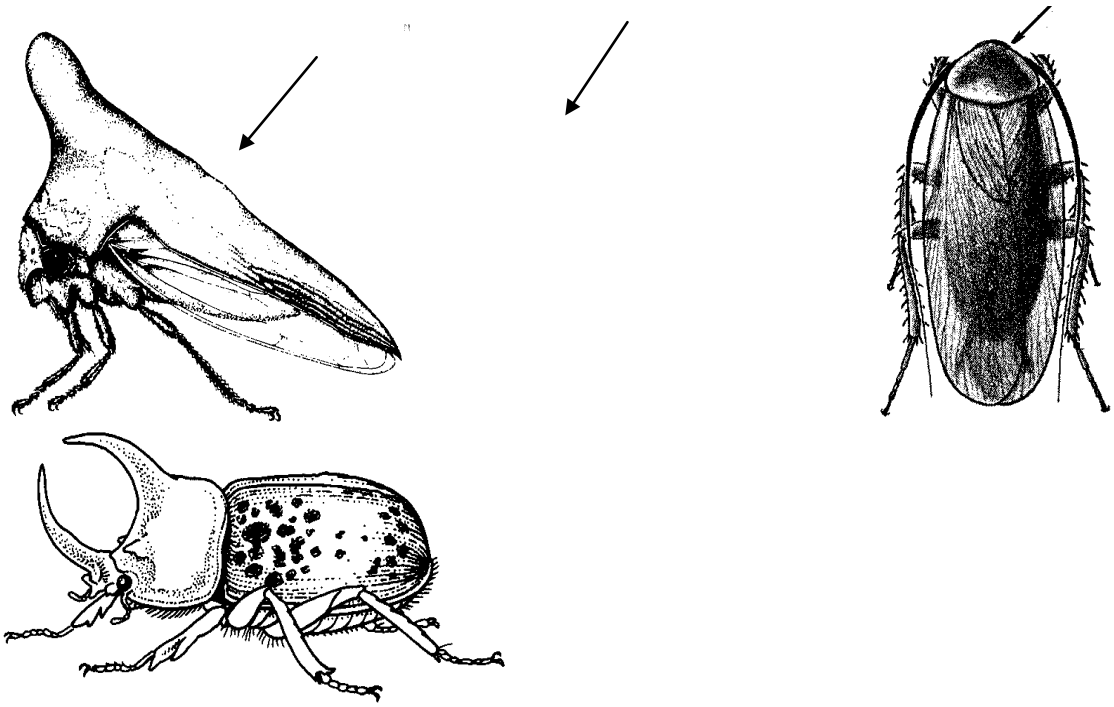
Saltatorial: Hind legs adapted for jumping; characterized by an elongated femur and tibia.



PRONOTUM

Natatorial: fore or hind legs adapted for swimming; charachterized by elongated setae on tarsi

Is the dorsal sclerite of the prothorax, which can be highly modified in various groups such as the Homoptera, Blattaria, and Coleoptera.



Types of legs

Insects are six legged arthropods and hence the class is also called Hexapoda. In insects legs perform varied functions and are modified accordingly.

1. Digging or Fossorial type: The forelegs are greatly expanded, tibia is digitate with three segmented tarsus beneath. The legs are used for digging soil. E.g. Mole cricket
2. Jumping or Saltatorial type: The hindlegs are modified for leaping or jumping. Femur is greatly enlarged, tibia is very long e.g. Grasshopper

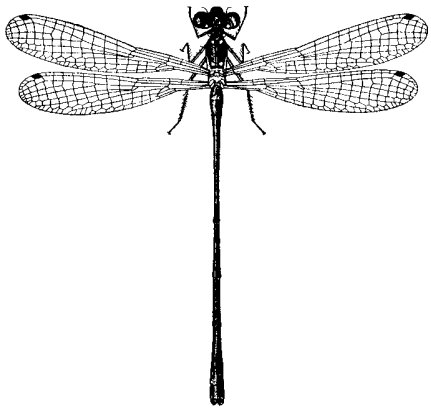
3. Walking or running type: All three pairs of legs are equal in size and comparatively long. Trochanter is two segmented. E.g. Cockroach
4. Grasping or Raptorial type: The forelegs are modified for catching prey. The coxae are elongate and moveable, the femora are spiny and grooved along the lower side, the tibiae are also spiny and fit into the groove along the femur. The prey is held between the femur and tibia. Tarsus is five segmented. E.g. Preying mantids.
5. Swimming or Natatorial type: Usually the hind legs are modified for swimming. Hind coxae are flat and fixed to the body. Numerous long stiff hairs are present on the lateral aspects of the tibia and tarsus. E.g. diving beetles.
6. Pollen carrying type: The hind legs of honey bees are modified for carrying pollen. At the junction of tibia and basitarsus, a cavity guarded by hairs is present which is used for carrying pollen. This structure is also called carbiculum. E.g. Worker honeybee.
7. Antenna cleaner: the forelegs of honey bees are modified for cleaning antenna. The first segment of tarsus has a notch, which can be closed by the flat tibial spur. The notch has an inner lining of fine hairs. The antenna is placed in the notch, closed by the spur and then drawn out to clean. E.g. Worker honeybees
8. clinging type: The legs are strong and adapted for maintaining a strong and firm hold on the host. Tarsi are single segmented and terminate in a single sickle shaped claw which works against a tibial process. E.g. Head louse and body louse.
9. Climbing type: The terminal segment of the leg, pretarsus, bears two claws and beneath the claws are two lobes ccalled pulvulii. Between the pulvulii is an elongate spine called empodium. The empodium and pulvulii help the insect to climb smooth surfaces. E.g. housefly.

LECTURE 6. Insect wing: structure and its modifications

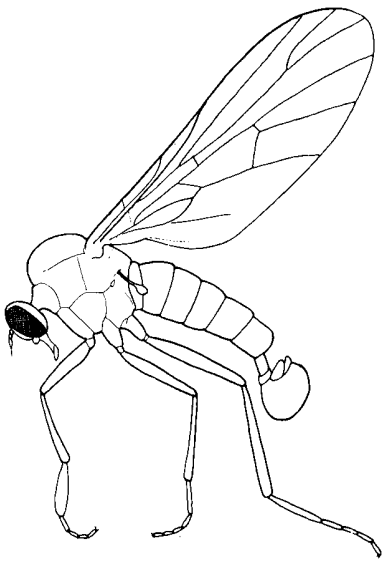
WINGS

Insects have evolved many variations of the wing. Wing venation is a commonly used taxonomic character, especially at the family and species level.

Membranous wings are thin and more or less transparent. This type of wings is found among the Odonata and Neuroptera.

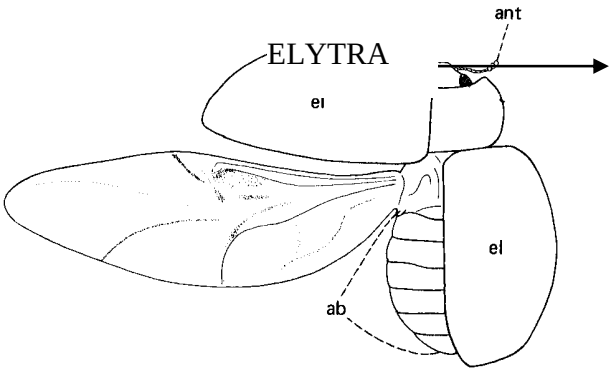


Halteres are an extreme modification among the order Diptera (true flies), in which the hind wings are reduced to mere nubs used for balance and direction during flight.

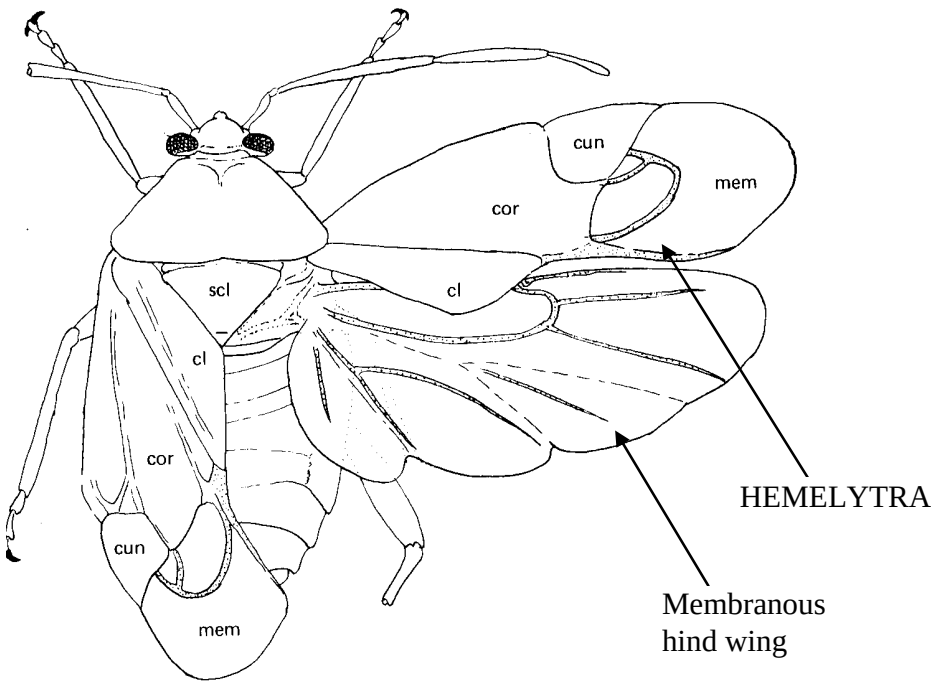


HALTERE

Elytra (sing. elytron) are the hardened, heavily sclerotized forewings of beetles (Order Coleoptera) and are modified to protect the hind wings when at rest.



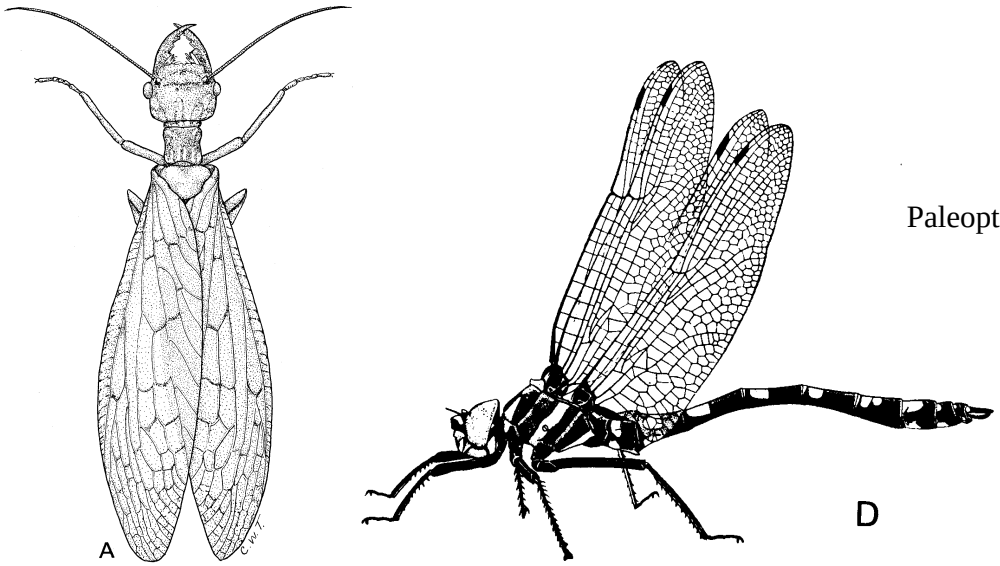
A variation of the elytra is the **hemelytra**. The forewings of Hemipterans are said to be hemelytrous because they are hardened throughout the proximal two-thirds (approximately), while the distal portion is membranous. Unlike elytra, hemelytra function primarily as flight wings. In both cases, the membranous hind wings (when present) are used in flight and are folded beneath the forewings when at rest.



The wings of butterflies and moths are covered with scales, and mosquitoes possess scales along wing veins.

NEOPTEROUS VS PALEOPTEROUS WING CONDITIONS

In most living insects (the Neoptera), there are three axillary sclerites that articulate with various parts of the wing. In the Neoptera, a muscle on the third axillary causes it to pivot about the posterior notal wing process and thereby to fold the wing over the back of the insect. (In some groups of Neoptera, such as butterflies, the ability to fold the wings over the back has been lost.) Two Orders of winged insects, the Ephemeroptera and Odonata, have not evolved this wing-flexing mechanism, and their axillary sclerites are arranged in a pattern different from that of the Neoptera; these two orders (together with a number of extinct orders) form the Paleoptera.



Paleopterous

Types of insect wings

Among invertebrate animals, only insects posses wings. Wings are present only in adult stage. Number of wings vary from two pairs to none. Certain primitive insects like silverfish and spring tail have no wings (apterous). Ectoparasites like head louse, poultry louse and flea are secondarily wingless. Wings are deciduous in ants and termites. There is only one pair of wings in the true flies. Normally, two pairs of wings are present in insects and they are borne on pterothoracic segments viz., mesothorax and metathorax. Wings are moved by thoacic flight muscles attached to their bases.

Wing is a flattened double - layered expansion of body wall with a dorsal and ventral lamina having the same structure as the integument. Both dorsal and ventral

laminane grow, meet and fuse except along certain lines. Thus a series of channels is formed. These channels serve for the passage of tracheae, nerves and blood. Wing is nourished by blood circulating through veins. Later the walls of these channels become thickened to form veins or nervures. The arrangement of veins on the wings is called venation which is extensively used in insect classification. The principal longitudinal veins arranged in order from the anterior margin are costa (C), sub costa (Sc), radius (R), median (M), cubitus (Cu) and anal veins (A). Small veins often found inter connecting the longitudinal veins are called cross veins. Due to the presence of longitudinal veins and cross veins, the wing surface gets divided into a number of enclosed spaces termed cells. In insects like dragonfly and damesefly, there is an opaque spot near the coastal margin of the wing called pterotigma.

Margins and angles: The wing is triangular in shape and has therefore three sides and three angles. The anterior margin strengthened by the costa is called coastal margin and the lateral margin is called apical margin and the posterior margin is called anal margin. The angle by which the wing is attached to the thorax is called humeral angle. The angle between the coastal and apical margins is called apical angle. The angle between apical and anal margins is anal angle.

Wing regions: The anterior area of the wing supported by veins is usually called remigium. The flexible posterior area is termed vannus. The two regions are separated by vannal fold. The proximal part of vannus is called jugum, when well developed is separated by a jugal fold. The area containing wing articulation sclerites, pteralia is called axilla.

Wing types:

1. Tegmina : (Singular : Tegmen) Wings are leathery or parchment like. They are protective in function. They are not used for flight. e.g. Forewings of cockroach and grasshopper.

2. Elytra : (Sigular : Elytron) The wing is heavily sclerotised. Wing venation is lost. Wing is tough and it is protective in function. It protects hind wings and abdomen. It is not used during flight. But during flight they are kept at an angle allowing free movement of hind wings. e.g. Fore wings of beetles and weevils.

3. Hemelytra : (Singular : Hemelytron) The basal half of the wing is thick and leathery and distal half is membranous. They are not involved in flight and are protective in function. e.g. Fore wing of heteropteran bugs.

4. Halteres: (Singular : Haltere) In true flies the hind wings are modified into small knobbed vibrating organs called haltere. Each haltere is a slender rod clubbed at the free end (capitellum) and enlarged at the base (scabellum). On the basal part two large group of sensory bodies forming the smaller hick's papillae and the large set of scapel plate. They act as balancing organs and provide the needed stability during flight. e.g. true flies, mosquito, male scale insect.

5. Fringed wings: Wings are usually reduced in size. Wing margins are fringed with long setae. These insects literally swim through the air. e.g. Thrips.

6. Scaly wings: Wings of butterfly and moths are covered with small coloured scales. Scales are unicellular flattened outgrowth of body wall. Scales are inclined to the wing surface and overlap each other to form a complete covering. Scales are responsible for colour. They are important in smoothing the air flow over wings and body.

7. Membranous wings: They are thin, transparent wings and supported by a system of tubular veins. In many insects either forewings (true flies) or hind wings (grass hopper, cockroach, beetles and earwig) or both fore wings and hind wings (wasp, bees, dragonfly and damselfly) are membranous. They are useful in flight.

Wing coupling: Among the insects with two pairs of wings, the wings may work separately as in the dragonflies and damselflies. But in higher pterygote insects, fore and hind wings are coupled together as a unit, so that both pairs move synchronously. By coupling the wings the insects become functionally two winged.

Types of wing coupling

1. **Hamulate** : A row of small hooks is present on the coastal margin of the hind wing which is known as hamuli. These engage the folded posterior edge of fore wing. e.g. bees.

2. **Amplexiform** : It is the simplest form of wing coupling. A linking structure is absent. Coupling is achieved by broad overlapping of adjacent margins. e.g. butterflies.

3. **Frenate** : There are two sub types. e.g. Fruit sucking moth.

i. Male frenate : Hindwing bears near the base of the coastal margin a stout bristle called frenulum which is normally held by a curved process, retinaculum arising from the subcostal vein found on the surface of the forewing.

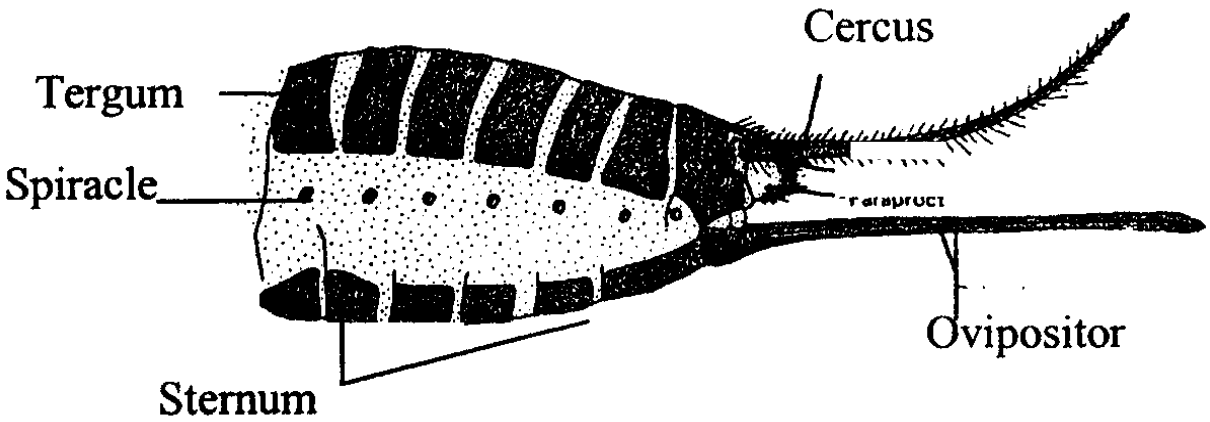
ii. Female frenate : Hindwing bears near the base of the costal margin a group of stout bristle (frenulum) which lies beneath extended forewing and engages there in a retinaculum formed by a patch of hairs near cubitus.

4. **Jugate :** Jugam of the forewings are lobe like and it is locked to the coastalmargin of the hindwings. e.g. Hepialid moths.

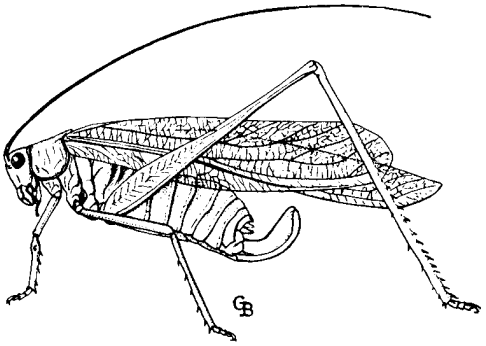
LECTURE 7. **Insect abdomen: structure and its modifications**

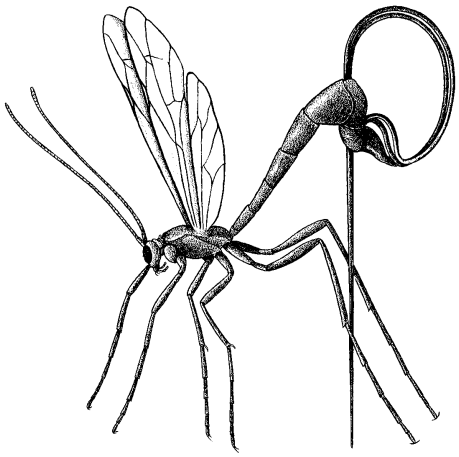
ABDOMEN

The dorsal and ventral abdominal segments are termed terga (singular tergum) and sterna (singular sternum), respectively. Spiracles usually can be found in the conjunctive tissue between the terga and sterna of abdominal segments 1-8. Reproductive structures are located on the 9th segment in males (including the aedeagus, or penis, and often a pair of claspers) and on the 8th and 9th abdominal segments in females (female external genitalia copulatory openings and ovipositor).

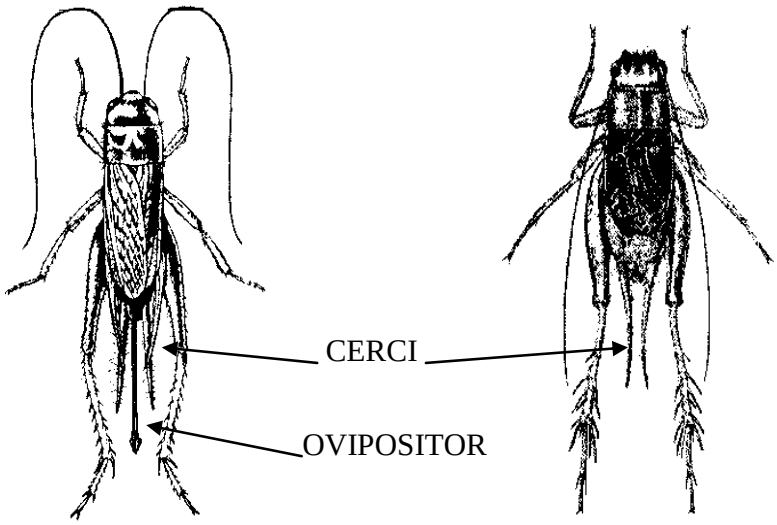


MODIFICATIONS OF THE OVIPOSITOR





SEXUAL DIMORPHISM



Female (note the long ovipositor Between the cerci)

Male (two cerci at the end of the abdomen)

Abdominal structures in insects

Basic structures

Segmentation is more evident in abdomen. The basic number of abdominal segments in insect is eleven plus a telson which bears anus. Abdominal segments are called uromeres. On eighth and nineth segment of female and nineth segment of male, the appendages are modified as external organs of reproduction or genitalia. These segments are known as genital segments. Usually eight pairs of small lateral openings (spiracles) are present on the first eight abdominal segments. In grasshoppers, a pair of tympanum is

found one on either side of the first abdominal segment. It is an auditory organ. It is obliquely placed and connected to the metathoracic ganglia through auditory nerve.

Modifications:

Reduction in number of abdominal segments has taken place in many insects. In spring tail only six segments are present. In house fly only segments 2 to 5 are visible and segments 6 to 9 are telescoped within others. In ants, bees and wasps, the first abdominal segment is fused with the metathorax and is called propodeum. Often the second segment forms a narrow petiole. The rest of the abdomen is called gaster. In queen termite after mating the abdomen becomes gradually swollen due to the enlargement of ovaries. The abdomen becomes bloated and as a result sclerites are eventually isolated as small islands. Obesity of abdomen of queen termite is called physogastry.

Abdominal appendages

i . Pregenital abdominal appendages in wingless insects:

1) **Styli** : (Stylus : Singular) Varying number of paired tube like outgrowths are found on the ventral side of the abdomen of silverfish. These are reduced abdominal legs which help in locomotion.

2). **Collophore or ventral tube or glue peg**: It is located on the ventral side of the first abdominal segment of spring tail. It is cylindrical. It is protruded out by the hydrostatic pressure of haemolymph. It might serve as an organ of adhesion. It aids in water absorption from the substratum and also in respiration.

3). **Retinaculum or tenaculum or catch**: It is present on the ventral side of the third abdominal segment. It is useful to hold the springing organ when not in use.

4). **Furcula or Furca**: This is a 'Y' shaped organ. It is present on the venter of fourth abdominal segment. When it is released from the catch, it exerts a force against the substratum and the insect is propelled in the air.

ii) **Abdominal appendages in immature insects**:

1) **Tracheal gills**: Gills are lateral outgrowths of body wall which are richly supplied with tracheae to obtain oxygen from water in naiads (aquatic immature stages of hemimetabolous insects). Seven pairs of filamentous gills are present in the first seven abdominal segments of naiads of may flyand are called as lateral gills. Three or two leaf like gills (lamellate) are found at the end of adbomen of naiad of damselfly and are called as caudal gills. In dragonfly the gills are retained within the abdomen in a pouch like rectum and are called as rectal gills.

2) **Anal papillae**: A group of four papillae surrounds the anus in mosquito larvae. These papillae are concerned with salt regulation.

3) **Dolichasters**: These structures are found on the abdomen of antlion grub. Each dolichaster is a segmental protuberance fringed with setae.

4) **Proloegs**: These are present in the larvae of moth, butterfly and sawfly. Two to five pairs are normally present. They are unsegmented, thick and fleshy. The tip of the proleg

is called planta upon which are borne heavily sclerotised hooks called crochets. They aid in crawling and clinging to surface.

iii) **Abdominal appendages in winged adults** :

1) **Cornicles**: Aphids have a pair of short tubes known as cornicles or siphonculi projecting from dorsum of fifth or sixth abdominal segment. They permit the escape of waxy fluid which perhaps serves for protection against predators.

2) **Caudal breathing tube**: It consists of two grooved filaments closely applied to each other forming a hollow tube at the apex of abdomen. e.g. water scorpion.

3) **Cerci** : (Cercus - Singular) They are the most conspicuous appendages associated normally with the eleventh abdominal segment. They are sensory in function. They exhibit wide diversity and form.

Long and many segmented :- e.g. Mayfly

Long and unsegmented :- e.g. Cricket

Short and many segmented :- e.g. Cockroach

Short and unsegmented :- e.g. Grasshopper

Sclerotised and forceps like : e.g. Earwig. Cerci are useful in defense, prey capture, unfolding wings and courtship.

Asymmetrical cerci :- Male embiid. Left cercus is longer than right and functions as clasping organ during copulation.

4) **Median caudal filament**: In mayfly (and also in a wingless insect silverfish) the epiproct is elongated into cercus like median caudal filament.

5) **Pygostyles**: A pair of unsegmented cerci like structures are found in the last abdominal segment of scoliid wasp.

6) **Anal styli**: A pair of short unsegmented structure found at the end of the abdomen of male cockroach. They are used to hold the female during copulation.

7) **Ovipositor**: The egg laying organ found in female insect is called ovipositor. It is suited to lay eggs in precise microhabitats. It exhibits wide diversity and form. Short and horny : e.g. Short horned grasshopper

Long and sword like : e.g. Katydid, long horned grasshopper

Needle like : e.g. Cricket

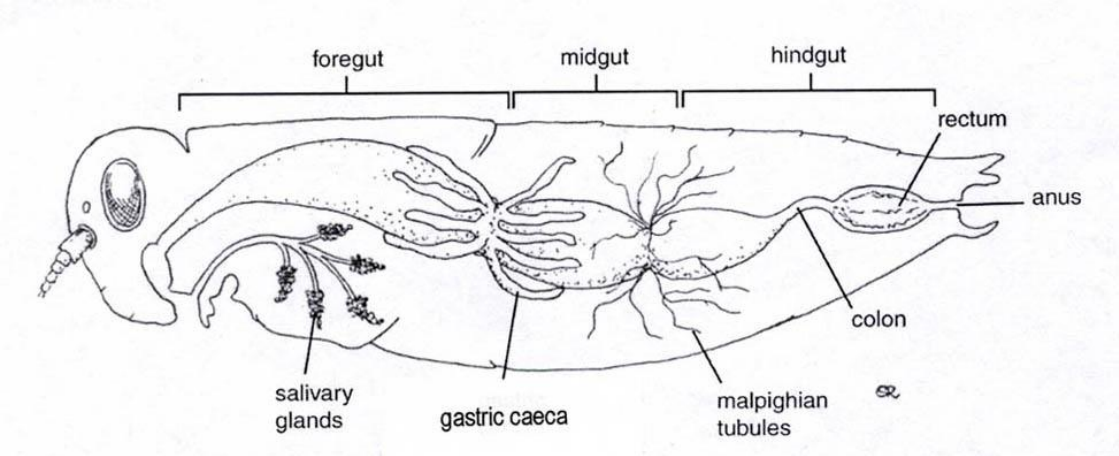
Ovipositor modified into sting : e.g. Worker honey bee.

Pseudoovipositor: An appendicular ovipositor is lacking in fruit flies and house flies. In fruit flies, the elongated abdomen terminates into a sharp point with which the fly pierces the rind of the fruit before depositing the eggs. In the house fly the terminal abdominal segments are telescopic and these telescopic segments aid in oviposition. The ovipositor of house fly is called pseudoovipositor or ovitubus or oviscapt.

Male genitalia: External sexual organs of male insects are confined to ninth abdominal segment. In damselfly, the functional copulatory organ is present on the venter of second abdominal segment

LECTURE 8. Anatomy: Digestive system

Digestive system



The **digestive system** (sometimes referred to as the **alimentary canal**) should be easily seen in the dissected specimens. It is a long tube-like structure that runs from the mouth to the anus and is centrally located within the body cavity, or **hemocoel**. The anterior-most region is called the **foregut** (or **stomodeum**) which includes the Buccal cavity, the esophagus, and the crop. The primary function of the foregut is to begin the breakdown of food particles and transport them to the next region, the **midgut** (or **mesenteron**). The midgut is the major area of digestion and absorption. Undigested food particles then pass into the third region, the **hindgut** (or **proctodeum**), which consists of the ileum, colon, **rectum**, and (often) rectal pads. The hindgut functions in water and solute reabsorption and waste excretion.

The three sections of the digestive tract can be easily identified by structures found at the junction of each region. **Gastric caecae**, for example, mark the end of the foregut and beginning of the midgut. It is believed that the purpose of these structures is to increase surface area for greater nutrient absorption. The constriction at the gastric caecae also marks the spot of the cardiac valve (or sphincter).

The alimentary canal of insects is a long, muscular and tubular structure extending from mouth to anus. It is differentiated into three regions viz., Foregut, midgut and hindgut.

1. **Foregut**: It is ectodermal in origin. Anterior invagination of ectoderm forms foregut (Stomodeum). Internal cuticular lining is present. Terminal mouthparts leads into a preoralcavity. Preoralcavity between epipharynx and hypopharynx is called as Cibarium. Preoralcavity between hypopharynx and salivary duct is Salivarium. Behind the mouth a

well musculated organ called Pharynx is present which pushes the food into oesophagous. Pharynx acts as a sucking pump in sap feeders. Oesophagous is a narrow tube which conduct food into crop. Crop is the dilated distal part of oesophagus acting as food reservoir. In bees crop is called as honey stomach where nectar conversion occurs. Proventriculus or Gizzard is the posterior part of foregut and is musculated. It is found in solid feeders and absent in fluid feeders or sap feeders. Food flow from foregut to midgut is regulated through cardial or oesophageal valve. The internal cuticle of gizzard is variously modified as follows.

i. Teeth like in cockroach to grind and strain food.
ii. Plate like in honey bee to separate pollen grains from nectar
iii.Spine like in flea to break the blood corpuscles

2. **Midgut**: It is endodermal in origin and also called as mesentron. This part contains no cuticular lining. Midgut is made up of three types of epithelial cells. (i) Secretory cells (Columnar cells) (ii) Goblet cells (aged secretory cells), (iii) Regenerative cells which replaces secretory cells. Important structures present in midgut are as follows:

a. **Peritrophic membrane**: It is the internal lining of midgut, secreted by anterior or entire layer of midgut epithelial cells. Present in solid feeders and absent in sap feeders. This layer is semipermeable in nature to digestive juices and digestion products. It lubricate and facilitate food movement. Envelops the food and protects the midgut epithelial cells against harder food particles.
(ii) **Gastric caecae**: (Enteric caecae or Hepatic caecae) Finger like outgrowths found in anterior or posterior ends of midgut. This structure increases the functional area of midgut and shelter symbiotic bacteria in some insects.
(iii) **Pyloric valve**: (Proctodeal valve) Midgut opens into hindgut through pyloric valve, which regulate food flow. In certain immature stages of insects midgut is not connected to hindgut till pupation. e.g. Honey bee grub.

(iv) **Filter chamber**: It is a complex organ in which two ends of ventriculus and the begining of hind gut are enclosed in a sac. This is useful to short circuit excess water found in liquid food in homopteran insects. This process avoids dilution of digestive enzymes and concentrates food for efficient digestion. Also helps in osmoregulation by preventing dilution of haemolymph.

3. **Hindgut**: It is ectodermal in origin and produced by the posterior invagination of ectoderm. Internal cuticular lining is present, which is permeable to salts, ions, aminoacids and water. The main functions of hindgut are the absorption of water, salt and other useful substances from the faeces and urine. Hindgut is differentiated into three regions viz., **ileum, colon and rectum**. In the larva of scarabids and termites, illeum is pouch like for housing symbionts and acts as fermentation chamber. Rectum contains rectal pads helping in dehydration of faeces and it opens out through anus.

Gut physiology: Primary functions of the gut is to digest the ingested food and to absorb the metabolites. Digestion process is enhanced with the help of enzymes produced by digestive glands and microbes housed in special cells.

Digestive glands:

a. **Salivary glands**: In Cockroach a pair of labial glands acts as salivary gland where the salivary ducts open into salivarium. In caterpillars mandibular glands are modified to secrete saliva, where the salivary glands are modified for silk production. Functions of saliva:

1. To moisten and to dissolve food
2. To lubricate mouthparts
3. To add flavour to gustatory receptors
4. In cockroach the saliva contains amylase for the digestion of starch.
5. In honey bee saliva contains invertase for sucrose digestion
6. In Jassid saliva contains lipase and protease for lipids and protein digestion. Jassid saliva also contains toxins which produces tissue necrosis and phytotoxemia on the plant parts.
7. In plant bug saliva contains pectinase which helps in stylet penetration and extra intestinal digestion.
8. In mosquito, saliva contains anticoagulin which prevents blood clotting.
9. In gall producing midges saliva contains Indole Acetic Acid (IAA).
10. In disease transmitting ectors the saliva paves way for the entry of pathogens.

b. **Hepatic caecae and midgut epithelial cells**: It secretes most of the digestive juices. Two types of cells were involved in the enzyme secretion.

Holocrine : Epithelial cells disintegrate in the process of enzyme secretion.

Merocrine : Enzyme secretion occurs without cell break down.

Digestive enzymes

Insect Group	**Enzyme**	**Substrate**
Phytophagous larvae	Amylase	Starch
Maltase		Maltose
Invertase		Sucrose
Omnivorous insects	Protease	Protein
Lipase		Lipid
Nectar feeders	Invertase	Sucrose
Wood boring insects and Termites	Cellulase	Cellulose
Meat eating maggots	Collagenase	Collagen and elastin
Bird lice	Keratinase	Keratin

C. Microbes in digestion: In the insect body few cells were housing symbiotic microorganisms called as mycetocyte. These mycetocytes aggregate to form an organ called mycetome.

(i) Flagellate protozoa - It produces cellulase for cellulose digestion in termites and wood cockroach.

(ii) Bacteria - It helps in wax digestion in wax moth.

(iii) Bed bug and cockroach obtain vitamin and aminoacids from microbes.

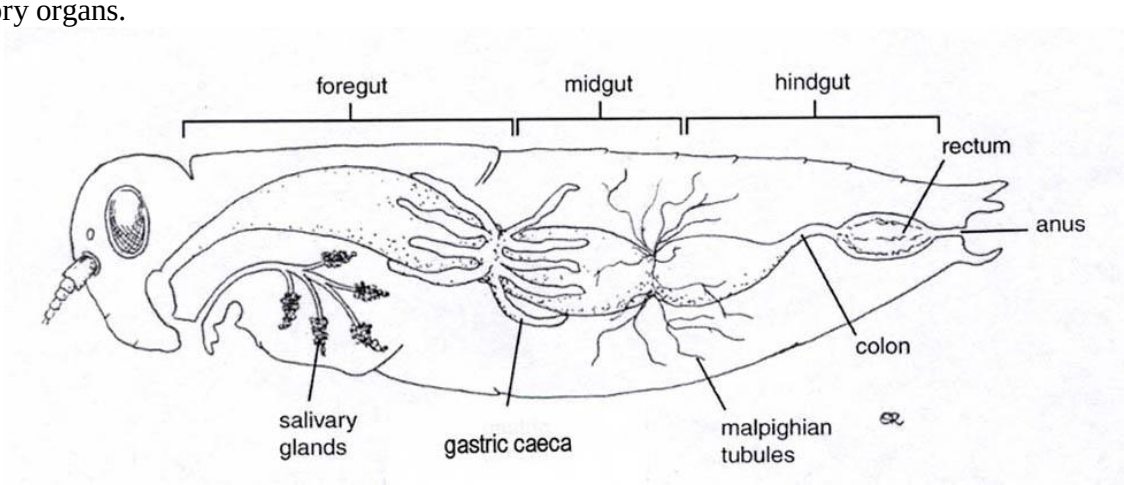
These microbes were transmitted between individuals through food exchange (mouth to mouth feeding) called **trophallaxis** and through egg called as **transovarial** transmission. In plant bug and ant lion grub partial digestion occurs in the host body prior to food ingestion called as extra intestinal digestion. In most of the insects digestion occurs in mid gut.

Absorption: In many insects absorption of nutrients occurs through microvilli of midgut epithelial cells by diffusion. Absorption of water and ions occur through rectum. In cockroach lipid absorption occurs through crop. In termites and scarabaeids (White grubs) absorption occurs through ileum. In solid feeders, resorption of water from the faeces occurs in the rectum and the faeces is expelled as pellets. In sap feeders (liquid feeders) the faeces is liquid like. The liquid faeces of homopteran bugs (aphids, mealy bugs, Scales and psyllids) with soluble sugars and amino acids is known as honey dew, which attracts ants for feeding.

LECTURE 9. Anatomy: Excretory system

Excretory system

Removal of waste products of metabolism, especially nitrogenous compounds from the body of insects is known as excretion. The excretion process helps the insect to maintain salt water balance and thereby physiological homeostasis. Following are the excretory organs.



Near the junction of the midgut and hindgut are long, thin structures called **Malpighian tubules**. These range in number from a few to hundreds, but only aphids (Order Homoptera) are currently known to have none. Malpighian tubules are creamy to yellow in color and work in conjunction with the ileum to provide the primary site for osmoregulation and excretion.

1. **Malpighian tubules**: Thin, blind-ending tubules, originating near the junction of mid and hindgut, predominantly involved in regulation of salt, water and nitrogenous waste excretion. This structure was discovered by Marcello Malpighi.

2. **Nephrocytes**: Cells that sieve the haemolmph for products that they metabolize (pericardial cells).

3. **Fat bodies** : A loose or compact aggregation of cells, mostly trophocytes, suspended in the haemocoel, responsible for storage and excretion.

4. **Oenocytes**: These are specialised cells of haemocoel, epidermis or fat body with many functions. One of the function is excretion.

5. **Integument**: The outer covering of the living tissues of an insect.

6. **Tracheal system**: The insect gas exchange system, comprising tracheae and tracheoles.

7. **Rectum**: The posterior part of hind gut.

Among the above organs, malpighian tubules are the major organ of excretion.

Excretion and Osmoregulation: Insect faeces, either in liquid form or solid pellets, contains both undigested food and metabolic excretions. Aquatic insects excrete dilute wastes from their anus directly into water by flushing with water. But, Terrestrial insects must conserve water. This requires efficient waste disposal in a concentrated or even dry form, simultaneously avoiding the toxic effects of nitrogen. Both terrestrial and aquatic insects must conserve ions, such as sodium (Na^+), potassium (K^+) and chloride (Cl^-), that may be limiting in their food or lost into the water by diffusion. Therefore the production of insect excreta (urine or pellets) is a result of two related processes: excretion and osmoregulation (maintenance of favourable osmotic pressure and ionic concentration of body fluid). The system responsible for excretion and osmoregulation is referred to as excretory system and its activities are performed largely by the Malpighian tubules and hindgut. However in fresh water insects, haemolymph composition is regulated in response to loss of ions to the surrounding water, with the help of excretory system and special cells. Special cells are called Chloride cells which are present in the hindgut, capable of absorbing inorganic ions from the dilute solutions. (e.g. Naids of dragonflies and damselflies).

Malpighian Tubules: The main organ of excretion and osmoregulation in insects are the malpighian tubules, acting in association with rectum or ileum. Malpighian tubules are outgrowths of the alimentary canal and consist of long thin tubules formed of a single layer of cells surrounding a blind-ending lumen, they are absent in spring tail and aphids, 2 numbers in scale insects, 4 in bugs, 5 in mosquitoes, 6 in moths and butterflies, 60 in cockroach and more than 200 in locusts. Generally they are free, waving around in the haemolymph where they filter out solutes. Each tubule is externally covered by peritonial coat and supplied with muscle fibres (aiding in peristalsis) and tracheloes. Functional differentiation of the tubules was seen, with the distal secretory region and proximal absorptive region.

Physiology: The malpighian tubules produce a filtrate (the primary urine) which is isosmotic but ionically dissimilar to the haemolymph and selectively reabsorbs water and certain solutes, but eliminates others. The malpighian tubules produces an iosmotic filtrate which is high in K^+ and low in Na^+ with Cl^- as major anion. The active transport of ions especially K^+ into the tubule lumen generates an osmotic pressure gradiant for the passive flow of water.

Sugars and most amino acids are also passively filtered from the haemolymph via junctions between the tubule cells, where as amino acids and non-metabolizables and toxic organic compounds are actively transported into the tubule lumen. Sugar is resorbed from the lumen and returned to the haemolymph. The continuous secretory activity of each malpighian tubule leads to a flow of primary urine from its lumen towards and into the gut. In the rectum, the urine is modified by removal of solutes and water to maintain fluid and ionic homeostasis of the body.

Nitrogenous excretion: Terrestrial insects excrete waste products as uric acid or certain of its salts called urates, which were water insoluble and requires less amount of water for

waste product removal. This type of excretion is known as **Uricotelism**. In aquatic insects ammonia is the excretory product, which is freely soluble in water and requires more amount of water for waste product removal. This type of excretion is known as **Ammonotelism**.

Cryptonephry: The distal ends of the Malpighian tubules are held in contact with the rectal wall by the perinephric membrane, which is concerned either with efficient dehydration of faeces before their elimination or ionic regulation. (e.g. Adult Coleptera, larval Lepidoptera and larval symphyta).

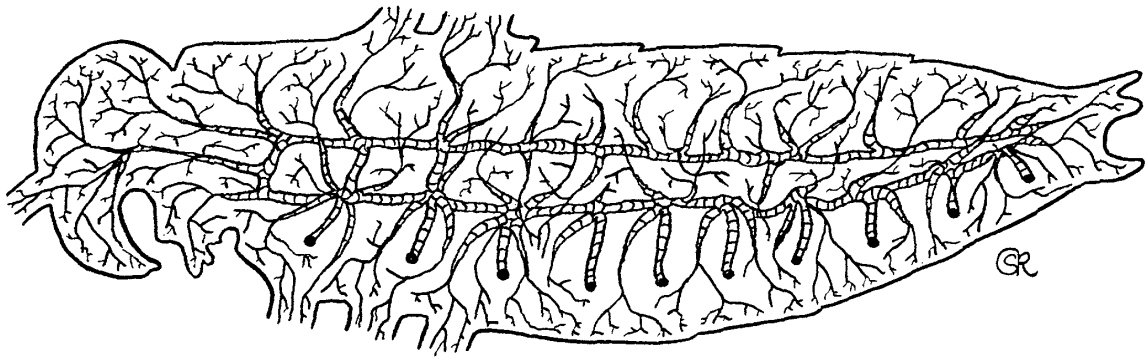
Functions of malphighian tubule: Excretory in function, mainly concerned with removal of nitrogenous wastes. The other accessory functions are as follows:
1. Spittle secretion in spittle bug
2. Light production in Bolitophila
3. Silk production in larval neuroptera

Storage Excretion: The excretory waste materials are retained within the body in different sites.
i. Uric acid is stored as urates in the cells of **fat body** e.g., American cockroach.
ii. Uric acid is stored in the **body wall**, giving white colour. e.g. Red cotton bug.
iii. Uric acid is stored in the **male accessory glands** to produce the outer coat of spermatophore, which is excreted during copulation.
iv. Uric acid is stored in the **wing scales** giving white colour. e.g., Pierid butterflies.
v. Waste products of pupal metabolism (**Meconium**) is stored and released during adult emergence.

LECTURE 10. Anatomy: Respiratory system

Respiratory System

The insect respiratory system is made up of a series of tubes that originate from **spiracles** (openings of the exoskeleton that allow for gas exchange) and extend throughout the body. Internally, the tubes, or **trachea**, appear as thin white lines throughout the hemocoel and are particularly noticeable surrounding internal organs. Trachea deliver oxygen to internal organs and tissues.



Compare the tracheae with the Malpighian tubules. They are often very similar in appearance. Did you confuse tracheae with Malpighian tubules earlier?

Two ways to distinguish the structures are color and location. Tracheae have a 'shinier' appearance under the scope and may even appear 'silvery'. As for location, Malpighian tubules are found at the junction of the midgut and hindgut (although they may extend outward into the hemocoel), whereas tracheae are positioned throughout the body.

Respiratory system

Similar to aerobic animals, insects must obtain oxygen from their environment and eliminate carbon dioxide respired by their cells. This is gas exchange through series of gas filled tubes providing surface area for gaseous exchange (Respiration strictly refers to oxygen-consuming, cellular metabolic processes). Air is supplied directly to the tissue and haemolymph (blood) is not involved in the respiratory role. Gas exchange occurs by means of internal air-filled tracheae. These tubes branch and ramify through the body. The finest branches called tracheole contact all internal organs and tissues and are

numerous in tissues with high oxygen requirements. Air usually enters the tracheae via spiracular openings positioned laterally on the body. No insect has more than ten pairs (two thoracic and eight abdominal).

Based on the number and location of functional spiracles respiratory system is classified as follows

1. Holopneustic:10 pairs, 2 in thorax and 8 in abdomen. e.g. grasshopper

2. Hemipneustic: Out of 10 pairs, one or two non-functional

3. Peripneustic: 9 pairs - 1 in thorax 8 in abdomen e.g. Caterpillar

4. Amphipneustic 2 pairs - One anterior, one posterior, e.g. maggot.

5. Propneustic: 1 pair -anterior pair e.g. Puparium

6. Metapneustic: 1 pair - posterior pair e.g.Wriggler

7. Hypopneustic:10 pairs - 7 functional (1 thorax + 6 abdominal), 3 non functional. e.g. head louse

8. Apneustic: All spiracles closed, closed tracheal system e.g. naiad of may fly.

Organs of respiration

Spiracles: Spiracles have a chamber or **atrium** with a opening and closing mechanism called **atrial valve**. This regulate air passage and minimise water loss. Each spiracle is set in a sclerotized cuticular plate called a **peritreme**. **Tracheae** are invaginations of the epidermis and thus their lining is continuous with the body cuticle. The ringed appearance of the tracheae is due to the spiral ridges called **taenidia**. This allow the tracheae to be flexible but resist compression. The cuticular linings of the tracheae are shed during moulting.

Tracheoles are less than 1 μm in diameter and they end blindly and closely contact the respiring tissues. Taenidia and waxlayer is absent. Cuticulin layer is permeable to gases. It is intracellular in nature, but enclosed only in the cytoplasm of tracheal and cell called tracheoblast. Gaseous exchange occurs across tracheoles. There are four tracheal trunks viz., lateral, dorsal, ventral and visceral, helping in the passage of air. In the trachea, thin walled-collapsable sac like dilations are present, called as airsacs where taenidia is absent. **Airsacs** acts as oxygen reservoir. Provide buoyancy to flying and aquatic insects. Provide space for growing organs. Acts as sound resonator and heat insulators.

Mechanism of respiration

Oxygen enters the spiracle and passes through the length of the tracheae to the tracheoles and into the target cells by a combination of ventilation and diffusion along a concentration gradient, from high in the external air to low in the tissue. Where as the net movement of oxygen molecules in the tracheal system is inward (Inspiration), the net movement of CO_2 and water vapour molecules is outward (Expiration).

Respiration in aquatic insects:

1.**Closed tracheal system**: In some aquatic and many endoparasitic larvae spiracles are absent and the tracheae divide peripherally to form a network. This covers the body surface, allowing cutaneous gas exchange. e.g. **Gills** : Tracheated thin outgrowth of body wall.

Lamellate gills - mayfly naiad
Filamentous gills - damselfly naiad
Rectal gills - dragonfly naiad

2. **Open tracheal system**:

i. **Air store**: Air bubble stored beneath wings acts as physical gill, e.g. water bug.

ii.**Respiratory siphon** - e.g. Wriggler

iii.**Caudal breathing tube** -e.g. Water scorpion

iv. **Plastron** : Closely set hydrofuge hairs of epicuticle hold a thin film of air indefinitely.

LECTURE 11. Anatomy: Circulatory system

Circulatory system

Unlike the "closed" circulatory system of humans, insect circulatory systems are said to be "open", meaning that they lack a complex network of veins and arteries to help transport blood throughout the body. Instead, insect blood (called **hemolymph**) flows relatively "freely" throughout the hemocoel.

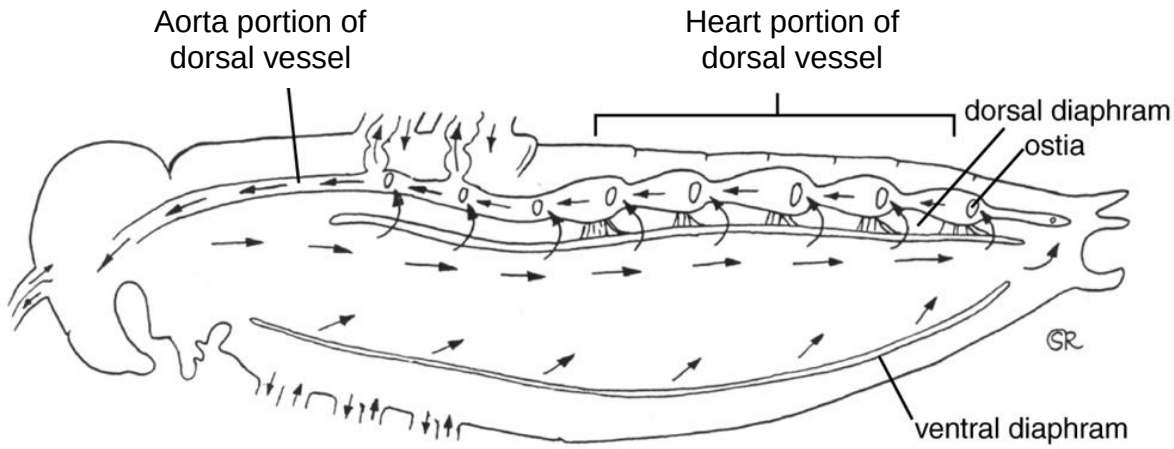


Figure 8-2. Circulatory system. Arrows indicate direction of flow of hemolymph.

Only one vessel is present in the insect circulatory system: the **dorsal vessel**. Posteriorly (in the abdominal region), the dorsal vessel acts as the **heart**, pumping hemolymph forward into the anterior region (in the head and thorax), where it acts as the **aorta** and dumps the hemolymph into the head. It flows posteriorly and is returned to the heart via **ostia**, which are small slits in the heart region of the dorsal vessel designed for hemolymph uptake.

To view the dorsal vessel, examine the "back" (or dorsal region) of the insect's body cavity for a very thin line that runs longitudinally from the head to the tip of the abdomen. Use the grasshopper or specimen that was ventrally dissected, as dorsal dissections will likely mutilate the vessel. Do not be discouraged if you have trouble finding it on your specimen. The dorsal vessel is very, very thin. Compare your specimen to those of your classmates.

Circulatory system in insects

Circulation in insects is maintained by a system of muscular pumps moving haemolymph through compartments separated by fibromuscular septa or membranes. The main pump is the pulsatile dorsal vessel. The anterior part may be called **aorta** and the posterior part the **heart**. The dorsal vessel is a simple tube, generally composed of one layer of myocardial cells and with segmentally arranged openings called **ostia**. The ostia permit the one-way flow of haemolymph into the dorsal vessel due to valves that prevent backflow. There may be up to three pairs of thoracic ostia and nine pairs of abdominal ostia. The dorsal vessel lies in the **pericardial sinus**, a compartment above a dorsal diaphragm (a fibromuscular septum - a separating membrane) formed of connective tissue and segmental pairs of alary muscles. The alary muscles support the dorsal vessel but their contractions do not affect heartbeat.

Haemolymph enters the periocardial sinus via segmental openings in the diaphragm and then moves into the dorsal vessel via the ostia during a muscular relaxation phase. Waves of contraction start at the posterior end of the body, pump the haemolymph forward in the dorsal vessel and out via the aorta into the head. Next the appendages of the head and thorax are supplied with haemolymph as it circulates posteroventrally and finally returns to the pericardial sinus and dorsal vessel.

Another important component of the insect circulatory system is the **ventral diaphragm**, a fibromuscular septum that lies in the floor of the body cavity associated with the ventral nerve cord. Circulation of the haemolymph is aided by active peristaltic contractions of the ventral diaphragm which direct the haemolymph backwards and laterally in the **perineural sinus** below the diaphragm. These movements are important in insects that use the circulation in thermoregulation. Ventral diaphragm also facilitates rapid exchange of chemicals between the ventral nerve cord and the haemolymph.

Haemolymph is generally circulated to appendages unidirectionaly by various tubes, septa, valves and pumps. The muscular pumps are termed **accessory pulsatile organs** and occur at the base of the antennae and legs. Antennal pulsatile organs releases neurohormones that are carried to the antennal

lumen to influence the sensory neurones. Circulation occurs in the wings of young adult. In wing circulation is sustained by influxes of air into the wing veins, rather than any pulsatile organs. Pulses of air in the fine tracheal tubes of the veins push the haemolymph through the enclosed space of the veins.

The insect circulatory system shows high degree of co-ordination between dorsal vessel, fibro-muscular diaphragms and accessory pumps.

Haemolymph and its functions

Haemolymph is a watery fluid containing ions, molecules and cells. It is often clear and colourless but may be variously pigmented or rarely red due to haemoglobin in the immature stages of few aquatic and endoparasitic flies (e.g., Chironomid larva). Haemolymph performs the function of both blood and lymph. It is not involved in gas transporting function (respiration). Haemolymph contains a fluid portion called plasma and cellular fractions called haemocytes.

1.**Plasma**: Plasma is an aqueous solution of inorganic ions, lipids, sugars (mainly trehalose), amino acids, proteins, organic acids and other compounds. pH is usually acidic (6.7). Density is 1.01 to 1.06. Water content is 84-92 per cent. Inorganic ions present are `Na' in predators and parasites, `Mg' and `K'in phytophagous insects. Carbohydrate is in the form of trehalose sugar. Major proteins are lipoproteins, glycoproteins and enzymes. Lipids in form of fat particles or lipoproteins. Higher concentration of amino acids leads to a condition called aminoacidemia which effects the osmosis process. In high altitude insects glycerol is present which acts as a anti freezing compound. Nitrogenous waste is present in the form of uric acid.

2. **Haemocytes**: The blood cells or haemocytes are of several types and all are nucleate. Different types of haemocytes are as follows:

a. Prohaemocyte : Smallest of all cells with largest nucleus.
b. Plasmatocyte (Phagocyte) aids in phagocytocis
c. Granular heamocyte: Contains large number of cytoplasmic inclusions
d. Spherule cell: Cytoplasmic inclusions obscure the nucleus
e. Cystocyte(Coagulocyte): Role in blood coagulation and plasma precipitation.

f. Oenocytoids: Large cells with ecentric nucleus
g. Adipo haemocytes: Round or avoid with distinct fat droplets
h. Podocyte: Large flattened cells with number of protoplasmic projections.
i. Vermiform cells: Rare type, long thread like.

Functions of haemolymph

1. **Lubricant** : Haemolymph keeps the internal cells moist and the movement of internal organs is also made easy.

2. **Hydraulic medium** : Hydrostatic pressure developed due to blood pumping is useful in the following processes.

a) Ecdysis (moulting)

b) Wing expansion in adults

c) Ecolosion in diptera (adult emergence from the puparium using ptilinum)

d) Eversion of penis in male insects

e) Eversion of osmeteria in papilionid larvae

f) Eversion of mask in naiad of dragonfly

g) Maintenance of body shape in soft bodied caterpillars.

3.**Transport and storage** : Digested nutrients, hormones and gases (chironomid larva) were transported with the help of haemolymph. It also removes the waste materials to the excretory organs. Water and raw materials required for histogenesis is stored in haemolymph.

4.**Protection**: It helps in phagocytocis, encapsulation, detoxification, coagulation, and wound healing. Non celluar component like lysozymes also kill the invading bacteria.

5. **Heat transfer**: Haemolymph through its movement in the circulatory system regulate the body heat (Thermoregulation).

6. **Maintenance of osmotic pressure**: Ions, amino acids and organic acids present in the haemolymph helps in maintaining osmotic pressure required for normal physiological functions.

7. **Reflex bleeding**: Exudation of heamolymph through slit, pore etc. repels natural enemies. e.g. Aphids.

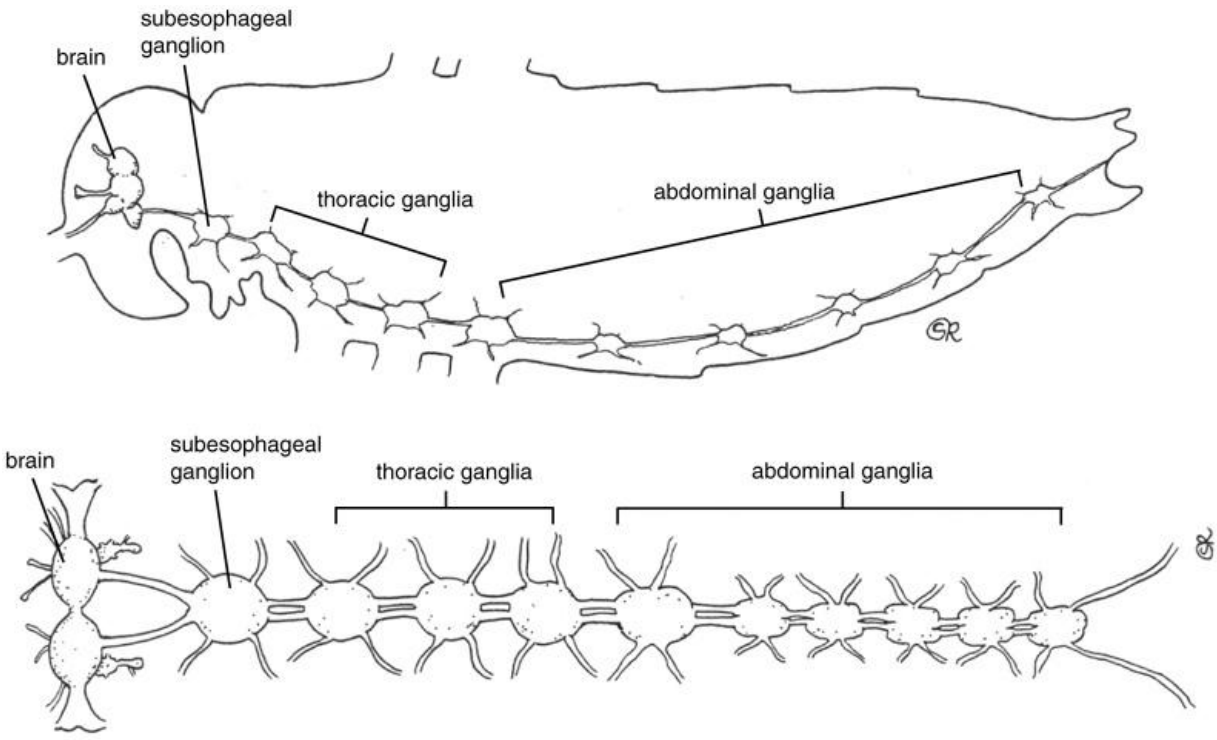
8. **Metabolic medium:** Haemolymph serves as a medium for on going metabolic reactions (trahalose is converted into glucose).

LECTURE 12. Anatomy: Nervous system

Nervous System

To view the **ventral nerve cord**, examine the ventral region of the roach's body cavity (or specimen you performed the dorsal dissection on) for something that resembles a railroad track running from the head posteriorly to the abdominal region. The "railroad track" is made up of two nerve cords (**connectives**) that run longitudinally with a series of node-like **ganglia**.

The anterior most region of the ventral nerve cord is called the **subesophageal ganglion**. Just dorsal to that structure is the insect "brain" (or **supraesophageal ganglion**).



The basic component in the nervous system is the nerve cell or neuron, composed of a cell body with two projections (fibers) the dendrites that receive stimuli and the axon that transmits information, either to another neuron or to an effector organ such as a muscle. Axon may have lateral branches called Collateral and terminal arborization and synapse. Insect neurons release a variety of chemicals at synapses either to stimulate or to inhibit effector neurons or muscles. Acetylcholine and catecholamines such as dopamine are the important neurotransmitters involved in the impulse conduction. Neurons are of following types based on structure and function.

A. On structural basis

i. Monopolar: neuron with a single axon
ii. Bipolar: neuron with a proximal axon and a long distal dendrite.
iii. Multipolar: neuron with a proximal axon and many distal dendrites.

B. Functional basis

i. Sensory neuron: It conducts impulse from sense organs to central nervous system (CNS).
ii. Motor neuron: It conducts impulse from CNS to effector organs
iii. Inter neuron (association neuron): It inter-links sensory and motor neurons.

The cell bodies of inter neurons and motor neurons are aggregated with the fibers inter connecting all types of nerve cells to form nerve centers called **ganglia.**

Mechanism of impulse conduction: Impulses are conducted by the neurons by two means.

Axonic conduction: Ionic composition varies between inside and outside of axon resulting in excitable conditions, which leads to impulse conduction as electrical response.

Synaptic conduction: Neurochemical transmitters are involved in the impulse conduction through the synaptic gap. Neurotransmitters and the type of reactions helping in the impulse conduction are as follows.

Nervous system can be divided in to three major sub-systems as

i. Central nervous system (CNS)

ii. Visceral nervous system (VNS)

iii. Peripheral nervous system (PNS)

i. Central nervous system: It contains double series of nerve centers (ganglia). These ganglia are connected by longitudinal tracts of nerve fibers called **connectives** and transverse tracts of nerve fibers called **commissures**. Central nervous system includes the following.

a. **Brain**: Formed by the fusion of first three cephalic neuromeres.

Protocerebrum: Large, innervate compound eyes and ocelli.

Deutocerebrum: Found beneath protocerebrum, innervate antennae.

Tritocerebrum: Bilobed, innervate labrum.

Brain is the main sensory centre controlling insect behaviour.

b. **Ventral nerve cord**: Median chain of segmental ganglia beneath oesophagus.

c. **Sub esophageal ganglia**: Formed by the last three cephalic neuromeres which innervate mandible, maxillae and labium.

d. **Thoracic ganglia**: Three pairs found in the respective thoracic segments, largest ganglia, innervate legs and muscles.

e. **Abdominal ganglia**: Maximum eight pairs will present and number varies due to fusion of ganglia. Innervate spiracles.

f. **Thoraco abdominal ganglia** : Thoracic and abdominal ganglia are fused to form a single compound ganglia. Innervate genital organs and cerci.

ii. Visceral nervous system: The visceral (sympathetic) nervous system consists of three separate systems as follows: (1) the stomodeal/stomatogastric which includes the frontal ganglion and associated with the brain, aorta and foregut; (2) Ventral visceral, associated with the ventral nerve cord; and (3) Caudal visceral, associated with the posterior segments of abdomen. Together the nerves and

$$\text{Acetyl CO-A} + \text{Choline chloride} \xrightarrow{\text{Acetylase}} \text{Acetyl choline}$$

$$\text{Acetyl choline} \xrightarrow{\text{Acetyl Choline Esterase}} \text{Choline} + \text{Acetic acid}$$

ganglia of these subsystems innervate the anterior and posterior gut, several endocrine organs (Corpora cardiaca and Corpora allata), the reproductive organs, and the tracheal system including the spiracles.

iii. Peripheral nervous system: The peripheral nervous system consists of all the motor neuron axons that radiate to the muscles from the ganglia of the CNS and visceral nervous system plus the sensory neurons of the cuticular sensory structures (the sense organs) that receive mechanical, chemical, thermal or visual stimuli from an environment.

LECTURE 13. Anatomy: Reproductive system

Reproductive System

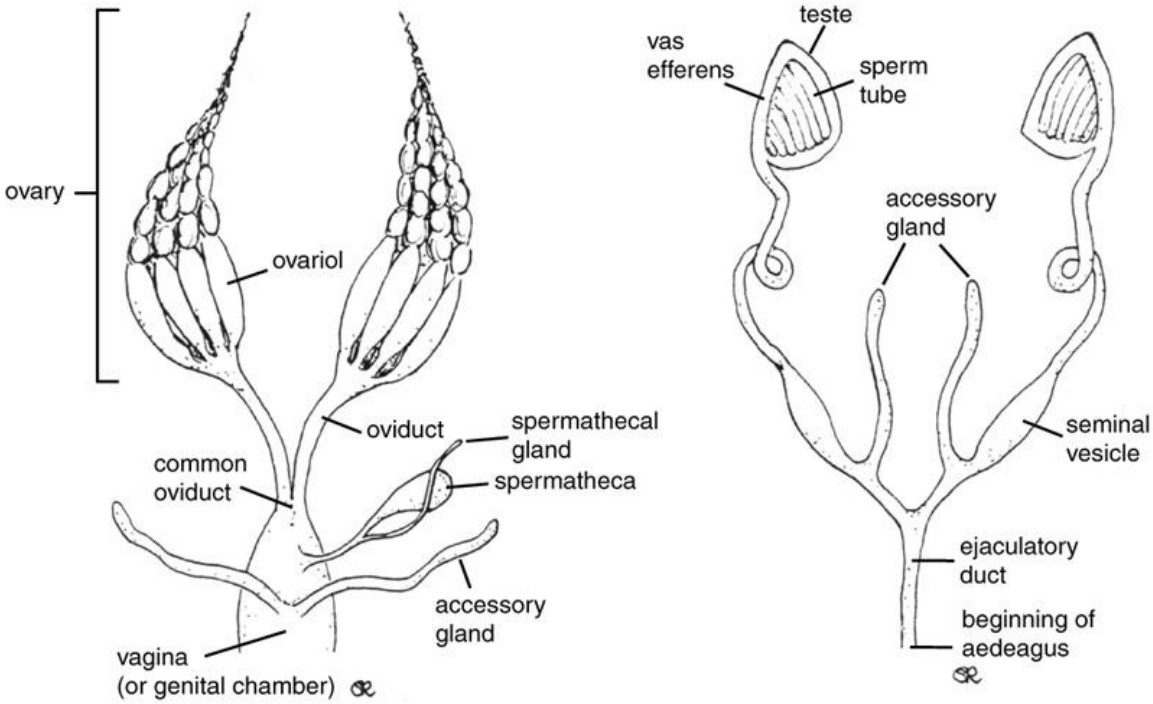
It is important to note here that variation among insect reproductive systems is great. Closely related species are often isolated from one another via small variations in the morphology of reproductive organs that prohibit interspecies mating. However, a generalized system can be constructed that closely represents all sexually reproducing insects. Do not be alarmed if you are unable to locate the indicated structures on your dissected specimens. Be familiar with differences in male and female genitalia and be able to identify structures when given a diagram. Directions are provided if you wish to attempt seeing the reproductive system of your specimen.

The Female Reproductive System

Remove the digestive tract from your female specimen by cutting it with a scalpel at the posterior- and anterior-most regions. Place digestive tract to the side. If necessary, remove muscle tissue, as well, until the **ovaries**, **lateral oviducts**, **median oviduct**, **seminal receptacle** and **vagina** are visible. Compare your specimen with the figures below. Then observe classmates' specimens.

The Male Reproductive System

Remove the digestive tract from your male specimen by cutting it with a scalpel at the posterior- and anterior-most regions. Place digestive tract to the side. If necessary, remove muscle tissue, as well, until the **testes**, **vas deferens**, **seminal vesicle**, **accessory glands**, and **ejaculatory duct** are visible. Compare your specimen with the figures below. Then observe classmates' specimens



In insects male and female sexes are mostly separate. Sexual dimorphism is common where the male differ from the female morphologically as in bees, mosquito and cockroach. The other types are:

Gynandromorph: (Sexual mosaic) Abnormal individual with secondary sexual characters of both male and female. e.g. mutant Drosophila.

Hermaphrodite: Male and female gonads are present in one organism. e.g. Cottony cushion scale.

Female reproductive system

The main functions of the female reproductive system are egg production and storage of male's spermatozoa until the eggs are ready to be fertilized. The basic components of the female system are paired **ovaries**, which empty their mature oocytes (eggs) via the calyces (Calyx) into the lateral **oviduct** which unite to form the common (median) oviduct. The **gonopore** (opening) of the common oviduct is usually concealed in an inflection of the body wall that typically forms a cavity, the **genital chamber**. This chamber serves as a copulatory pouch during mating and thus is often known as the **bursa copulatrix**. Its external opening is the vulva. In many insects the vulva is narrow and the genital chamber becomes an enclosed pouch or tube referred to as the **vagina**.

Two types of ectodermal glands open into the genital chamber. The first is the **spermatheca** which stores spermatoza until they are needed for egg fertilization. The

spermatheca is single and sac-like with a slender duct, and often has a diverticulum that forms a tubular spermathecal gland. The gland or glandular cells within the storage part of the spermatheca provide nourishment to the contained spermatozoa.

The second type of ectodermal gland, known collectively as **accessory glands**, opens more posteriorly in the genital chamber. Each ovary is composed of a cluster of egg or ovarian tubes, the **ovarioles**, each consisting of a terminal filament, a germarium (in which mitosis gives rise to primary oocytes), a vitellarium (in which oocytes grow by deposition of yolk in a process known as **vitellogenesis**) and a pedicel. An ovariole contain a series of developing oocytes each surrounded by a layer of follicle cells forming an epithelium (the oocyte with its epithelium is termed a **follicle**), the youngest oocyte occur near the apical germarium and the most mature near the pedicel. There are different types of ovarioless based on the presence or absence of specialized nutritive cells called trophocytes / nurse cells for nourishment of oocytes.

Paniostic ovariole: Lacks specialized nutritive cells so that it contains only a string of follicles, with the oocytes obtaining nutrients from the haemolymph via the follicular epithelium. e.g. Cockroach.

Telotrophic ovariole: (Acrotrophic) The trophocyte is present and its location is confined to the germarium and remain connected to the oocytes by cytoplasmic strands as the oocytes move down the ovariole. eg. bugs.

Polytrophic ovariole: A number of trophocytes are connected to each oocyte and trophocytes moves down along with the ovariole, providing nutrients until depleted. Thus individual oocytes are alternated with groups of smaller trophocytes in the ovarioles. e.g. moths and flies.

Accessory glands of the female reproductive tract are often called as **colleterial or cement glands**, because their secretions surround and protect the eggs or cement them to the substrate. e.g. egg case production in mantis, ootheca formation in cockroach, venom production in bees.

Male reproductive system

The main functions of the male reproductive system are the production and storage of spermatozoa and their transport in a viable state to the reproductive tract of the female. Morphologically, the male tract consists of paired **testes**, each containing a series of **testicular tubes or follicles** (in which spermatozoa are produced) which open separately into the **sperm duct or vas deferens.** This vas deferens expands posteriorly to form a sperm storage organ or **seminal vesicle**. Tubular paired **accessory glands** are formed as diverticula of the vasa deferentia. Some times the vasa deferentia themselves are glandular and fulfil the functions of accessory glands. The paired vasa deferentia unite where they lead into **ejaculatory duct** (the tube that transports the semen or the

sperm to the gonopore). Accessory glands are 1-3 pairs associated with vasa deferentia or ejaculatory duct. Its function is to produce seminal fluid and **spermatophores** (sperm containing capsule).

Physiology of reproduction

Spermatogenesis	**Oogenesis**
(occurs inside sperm tube)	(occurs inside egg tube)
Spermatogonia	Oogonia
Mitosis	Mitosis
Primary Spermatocytes (2n)	Primary oocytes (2n)
Meiosis	Meiosis
Secondary Spermatocytes (n)	Secondary oocytes (n)
Mitosis	Mitosis
Spermatids (n)	Oocytes (n)
Spermiogenesis	Vitellogenesis
Sperms (n)	Ovum (n)

3. Sperm transfer:

(i) Intragenital: Common method, through, aedeagus via vaginal orifice into female genital passage.

(ii) Haemocoelous : Sperms transfered into the body cavity e.g. Bed bug.

(iii) External: Spermatophores are ejected out into open place by male while female walk over it and gets inseminated e.g. Silver fish.

4. Fertilization: Sperm enter into egg to produce morphogenesis. Egg nucleus divides meiotically into female gamete nucleus and polar body. Then the fertilization occurs by the fusion of male and female gamete nuclei.

Types of reproduction

1. **Oviparity**: Majority of female insects, are oviparous, lay eggs. Embryonic development occurs after oviposition by utilizing the yolk, e.g.Head louse, moths.

2. **Viviparity**: Unlike oviparous, here initiation of egg development takes place within the mother. The life cycle is shortened by retention of eggs and even developing young within the mother. Four main types of viviparity are observed in different insect groups.

i. **Ovoviviparity**: Fertilized eggs containing yolk are incubated inside the reproductive tract of the female and hatching of egg occur just prior to or soon after oviposition e.g. Thrips, some cockroaches, few beetles, and flesh fly. Fecundity of this group is low.

ii. **Pseudoplacental viviparity**: This occurs when a yolk deficient egg develops in the genital tract of the female. The mother provides a special placenta-like tissue, through which nutrients are transferred to developing embryos. There is no oral feeding and larvae are laid upon hatching. e.g. aphids, some earwigs, psocids and polytenid bugs.

iii. **Haemocoelous viviparity**: This involves embryos developing free in the female's haemolymph with nutrients taken up by osmosis. This form of internal parasitism occurs only in sterpsiptera and some gall midges.

iv. **Adenotrophic viviparity**: This occurs when a poorly developed larva hatches and feeds orally from accessory gland (milk gland) secretion within the uterus of the mother. The full grown larva is deposited and pupates immediately (e.g.) Tsetse flies, louse, ked, bat flies.

3.**Parthenogenesis** : Reproduction without fertilization is parthenogenesis. Different types of parthenogenesis are as follows:

a. **Based on occurrence**

i. Facultative (not compulsory) e.g. bee.

ii. Obligatory or constant (compulsory) e.g. stick insect

iii. Cyclic/ sporadic: alternation of gamic and agamic population. e.g.aphid.

b. **Based on sex produced**:

i. Arrhenotoky: Produce male e.g. bee

ii. Thelytoky: produce female e.g. aphids

iii. Amphitoky / deuterotoky: produce both male and female e.g. Cynipid wasp.

c. **Based on meiosis**:

i. Apomictic : no meiosis occurs

ii. Automictic : meiosis occurs, but diploidy is maintained

4. **Polyembryony**: This form of asexual reproduction involves the production of two or more embryos from one egg by subdivision. Mostly observed in parasitic insects (e.g. *Platygaster*). Nutrition for a large number of developing embryo cannot be supplied by the original egg and is acquired from the host's haemolymph through a specialized enveloping membrane called **trophamnion.**

5. **Paedogenesis**: Some insects cut short their life cycles by loss of adult and pupal stages. In this precocious stage gonads develop and give birth to young one by parthenogenesis ie. reproduction by immature insects.

i. Larval paedogenesis - e.g. Gall midges

ii. Pupal paedogenesis – eg. *Miaster* sp.

Sense organs

Sensilla are the organs associated with sensory perception and develop from epidermal cells. The different types of sense organs are:

1. Mechanoreceptors
2. Auditory receptors
3. Chemoreceptors
4. Thermo receptors and
5. Photo receptors.

1. Mechano receptors (detect mechanical forces)

i. **Trichoid sensilla**: Hair like little sense organ. Sense cell associated with spur and seta. These cells are sensitive to touch and are located in antenna and trophi (mouth parts).

ii. **Campaniform sensilla** (Dome sensilla): Terminal end of these sensilla is rod like and inserted into dome shaped cuticula. These cells are sensitive to pressure and located in leg joints and wing bases.

iii. **Chordotonal organ**: The specialized sensory organs that receive vibrations are subcuticular mechano receptors called chordotonal organ. An organ consists of one to many scolopidia, each of which consists of cap cell, scolopale cell and dendrite. These organs are interoceptors attached to both ends of body wall.

Functions :

i. Proprioception (positioning of their body parts in relation to the gravity).

ii. Sensitive to sound waves, vibration of substratum and pressure changes.

iii. Johnston's organ: All adults insects and many larvae have a complex chordotonal organ called Johnston's organ lying within the second antennal segment (Pedicel). These organs sense movements of antennal flagellum. It also functions in hearing in some insects like male mosquitoes and midges.

iv. Subgenual organ: Chordotonal organ located in the proximal tibia of each leg, used to detect substrate vibration. Subgenual organs are found in most insects, except the Coleoptera and Diptera

2. Auditory receptors (detect sound waves)

i. Delicate tactile hairs: Present in plumose antenna of male mosquito.

ii. Tympanum: 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. Tympanal organs are located

* Between the metathoracic legs of mantids.
* The metathorax of many nectuid moths.
* The prothoracic legs of many orthopterans.
* The abdomen of short horned grasshopper, cicada.
* The wings of certain moths and lacewings.

3. Chemoreceptors (detect smell and taste)

Detect chemical energy. Insect chemoreceptors are sensilla with one pore (uniporous) or more pores (multiporous). Uniporous chemorceptors mostly detect chemicals of solid and liquid form by contact and are called as **gustatory receptor**. Many sensor neurons located in antenna are of this type. Multiporous chemoreceptors detect chemicals in vapour form, at distant by smell and are acalled as **olfactory receptor**. Few sensory neurons located in trophi and tarsi are of this type. Each pore forms a chamber known as **pore kettle** with more number of pore tubules that run inwards to meet multibranched dendrites.

4. Thermoreceptors (detect heat)

Present in poikilothermic insects and sensitive to temperature changes. In bed bug it is useful to locate the host utilizing the temperature gradient of the host.

5. Photoreceptors (detect light energy)

a. Compound eyes: The compound eye is based on many individual units called **ommatidia**. Each ommatidium is marked externally by a hexagonal area called facet. Compound eye is made up of two parts called optic part and sensory part. **Optic part** contains a cuticular lens called **corneal lens** secreted by corneagenous cells and **crystalline cone** covered by **primary pigment cells**. Function of the optic part is to gather light. **Sensory part** contains six to ten

visual cells called **retinular cells** covered by secondary pigment cells which collectively secrete a light sensitive rod at the centre called **rhabdom**. Rhabdom contains light sensitive pigments called **rhodopsin**. Each ommatidium is covered by a ring of light absorbing pigmented cells, which isolates an ommatidium from other. Nerve cells are clustered around the longitudinal axis of each ommatidium.

Types of ommatidia

i. **Apposition type** (light tight): Due to the presence of primary pigment cells light cannot enter the adjacent cells. The mosaic image formed is very distinct. The image formed by the compound eye is of a series of opposed points of light of different intensities. This functions well in diurnal insects.

ii. **Super position type**: Primary pigment cells are absent allowing light to pass between adjacent ommatidia. Image formed in this way are indistinct, bright and blurred. This type is seen in nocturnal and crepuscular insects.

b. Lateral ocelli (Stemmata): Visual organs of holometabolous larva. Structure is similar to ommatidium. It helps to detect form, colour and movement, and also to scan the environment.

c. Dorsal ocelli: Visual organs of nymph and it vary from 0-3 in numbers. It contains a single corneal lens with many visual cells individually secreting the rhabdomere. Dorsal ocelli perceive light to maintain diurnal rhythm and is not involved in image perception.

LECTURE 14. Sensory organs. Metamorphosis: Egg structure and types of eggs

Metamorphosis and immature stages in insects

Metamorphosis is the change in growth and development an insect undergoes during its life cycle from birth to maturity. There are four basic types of metamorphosis in insects.

1. **Ametabola:** (No metamorphosis) e.g. Silver fish. These insects have only three stages in their life namely egg, young ones and adult. It is most primitive type of metamorphosis. The hatching insect resembles the adult in all respects except for the size and called as juveniles. Moulting continues throughout the life.

2. **Hemimetabola**: (Incomplete metamorphosis) e.g. Dragonfly, damselfly and may fly. These insects also have three stages in their life namely egg, young one and adult. The young ones are aquatic and are called as **naiads**. They are different from adults in habit and habitat. They breathe by means of tracheal gills. In dragonfly naiad the lower lip (labium) is called mask which is hinged and provided with hooks for capturing prey. After final moult, the insects have fully developed wings suited for aerial life.

3. **Paurometabola**: (Gradual metamorphosis) e.g. Cockroach, grasshopper, bugs.

The young ones are called **nymphs**. They are terrestrial and resemble the adults in general body form except the wings and external genitalia. Their compound eyes and mouth parts are similar to that of adults. Both nymphs and adults share the same habitat. Wing buds externally appear in later instars. The genitalia development is gradual. Later instar nymphs closely resemble the adult with successive moults.

4. **Holometabola**: (Complete metamorphosis) e.g. Butterfly, moth, fly and bees.

These insects have four life stages namely egg, larva, pupa and adult. Majority of insects undergo complete metamorphosis. Larvae of butterflies are called caterpillar. Larva differs greatly in form from adult. Compound eyes are absent in larva. Lateral ocelli or stemmata are the visual organs. Their mouth parts and food habit differ from adults. Wing development is internal. When the larval growth is completed, it transforms into pupa. During the non-feeding pupal stage, the larval tissues disintegrate and adult organs are built up.

1. **Eggs**: The first stage of development in all insects is egg. Majority of insects are oviparous. Egg stage is inconspicuous, inexpensive and inactive. Yolk contained in the egg supports the embryonic development. Eggs are laid under conditions where the food is available for feeding of the future Youngones. Eggs are laid either individually or in groups. The outer protective shell of the egg is called chorion. Near the anterior end of the egg, there is a small opening called micropyle which allows the sperm entry for fertilization. Chorion may have a variety of textures. Size and shape of the insect eggs vary widely.

TYPES OF EGGS :

a) **SINGLY LAID** :

1) **Sculptured egg :** Chorion with reticulate markings and ridges e.g. Castor butterfly.

2) **Elongate egg** : Eggs are cigar shaped. e.g. Sorghum shoot fly.

3) **Rounded egg**: Eggs are either spherical or globular. e.g. Citrus butterfly

4) **Nit :** Egg of head louse is called nit. It is cemented to the base of the hair. There is an egg stigma at the posterior end, which assists in attachment. At the anterior end, there is an oval lid which is lifted at time of hatching.

5) **Egg with float :** Egg is boat shaped with a conspicuous float on either side. The lateral sides are expanded. The expansions serve as floats. e.g. *Anopheles* mosquito.

b**) EGGS LAID IN GROUPS** :

1) **Pedicellate eggs :** Eggs are laid in silken stalks of about

1.25mm length in one groups on plants. e.g. Green lacewing fly.

2) **Barrel shaped eggs :** Eggs are barrel shaped. They look like miniature batteries. They are deposited in compactly arranged masses. e.g. Stink bug.

3) **Ootheca** (Pl. Oothecae) : Eggs are deposited by cockroach in a brown bean like chitinous capsule. Each ootheca consists of a double layered wrapper protecting two parallel rows of eggs.Each ootheca has 16 eggs arranged in two rows. Oothecae are carried for several days protruding from the abdomen of female prior to oviposition in a secluded spot. Along the top,there is a crest which has small pores which permit gaseous exchange without undue water loss. Chitinous egg case is produced out of the secretions of colleterial glands.

4) **Egg pod :** Grasshoppers secrete a frothy material that encases an egg mass which is deposited in the ground. The egg mass lacks a definite covering. On the top of the egg,the frothy substance hardens to form a plug which prevents the drying of eggs.

5. **Egg cass** : Mantids deposit their eggs on twigs in a foamy secretion called spumaline which eventually hardens to produce an egg case or ootheca. Inside the egg case, eggs are aligned in rows inside the egg chambers.

6. **Egg mass:** Moths lay eggs in groups in a mass of its body hairs. Anal tuft of hairs found at the end of the abdomen is mainly used for this purpose. e.g. Rice stem borer.

Female silk worm moth under captivity lays eggs on egg card. Each egg mass is called a dfl (diseases free laying).

7**. Eff raft** : In *Culex* mosquitoes, the eggs are laid in a compact mass consisting of 200-300 eggs called egg raft in water.

LECTURE 15. Metamorphosis: Larva and types of larvae

LARVAE

Larval stage is the active growing stage. It is the immature stage between the egg and pupal stage of an insect having complete metamorphosis. This stage differs radically from the adult.

TYPES OF LARVAE: There are three main types of insect larvae namely oligopod, polypod and apodous.

1. OLIGOPOD : Thoracic legs are well developed. Abdominal legs are absent. There are two subtypes.

a. Campodeiform : They are so called from their resemblance to the dipluran genus Campodea. Body is elongate, depressed dorsoventrally and well sclerotised. Head is prognathous. Thoracic legs are long. A pair of abdominal cerci or caudal processes is usually present. Larvae are generally predators and are very active. e.g. grub of antlion or grub of lady brid beetle.

b. Scarabaeiform : Body is `C' shaped, stout and subcylindrical. Head is well developed. Thoracic legs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. grub of rhinoceros beetle.

2. POLYPOD or ERUCIFORM : The body consists of an elongate trunk

with large sclerotised head capsule. Head bears a pair of powerful mandibles which tear up vegetation. Two groups of single lensed eyes (Stemmata) found on either side of the head constitute the visual organs. The antenna is short. Three pairs of thoracic legs and upto five pairs of unjointed abdominal legs or prolegs are present. Thoracic legs are segmented and they end in claws which are used for holding on to the leaf. Bottom of the proleg is called planta which typically bears rows or circlet of short hooked spines or crochets which are useful in clinging to the exposed surface of vegetation and walking. Abdominal segments three to six and ten typically bear prolegs. e.g. Caterpillar (larvae of moths ad butterflies).

a. Hairy caterpillar : The body hairs may be dense, sparse or arranged in tufts. Hairs may cause irritation, when touched. e.g. Red hairy caterpillar.

b. Slug caterpillar : Larva is thick, short, stout and fleshy. Laval head is small and retractile. Thoracic legs are minute. Abdominal legs are absent. Abdominal segmentation is indistinct. Larva has poisonous spines called scoli distributed all over the body. Such larva is also called platyform larva.

c. Semilooper : Either three or four pairs of prolegs are present. Prolegs are either wanting or rudimentary in either third or third and fourth abdominal segments. e.g. castor semilooper.

d. Looper : They are also called measuring worm or earth measurer or inch worm. In this type, only two pairs of prolegs are present in sixth and tenth abdominal segments. e.g. Daincha looper.

3. APODOUS: They are larvae without appendages for locomotion. Based on the degree of development and sclerotization of head capsule there are three subtypes.

a. Eucepalous : Larva with well developed head capsule with functional mandibles, maxillae, stemmata and antennae. Mandibles act transversely. e.g. Wriggler (larva of mosquito) and grub of red palm weevil.

b. Hemicephalous : Head capsule is reduced and can be withdrawn into thorax. Mandibles act vertically.

e.g. Larva of horse fly and robber fly.

c. Acephalous : Head capsule is absent. Mouthparts consist of a pair of protrusible curved mouth hooks and associated internal sclerites. They are also called vermiform larvae. e.g. Maggot (larva of house fly).

LECTURE 16. Metamorphosis: Pupa and types of pupae

PUPA :

It is the resting and inactive stage in all holometabolous insects. During this stage, the insect is incapable of feeding and is quiescent. During the transitional stage, the larval characters are destroyed and new adult characters are created. There are three main types of pupae.

1. OBTECT : Various appendages of the pupa viz., antennae, legs and wing pads are glued to the body by a secretion produced during the last larval moult. Exposed surfaces of the appendages are more heavily sclerotised than those adjacent to body. e.g. moth pupa.

a. Chrysalis : It is the naked obtect pupa of butterfly. It is angular and attractively coloured. The pupa is attached to the substratum by hooks present at the terminal end of the abdomen called cremaster. The middle part of the chrysalis is attached to the substratum by two strong silken threads called gridle.

b. Tumbler : Pupa of mosquito is called tumbler. It is an obtect type of pupa. It is comma shaped with rudimentary appendages. Breathing trumpets are present in the cephalic end and anal paddles are present at the end of the abdomen. Abdomen is capable of jerky movements which are produced by the anal paddles. The pupa is very active.

2. EXARATE : Various appendages viz., antennae, legs and wing pads are not glued to the body. They are free. All oligopod larvae will turn into exarate pupae. The pupa is soft and pale e.g. Pupa of rhinoceros beetle.

3.COARCTATE : The pupal case is barrel shaped, smooth with no apparent appendages. The last larval skin is changed into case containing the exarate pupa. The hardened dark brown pupal case is called puparium. e.g. Fly pupa.

PUPAL PROTECTION

In general pupal stage lacks mobility. Hence it is the most vulnerable stage. To get protection against adverse conditions and natural enemies, the pupa is enclosed in a protective cover called cocoon. Based on the nature and materials used for preparation of cocoons, there are several types.

Types of cocoon	Materials used	Example
silken cocoon	Silk	Silk worm
Earthen cocoon	Soil + saliva	Gram pod borer
Hairy cocoon	Body hairs	Woolly bear
Frassy cocoon	Frass + saliva	Coconut black headed caterpillar
Fibrous cocoon	Fibres	Red plam weevil
Puparium	Hardened last larval skin	House fly

LECTURE 17. Taxonomy, principles and procedures. Nomenclature and identification

Taxonomy is the science of classification. It can be defined as placing biological organisms or forms in order. Simpson (1961)has defined taxonomy as the theoretical study of classification including basis, principles, procedures and rules. Taxonomy includes nomenclature and classification.

Systematics: The science of study of kind and diversity of organisms and any or all relations among them. Systematics includes taxonomy and evolution.
Stages of taxonomy: The taxonomy of any group passes through several stages.

(i) Alpha taxonomy (α) : It is concerned with naming and characterisation of species.

(ii) Beta taxonomy (β) : Concerned with classification

(iii) Gama taxonomy (γ) : Concerned with evolutionary relations and phylogeny.

Basis for classification: Classification is the ordering of a large group of organisms based on certain characters into small groups. Classification is mainly based on evolutionary relationship and not based on superficial resemblance. Points considered while classifying are (i) external structure, (ii) internal characters, (iii) developmental history, (iv) physiological data and (v) cytogenetic data.

The biological system of classification is called hierarchial concept of classification. This was introduced by Carl Von Linnaeus (1758). A large group of organism is successively subdivided into small group. These groups are called taxa (taxon-singular). Each group is at a particular level in this system. This level is called the rank. Groups of the same rank are grouped together and that constitutes the taxonomic category. e.g. Class. Certain taxonomic categories are obligate, while others are optional. For describing and classifying any organism the basic taxonomic category is species. The lowermost category for classifying an organism is subspecies.

Systematic position of Indian honey-bee
* 1. Kingdom: Animalia
* 2. Phylum: Arthropoda
* 3. Class: Insecta
  4. Sub class: Pterygota
*5.Order:Hymenoptera

6. Suborder: Apocrita
7. Super family: Apioidea
* 8. Family: Apidae
9. Subfamily: Apinae
* 10. Genus: Apis
* 11. Species: indica
(* - Obligate, while others optional)

Sub species is the geographic variety or race. Species is the natural reproductive unit among animals. It is a group of individuals having similar structure, development and behaviour which interbreed to produce viable offsprings. (Biological species concept says that a species is a natural, interbreeding population which is reproductively isolated from the individuals of other species).
Functions of species

i. **Reproductive community:** The individuals of the species are able to recognise each other as potential mate and seek each other for the purpose of reproduction.
ii. An ecological unit: Irrespective of the number of individuals they act as a unit and interact with the individuals of other species with which they share the habitat.
iii. A genetic unit: it consists of a large number of inter-communicating gene pool in which the individual is a temporary reservoir holding a portion of genes for a short period.
Body text young one by parthenogenesis.
i. Larval paedogenesis - e.g. gall midges.

26. **Nomenclature and identification**

A name is required for identification of any organism. Generally two types of names are used (i) common name (ii) scientific name.

I. Common name

(i) They are **inaccurate** because it varies from region to region and country to country and there is **no uniformity** followed in naming the organisms.

e.g. Locust is a bug referring cicada in European countries and normally locusts also refer to short horned grasshoppers living in groups.

(ii) Common name is not available for all organisms

e.g. **Squash bugs** present in cucurbitaceous plants are represented by many species, but no common name is available for each species. It is available only for a large group like order and family.

(iii) Same common name is used for insects of different orders.

e.g. Flies. A true fly has only 2 wings, whereas other insects like mayfly, dragonfly, etc., are also mentioned as flies.

(iv) Homonym - Same name is used for describing two different type of insects.

e.g. Boll worm is a common term used for more than five species of boll feeding insects.

(v) Synonym - More than one name denoting a single insect.

e.g. Gram pod borer, American bollworm denotes *Helicoverpa armigera*

II. **Scientific name:** The system of naming organisms using two words is called **Binomial nomenclature (Trinomial nomenclature** if three words are used). This system of naming gives accurate information. It is universal and is accepted in all parts of

the world. The rule regarding the naming of organisms is contained in **International code for zoological nomenclature.**

Normally there are two names, the first name is the generic name and the second name is the species name**.** The names that follow the generic name are called **Trivial names.** The trivial names may be either species or a subspecies name.

e.g. Head louse: *Pediculus humanus captis*

Body louse: *Pediculus humanus corporis*

The first letter of the generic name is in capital and the first letter of species and subspecies are in small letter. All the words are Latinized and written in italics or it should be written and underlined separately. The **authority** name is written after the species name. It starts with capital letter. The author name is put in bracket if the taxa has been reclassified and placed in another group. e.g. Moringa fruit fly *Gitona distigma* (Meigon)

IDENTIFICATION

All insects present in the world are not yet identified and described (about 25% of the insect species are unidentified). An already described species produce new **race** which requires further identification. Identification helps to understand about the organism and to take proper control measure. Insects can be identified through an expert, by comparing the available collections, using photographs and pictures and by using **taxonomic keys**. Key is a tabular statement presenting alternatives, describing about the features of an organism. Most of the keys are **dichotomous** i.e., always dividing into two or they are always in the form of couplets and give a clear cut alternative. Keys can be constructed based on single character (**monothetic key**) or many characters (**polythetic key**). Polythetic key is more advantageous. Monothetic key has three disadvantages (i) the organism may be an exception for a particular character (ii) chances of erring is more (iii) if the particular body part is broken on which the key is made, then the key cannot be used. Key can be classified based on evolutionary principles also as **phylogenetic key** and **arbitrary key**

(i) Phylogenetic key: The key is based on the evolutionary relationship. The group appears only once in the phylogenetic key.

(ii) Arbitrary key : The taxa or group appears at several places in the key. It has more advantages.

CHAPTER 18. Classification of insects and different groups

Insects are the six legged flying arthropods coming under the phylum Arthropoda and class Insecta. The widely accepted classification of insects was proposed the eminent insect taxonomist **A.D.Imms**.

Characters of class Insecta

1. Body is divided into three regions
2. In head a pair of antenna and a pair of compound eyes are usually present.
3. Thorax is the centre of locomotion with, 3 pairs of five jointed legs and two pairs of wings.
4. Excretion is mainly through malpighian tubules.
5. Tracheal system of respiration well developed.
6. Brain is divided into protocerebrum, deutocerebrum and tritocerebrum.

Entognathous Hexapods

1. Order: **Protura** - proturans
2. Order: **Collembola**- springtails
3. Order: **Diplura** - diplurans

Apterygote Hexapods

4. Microcoryphia - bristletail
5. Thysanura – silverfish

Pterygote Hexapods

6. Ephemeroptera : Mayflies
7. Odonata: Dragonflies and Damselflies
8. Orthoptera: Grasshoppers, Crickets and Katydids
9. Phasmatodea: Walkingsticks and leaf insects
10. Grylloblattodea: Rock Crawlers
11. Mantophasmatodea: Gladiators
12. Dermaptera: Earwigs
13. Plecoptera: Stoneflies
14. Embiidina: Web-spinners
15. Zoraptera: Angel insects

16. Isoptera: Termites
17. Mantodea: Mantids
18. Blattodea: Cockroaches
19. Hemiptera: True bugs, cicadas, hoppers, psyllids, whiteflies, aphids and scale insects
20. Thysanoptera: Thrips
21. Psocoptera : Psocids
22. Phthiraptera: Lice
23. Coleoptera : Beetles and weevils
24. Neuroptera: Alderflies, Dobsonflies, Fishflies, Snakeflies, Lacewings, antlions, and Owlflies
25. Hymenoptera: Sawflies, parasitic wasps, ants, wasps and bees
26. Trichoptera: Caddisflies
27. Lepidoptera: Butterflies and Moths
28. Siphonoptera: Fleas
29. Mecoptera: Scorpionflies and Hangingflies
30. Strepsiptera: Twisted-wing parasites
31. Diptera: Flies

The class Insecta has two subclasses viz., Apterygota and Pterygota.

Apterygota Pterygota

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1. Primarily wingless-evolved Winged or secondarily wingless-
from wingless ancestors. evolved from winged ancestors
e.g. Flea, head louse, bed bug.
2. Metamorphosis is totally Present.
absent or slight.
3. Mandibular articulation in Dicondylic i.e., double.
head is monocondylic i.e. single
4. Pleural sulcus in thorax is absent. Present.
5. Pregenital abdominal appen- Absent.
dages present.

The subclass Apterygota has 4 orders namely

1. Thysanura - Silverfish (Thysan-fringed, Ura-tail)
2. Collembola- Springtail or snowflea (coll-glue; embol-peg)
3. Protura - Proturans or Telsontail (Pro-first, Ura-tail)
4. Diplura - Diplurans or Japygids (Di-two; Ura-tail)

The sub class Pterygota has **two divisions**, namely **exopterygota** and **endopterygota** based on the wing development.

Character	**Exopterygota**	**Endopterygota**
1 .Wing development	External	Internal
2 .Metamorphosis	Incomplete (Hemimetabola) or gradual (Paurametabola)	Complete (Holometabola)
3. Pupal stage	Absent	Present
4. Immature stage	Naiad or Nymph	Larva
5. No. of orders	9	16

The class Insecta is divided in to 29 orders (4 in Apterygota and 25 in Pterygota).

EXOPTERYGOTA GROUPS

01. Ephemeroptera - Mayflies I. **Paleopteran orders** (1,2)
02. Odonata-Dragonfly, Damselfly
03. Plecoptera - Stonefly II. **Orthopteroid orders**(3-11)
04. Grlloblatodia - Rock crawlers
05. Orthoptera-Grasshopper, locust, cricket, mole cricket
06. Phasmida-stick insect, leaf insect
07. Dermaptera-Earwigs
08.Embioptera-Webspinners/Embids
09. Dictyoptera-cockroach, preying mantis
10. Isoptera - Termites
11. Zoraptera - Zorapterans
12. Psocoptera - Book lice III. **Hemipteroid orders**(12-16)
13. Mallophaga - Bird lice
14. Siphonculata - Head and body louse
15. Hemiptera - Bugs
16. Thysanoptera - Thrips

ENDOPTERYGOTA

01. Neuroptera- Antilions, aphidlion, owl flies, mantispid flies.

02. Mecoptera - Scorpionflies.

03. Lepidoptera - Butterflies and moths.

04. Trichoptera - Caddisfly.

05. Diptera - True fly. **Group IV. Panorpoid complex (1-6)**

06. Siphonaptera - Fleas.

07. Hymenoptera - Bees, wasps, ants.

08. Coleoptera - Beetles and weevils.

09. Strepsiptera - Stylopids.

Paleopteran insects cannot flex the wings over the abdomen, i.e., wing flexing mechanism is absent. The characters of insects belonging to Orthopteroid group include mandibulate mouth parts, anal area of hind wing well developed, abdomen is always with cerci, many numbers of malpighian tubules and the ganglia of the ventral nerve cord are not fused. Hemipteroid insects have the haustellate mouth parts and mainly they feed on liquid food like plant sap. Panarpoid insects are holometabolous and they have larval and pupal stage.

CHAPTER 19. Study of insect orders: Protura, Collembola, Diplura, Microcoryphia

1. Order: Protura (Proturans)

The proturans are minute whitish hexapods, 0.6 to 1.5 mm in length. The head is somewhat conical, and there are no eyes or antennae. The mouth parts do not bite, but are apparently used to scrape off food particles that are then mixed with saliva and sucked into the mouth. The first pair of legs is principally sensory in function and is carried in an elevated position like antennae. The tarsi are one-segmented. Styli are present on the first three abdominal segments. On hatching from the egg, the proturan abdomen consists of 9 segments. At each of the next three molts, segments are added anterior to the apical portion (the telson), so that the adult abdomen appears to have 12 segments (11 metameric segments and the apical telson). These hexapods live in the moist soil or humus, in leaf mold, under bark, and in decomposing logs. They feed on decomposing organic matter and fungal spores. They are found worldwide and approximately 200 species are known at present.

Important identification characteristics

a) Minute insects, with entognathous piercing mouth parts
b) Antennae and eyes are absent
c) Abdomen 11 segmented with a terminal telson, first 3 segments with a pair of small appendages called styli
d) Forelegs sensory and held above the head, like antennae
e) Metamorphosis slight, chiefly evident as an increase in number of abdominal segments following each moult (anamorphosis)

e.g. *Eosentomon indicus*

2. Order: Collembola

Synonyms : Oligentoma, Oligoentomata

Etymology : coll-glue; embol - wedge or peg.

Common names : Spring tail, Snow flea

Characters: They are minute insects. Body is globose or tubular. Compound eyes are absent. One to several pairs of lateral ocelli form an eye patch. Antenna is four segmented. Mouthparts are entognathous biting type and found within a pouch. Tibia is fused with tarsus to form tibio-tarsus. They are primarily wingless. Abdomen is six segmented with there medially situated pregenital appendages.

* **Ventral tube** or **Collophore** or **Glue peg**: It is a bilobed adhesive organ found on the first abdominal sternite. It is beleived to be associated with respiration, adhesion and water absorption.

* **Hamula** or **Tenaculum** or **Retinaculum**: It is present on the third abdominal sternite. It consists of a fused basal piece, corpus and free distal part called rami. It holds the furcula.

* **Furcula** or **Springing organ**: It consists of a basal manubrium, paried dens and distal claws called mucro. It is held under tension beneath the abdomen by retinaculum when at rest.

Malpighian tubules, tracheal system and metamorphosis usually absent.

Importance: *Sminthurus viridis* is a pest on alfalfa. It can be collected from moist places in soil. They are also found in mushroom houses as a pest.

3. Order: Diplura (Diplurans)

The diplurans appears somewhat similar to the silverfish and bristletails, but they lack a median caudal filament and thus have only two caudal filaments or appendages. The body is usually not covered with scales; compound eyes and ocelli are absent; the tarsi are one segmented; and the mouthparts are mandibulate and withdrawn into the head. The antennae are long and multisegmented; styli are present on abdominal segments 1-7 or 2-7. These hexapods are small (generally less than 7 mm in length) and usually pale in color. They are found in damp places in the soil, under bark, under stones or logs, in rotting wood, in caves, and in similar moist situations.

Identification characteristics

a) Small to large, narrow bodied entognathous insects
b) Antennae moniliform, with intrinsic musculature
c) Compound eyes and ocelli absent
d) Abdomen with 10 segments, ending in a pair of cerci
e) Larval development epimorphic

e.g. *Campodea staphylinus*

e.g. *Sminthurus viridis*

Class: INSECTA
Subclass: APTERYGOTA

4. Order: Microcoryphia (=Archaeognatha) – Bristle tails

The Microcoryphia resemble the silverfish in the order Thysanura. However, they are more cylindrical, with the thorax somewhat arched; the compound eyes are large and contiguous; ocelli are always present; each mandible has a single point of articulation with the head capsule; the tarsi are three-segmented; and the middle and hind coxae usually bear styli. These styli are sometimes lacking on the middle coxae, or they may be completely absent. The abdomen bears a pair of styli on segments 2-9, and segments 2-7 each bear three ventral sclerites (the coxopodites and a median sternum; the sternum is

sometimes much reduced). Segments 1-7 usually bear one or two pairs of eversible vesicles.

These insects live in grassy or wooded areas under leaves, under bark, in dead wood, under stones, under rocks and cliffs, and in similar situations. Most are nocturnal, and their eyes glow at night when illuminated with a flashlight. The largest members of the order are about 15 mm in length.

The Microcoryphia are quite active and jump when disturbed, sometimes as far as 25-30 cm. The eversible vesicles on the abdomen function as water absorbing organs. Before these insects molt, they cement themselves to the substrate (the cement appears to be fecal material). If the cement fails, or if the substrate (such as sand) is not firm, they are unable to molt, and die. The bodies of the insects are covered with scales, which sometimes form distinctive patters. The scales are often lost during the collecting process or when the insects are preserved in fluid. The jumping bristletails feed chiefly on algae, but feed also on lichens, mosses, decaying fruits, and similar materials.

Identification characteristics

a) Fusiform, subcylindrical, apterygotes with ability to jump
b) Body bearing pigmented scales
c) Compound eyes large, contiguous, ocelli present
d) Mandibles with single articulation, maxillary palpi 7-9 segmented
e) Thorax strongly arched, terga extending over pleura
f) Styli often present on mid and hind coxae, tarsi 3 segmented
g) Abdominal segments 2-9 with ventral styli, 1-7 with eversible vesicles.

e.g. *Graphitarsus sudindicus*

CHAPTER 20. Study of insect orders: Thysanura, Ephemeroptera, Odonata

8. Order: Thysanura

Synonyms : Ectognatha, Ectotrophi

Etymology : Thysan - fringe; ura – tail.

Common names : Silverfish, Fire brat, Bristle tail

Characters: Body is elongate and flattened. Body is glistening and clothed with scales. Compound eyes are present or absent. Antennae is long, filiform and multisegmented. Mouthparts are ecotognathous, biting type. They are primarily wingless insects. Abdomen is 11 segmented. Varying number of bilateral styli are present on abdominal sternites. Styli are belived to be reduced abdominal legs. Female has elongate jointed ovipositor. Abdomen at its tip carries a pair of elongate many segmented cerci and a median caudal filament. Insemination is indirect. Metamorphosis is absent. Moulting continues even after attaining sexual maturity.

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.

Class: INSECTA
Subclass: PTERYGOTA

9. Order: Ephemeroptera

Synonyms : Ephemerida, Plectoptera

Etymology : Ephemero-living for a day; ptera-wing

Common names : Mayflies, Shadflies, Dayflies

Characters: Small to medium sized soft bodied insects. Compound eyes are large. There are three ocelli. Antenna is short and setaceous. Mouthparts in adults are atrophied. Forewings are large and triangular. Hind wings are small and absent in some species. Numerous cross and intercalary veins are present. Wings are held vertically over the abdomen. Wing flexing mechanism is absent. Abdomen is slender with a pair of long cerci. Median caudal filament may be present or absent. Metamorphosis is incomplete with three stages viz., egg, naiad and adult. Naiad is aquatic with biting mouthparts. It breaths through bilateral abdominal gills. At tip of the abdomen a pair of long cerci and a median caudal filament are usually present. Immediately after the adult emergence body of the insect is covered with closely set fine hairs called pellicle and this stage is called as subimago. It is dull in colour with opaque wings and legs and cerci are not well developed. In imago wings are transparent. Legs and cerci are well developed. Body is shiny and not covered with pellicle. Adults are found near lakes and ponds and are also attracted by light.

Importance: Naiads are important fish food. Adults are short lived and hence the name dayfly. When they emerge in large numbers the pose nuisance problem

10. Order: Odonata

Etymology : Odon - tooth

Common names : Dragonflies and damselflies

Characters: Medium to large sized insects. They are attractively coloured. Head is globular and constricted behind into a petiolate neck. Compound eyes are large. Three ocelli are present. Mouthparts are adapted for biting. Mandibles are strongly toothed Lacinia and galea are fused to form mala which is also toothed.

Wings are either equal or sub equal, membraneous; venation is net work like with many cross veins. Wings have a dark pterostigma towards the costal apex. Sub costa ends in nodus. Wing flexing mechanism is absent.

Legs are anteroventrally placed. They are suited for grasping, holding and conveying the prey to the mouth. Spinous femora and tibiae are useful for holding the prey. Forward shift of leg attachments allow easy transfer of prey items to mouth in flight. Legs are held in such a way that a basket is formed into which the food is scooped.

Abdomen is long and slender. In male gonopore is present on ninth abdominal segment. But the functional copulatory organ is present on the second abdominal sternite. Before mating sperms are transferred to the functional penis. Cercus is one segmented.

Metamorphosis is incomplete with three life stages. The naiad is aquatic. Labium is greatly elongated, jointed and bears two hooks at apex. It is called mask. It is useful to capture the prey.

Importance: Adults are aerial predators. They are able to catch, hold and devour the prey in flight. Naiads are aquatic predators. Dragonflies and damselflies can be collected with an aerial net near streams and ponds especially on a sunny day. Naiads can be collected from shallow fresh water ponds and rice fields.

Classification: There are two sub-orders. Dragonflies are classified under **Ani-soptera** and damselflies are grouped under **Zygoptera.**

CHAPTER 21. Study of insect orders: Orthoptera

11. Order: Orthoptera

Synonyms : Saltatoria, Saltatoptera

Etymology : Ortno - straight; ptera-wings.

Common names : Grasshoppers, Locust, Katydid, Cricket, Mole cricket

Characters : They are medium to large sized insects. Antenna is filiform. Mouthparts are mandibulate. Prothorax is large. Pronotum is curved, ventrally covering the pleural region. Hind legs are saltatorial. Forewings are leathery, thickened and known as tegmina. They are capable of bending without breaking. 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 in female. Metamorphosis is gradual. In many Orthopterans the newly hatched frist instar nymphs are covered by loose cuticle and are called pronymphs. Wing pads of nymphs undergo reversal during development. Specialized stridulatory (sound-producing) and auditory (hearing) organs are present.

Classification

This order is sub divided into two suborders, viz., **Caelifera** and **Ensifera**.

Caelifera	Ensifera
1. Antenna is short with less than	Antenna is long with more
than 30 segments.	
2. Tympanum is found on the lateral	Tympanum is fund on the
side of the first abdominal	the foretibia segment.
3. Vision and hearing acute	tactile response is well developed.
4. Mandibles are specialized for	Feed on dicot plants consuming monocot foliage.
5. Diurnal	Nocturnal
6. Rely on jumping to escape from	Rely on crypsis predators
7. Eggs are laid in groups in soil	Eggs are singly inserted inside shallow burrows. into
plant tissue or soil.	

I. Sub order : Caelifera

Family: Acrididae : Short horned grasshoppers and locusts.

II. Sub order: Ensifera

Families:1. Tettigonidae: Long horned grasshoppers, Katydids and bush crickets.

2. Gryllidae: Crickets. **3. Gryllotalpidae :** Mole crickets.

CHAPTER 22. Study of insect orders: Phasmida, Grylloblattodea

12. Order: Phasmida

Synonyms : Phasmodea, Phasmatodea

Etymology : Phasma - an apparition

Common names : Stick insects, Leaf insects

Characters : Body is stick - like or leaf – like. Head is prognathous. Mouthparts are chewing type. Prothorax is short. Meso and metathorax are long. Metathorax is closely associated with the first abdominal segment. Legs are widely separted. They are long and slender resembling twigs in stick insect. Tibia and femur shows lamellate expansion in leaf insects. A line of weakness is found between the tro-chanter andrest of the leg. The legs get broken easily at this region and such legs get regenerated subsequetly. Tarsus is five segmented. Wings may be present or absent. Forewings when present are small and modified into tegmina. In leaf insects the wing venation mimics leaf venation. Cerci are short and unsegmented. They show protective resemblance. They are herbivorous. **Classification** : There are two families. Stick insects are grouped under **Phasmidae** and leaf insects are classified under **Phyllidae.**.

13. Order: Grylloblattodea (Rock crawlers)

The first member of this group was not discovered until 1914, when Walker described *Grylloblatta campodeiformis* from Banff, Alberta. Rock crawlers are slender, elongate, wingless insects, usually about 15-30 mm in length. The body is pale in color and finely pubescent. The eyes are small or absent, and finely are no ocelli. The antennae are long and filiform, consisting of 23 to 45 segments; the cerci are long, with either 5 or 8 segments; and the sword-shaped ovipoisitor of the female is nearly as long as the cerci.

There are only 25 species and four genera of living rock crawlers in the world. Rock crawlers live in cold places such as the talus slopes at the edges of glaciers and in ice caves, often at high elevations. They are mainly nocturanal, and their principal food appears to be dead insects and other organic matter found on the snow and ice fields. They are soft-bodied, and probably best preserved in alcohol.

Identification characteristics

a) Slender, elongated wingless insects (15-30mm)
b) Body is pale and finely pubescent
c) Eyes are small or absent and no ocelli
d) Antennae long filiform
e) Cerci are long and the sword-shaped ovipositor

Eg. *Grylloblatta* sp.

CHAPTER 23. Study of insect orders: , Mantophasmotodea, Dermaptera

14. Order: Mantophasmatodea (Gladiators)

The Mantopahsmatodea is the newest addition to the cast of insect orders. The genus *Raptophasma* was first described in 2001 for fossil specimens preserved in Baltic amber, approximately 30 million years old. Specimens of similar species were later discovered in collections from Mamibia and Tanzania in Africa, and a new order was proposed for them. Mantophasmatodea have since been posed for them. Mantophasmatodea have since been found in a number of locations in South Africa in Cape Faunal Zone, an area well known for species richness and endemism. The order contains only single family, Mantophasmatidae, and three genera: the fossil *Raptophasma* (one described species) and the living genera *Mantophasma* (two species) and *Praedatophasma* (one species). Researchers think there are at least three new species in South Africa.

Mantophasmatodea are rather small, generally 2-3 cm in length, and both sexes are singles. They have chewing mouthparts, the head is hypognathous, and the antennae are long and filiform. The tarsi are five-segmented. They have simple metamorphosis. According to van Noort (2003), Mantophasmatodea superficially resemble immature mantids, but the fore legs are not modified for prey capture. Nevertheless, these are predatory insects. Adults are rather short-lived, surviving for only a few weeks.

In the original description of the order, it was unclear which order(s) of insects were the closest relatives of Mantophasmatodea, but Grylloblattodea and Phasmatodea were suggested as possibilities. Unfortunately, no phylogenetic analysis preceded the description. It is unclear, at this early point, whether the recognition of this group as an order will meet with general acceptance or if it will eventually be subsumed within Grylloblattodea or another group.

Identification characteristics

a) Small, generally 2-3 cm in length
b) Both sexes are wingless
c) Have chewing and biting types of mouth part
d) Head is hypognathous
e) Antennae are long filiform
f) Tarsi are five segmented
g) the newest order added to the class insecta

Eg. *Praedatophasma maraisi*

15. Order: Dermaptera

Synonyms : Euplexoptera, Euplecoptera

Etymology : Derma - skin; ptera - wing

Common names : Earwigs

Characters: They are generally elongate insects. Head is with a distinct `Y' shaped epicranial suture. They have chewing mouthparts. Prothorax is large, well developed and mobile. Meso and Metathorax are fused with the first abdominal segment. Forewings are short, leathery and veinless. Both the wings meet along a mid dorsal line. They are called tegmina or elytra. They are protective in function and are not used for flight. Hindwings are large, membranous, semicircular and ear like. The anal area of the wings is large with a number of branches of anal veins which are radially arranged. They are folded fan like, longitudinally and twice transversely and kept beneath the forewings at rest. Wings do not cover the abdomen fully. Cerci are found at the end of the abdomen. They are unsegmented enlarged, highly sclerotised and forceps like. They are large and bowed in male and nearly straight in female. They are useful in defence, folding and unfolding of wings, prey capture and copulation. Parental care is shown by female earwigs. It literally, roost on the eggs until hatching occurs and also cares for the nymphs.

Importance: *Euborellia annulipes* bores into groundnut pods and feeds on the kernel.

CHAPTER 24. Study of insect orders: Plecoptera, Embioptera

16. Order: Plecoptera (Stoneflies)

Stoneflies are mostly medium-sized or small, some what flattened, soft-bodied, rather drab-colored insects found near streams or rocky lake shore. They are generally poor fliers and are seldom found far from water. Most species have four membranous wings. The front wings are elongate and rather narrow and usually have a series of crossveins between M and Cu_1 and between Cu_1 and Cu_2. the hind wings are slightly shorter than the front wings and usually have a well-developed anal lobe that is folded fanwise when the wings are at rest. A few species of stoneflies have reduced wings or lack wings, usually in the male. Stoneflies at rest hold the wings flat over the abdomen. The antennae are long, slender, and many-segmented. The tarsi are three-segmented. Cerci are present and may be long or short. The mouthparts are of the chewing type, although in many adults (which do not feed) they are somewhat reduced. The stoneflies undergo simple metamorphosis, and the nymphal stages of development are aquatic.

Stoneflies nymphs are somewhat elongate, flattened insects with long antennae and long cerci, and often with branched gills on the thorax and about the bases of the legs. They are very similar to mayfly nymph but lack a median caudal filament; that is, they have only two tails, whereas mayfly nymphs nearly always have three. Stonefly nymphs have two tarsal claws and mayfly nymphs have only one, and the gills are different: Mayfly nymphs have leaflike gills along the sides of the abdomen, whereas stonefly gills are always fingerlike, either simple or branched, and only occur ventrally. Stonefly nymphs are often found under stones in streams or along lake shores (hence the common name of these insects), but may occasionally be found anywhere in a stream where food is available. A few species live in underground water, and their nymphs sometimes appear in wells or other drinking water supplies. Some species are plant feeders in the nymphal stage, and others are predaceous or omnivorous. Some species of stoneflies emerge, feed, and mate during the fall and winter months. The nymphs of these species are generally plant feeders, and the adults feed chiefly on blue-green algae and are diurnal in feeding habits. The species that emerge during the summer vary in nymphal feeding habits. Many do not feed as adults.

In many species of stoneflies, the sexes get together in response to acoustic signals. The males drum by tapping the tip of the abdomen on the substrate. Virgin females respond to this drumming, and answer with a drumming of their own either during or immediately after the male drumming. The males drum throughout their adult life, and the signals are species specific.

Identification chateristics

a) Soft bodied insects with long setaceous antennae
b) Mouth parts weak, biting type, mandibles normal or vestigial, ligula 4 lobed.
c) Wings membranous, held flat over the body at rest; hind pair usually larger, with well developed anal lobes
d) Tarsi 3 segmented; cerci long

e) Naiads respire through filamentous tracheal gills

e.g. *Hemoura punjabensis*

17. Order: Embioptera

Synonyms : Embiodea, Embiidina

Etymology : Embia-lively; ptera-wings

Common names : Embiids, Webspinners

Characters: They are small elongate soft bodied insects. Antenna is filiform. Mouthparts are chewing type. Basitarsus of the foreleg is greatly enlarged. Silk glands and spinnerets are found in the basitarsus. Hind femur is enlarged and helps in backward running. Male has well developed wings; while female is apterous. Wings are elongate, nearly equal, smoky brown with reduced wing venation. Radial vein is thick. Cerci are asymmetrical; left cercus is one segmented and it serves as clasper. Cerci are equal and two segmented in female. Embiids are gregarious and live inside tubular silken tunnels beneath stones, logs and bark of trees. Silken tunnels give protection against predators, prevent excessive water loss from the body and provide a humid atmosphere. Females show strong parental care and they nurse the eggs and nymphs. They feed on decaying plant matter.

CHAPTER 25. Study of insect orders: Isoptera, Zoraptera

18. Order: Isoptera

Synonyms : Termitina, Termitida,Socialia

Etymology : Iso - equal; ptera - wing.

Common names : Termites, White ants

Characters: They are small greyish white, soft bodied insects. The body is pale yellow in colour because of weak sclerotization. Compound eyes are present in alate forms and usually absent in apterous forms. Antennae are short and moniliform. Mouthparts are adapted for biting and chewing. Two pairs of wings are present which are identical in size form and venation. Wings are membranous and semitransparent. Venation is not distinct. Veins near the costal and anal margin alone are distinct. Anterior veins are more sclerotised. Wings are flexed over the abdomen at rest. They are extended beyond the abdomen. Wings are present only in sexually mature forms during swarming season. Wing shedding takes place along the basal or humeral suture, after swarming. The remanant or the stump remaining behind is called **`scale'.** Abdomen is broadly jointed to the thorax without constriction. External genital organs are lacking in both the sexes. Cerci are short.

Specialities: They are ancient polymorphic, social insects living in colonies.

Internal characters: Salivary glands are well developed. Rectum is distended forming rectal pouch to accommodate large number of intestinal symbionts. Fat body development is extensive in male and female reproductives. Soil inhabiting termites construct earthern mounds called **termitaria**. They have evolved complex relationships with other organisms like bacteria, protozoa and fungi which help them in the digestion of wood. Incessant food sharing (**trophallaxis**) occurs between the members of the commounity by mouth-to-mouth and anus-to-mouth food transfer.

Importance: Termites are nature's scavengers. They convert logs, stumps, branches etc, to humus. Many are injurious to crops, furniture and wood works of buildings.

19. Order: Zoraptera (Zorapterans, Angelinsects)

The zorapterans are minute insects, 3 mm or less in length, and may be winged or wingless. The winged forms are generally dark, and the wingless forms are usually pale. The zorapterans are a little like termites in general appearance and are gregarious. The order was not discovered until 1913.

Winged and wingless forms occur in both sexes. The four wings are membranous, with much reduced venation and with the hind wings smaller than the front wings. The wings of the adult are eventually shed, as in ants and termites, leaving stubs attached to the thorax. The antennae are moniliform and nine-segmented as adults. The wingless forms lack both compound eyes and three ocelli. The tarsi are two-segmented, and each tarsus bears two claws. The cerci are short and unsegmented and terminate in a

long bristle. The abdomen is short, oval and terminates in a long bristle. The abdomen is short, oval and 10 segmented. The mouthparts are simple. Apparently there are four juvenile instarts in the common species in North America.

Identification characteristics

a) are minute inects (3mm or less in length)
b) winged or wingless
c) Four wings are membranous with reduced venation
d) Antennae are moniliform
e) Cerci are unsegmented with terminal bristle

Eg. *Usazorus hubbardi*

CHAPTER 26. Study of insect orders: , Mantodea, Blattodea

19. Order: Mantodea –mantids

Mantids are large, elongate, rather slow-moving insects that are striking in appearance because of their peculiarly modified front legs. The prothorax is greatly lengthened and movably attached to the pterothorax; the front coxae are very long and mobile; and the front femora and tibiae are armed with strong spines and fitted for grasping prey. The head is freely movable. Mantids are the only insects that can "look over their shoulders". These insects are highly predaceous and feed on a variety of insects (including other mantids). They usually lie in wait for their prey with the front legs in an upraised position. This position has front legs in an upraised position. This position has front legs in an upraised position. This position has given rise to the common names "praying mantis" and "soothsayer" that are often applied to these insects.

Mantids overwinter in the egg stage, and the eggs are deposited on twigs or grass stems in a Styrofoam-like egg case of ootheca secreted by the female. Each egg case may contain 200 or more eggs. If brought into the house and kept warm, the eggs will hatch in late winter or early spring, and the nymphs, unless supplied with food, will eat each other until one, large nymph remains.

There are more than 1500 species in eight families of mantids in the world, most of which are tropical.

Identification characteristics

a) Antennae setaceous filiform
b) Mouth parts biting type
c) Prothorax is greatly lengthened
d) Front coxae are very long and mobile
e) Front leg is raptorial type
f) Head is distinct and freely movable
g) Cerci many segmented
h) Eggs contained in ootheca

e.g. *Gongylus gongyloides*

20. Order: Blattodea -cockroaches

Cockroaches are cursorial insects with 5-segmented tarsi and none of the legs modified for digging or grasping. They run very fast, as anyone who attempts to step on one soon discovers. The body is oval and flattened, and the head is concealed from above by the pronotum. Tympana and stridulating organs usually are absent. Wings are generally present, although in some species they are much reduced. The females of many species have shorter wings than the males. The cerci are one- to many-segmented and usually fairly long; the antennae are long and filiform. These insects are rather generalized

feeders. The eggs are enclosed in capsules or oothecae, which may be deposited immediately after they are formed, carried about on the end of the abdomen of the female until the eggs hatch, or carried internally in uterus or brood pouch for the full gestation period.

Cockroaches are primarily tropical insects, and most North American species occur in the southern part of the United States. Some tropical species are occasionally brought into the North in shipments of bananas or other tropical fruits. The most commonly encountered cockroaches in the North are those that invade houses, where they are often serious pests. None is known to be a specific vector of disease, but thy fee on all sorts of things in house. They contaminate food, they have an unpleasant odor, and their presence is often very annoying.

Identification chateristics

a) Had covered from above by the pronotal shield
b) Body dorsoventrally flattened
c) Ocelli 2
d) All legs are modified as cursorial (running) type

e.g. *Periplanata Americana, Blatta orientalis*

CHAPTER 27. Study of insect orders: Hemiptera, Thysanoptera

21. Order: Hemiptera

Synonym : Rhynchota

Etymology : Hemi - half; ptera - wing

Common name : True bugs

General characters: Head is opisthognathous. Mouthparts are piercing and sucking type. Two pairs of bristle like stylets which are the modified mandibles and maxillae are present. Stylets rest in the grooved labium or rostrum. Both labial palps and maxillary palps are atrophied. Mesothorax is represented dorsally by scutellum. Forewings are either uniformly thickened throughout or basally coriaceous and distally membranous. Cerci are always absent. Metamorphosis usually gradual; rarely complete. Alimentary canal is suitably modified (**filter chamber)** to handle liquid food. Salivary glands are universally present. Extra-oral digestion is apparently widespread. Abdominal ganglia fused with thoracic ganglia.

Classification: There are two suboders *viz*., Heteroptera and Homoptera.

Heteroptera Homoptera
(Hetero-different; ptera-wing) (Homo-uniform; ptera-wing)

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1. Head is project or horizontal Head is deflexed

2. Bases of the forelegs do not Bases of the forelegs touch touch the head the head

3. Beak arises from the anterior Beak arises from the posterior part of the head part of the head

4. Gular region of the head Gular region not clearly (midventral sclerotised defined

part between labium and foramen magnum) well defined.

5. Pronotum usually greatly Pronotum is almost alway small enlarged. and collar-like.

6. Scutellum (triangular plate Scutellum not well developed, found between the wing bases) well developed

7. Forewings heavily sclerotized Forewings are of uniform at the base and the apical texture. They are frequently half is membranous (Hemelytra)harder than hind pair.

8. Wings are held flat over the Wings are held roof-like over the back at rest and the left theback and wings do not over and right side overlap on lap the abdomen.

9. Honey dew secretion uncommon Honey dew secretion common

10. Repungnatorial or odori- Wax glands usually present ferous or scent glands present.

11. Both terrestrial and aquatic Terrestrial.

12. Herbivorous, predaceous or Herbivorous

Important families of heteroptera

1. Gerridae: (Jesus bugs, Water striders, or Pond skater)

2. Reduviidae: (Assassin bugs, Kissing bugs or cone nose bugs)

3. Cimicidae: (Bed bugs)

4. Tingidae: (Lacewing bugs)

5. Miridae: (Plant bugs or Leaf bugs)

6. Lygaeidae: (Seed bugs or Chinch bugs)

7. Pyrrhocoridae: (Red bugs or Stainers)

8. Coreidae: (Squash bugs or leaf footed bugs)

9. Pentatomidae: (Stink bugs or Shield bugs)

10. Nepidae: (Water scorpions)

11. Belostomatidae: (Giant water bugs or electric light bugs)

Important families of homoptera

1. Cicadidae: (Cicadas)

2. Membracidae: (Tree hoppers or Cowbugs)

3. Cicadellidae: (Leaf hoppers or Jassids)

4. Cercopidae: (Spittle bug or Cuckoo-spilt or Frog hopper)

5. Delphacidae : (Plant hoppers)

6. Lophopidae: (Aeroplane bugs)

7. Psyllidae: (Jumping plant lice)

8. Aleyrodidae: (Whiteflies)

9. Aphididae: (Aphids or Plant lice or Greenflies)

10. Coccidae: (Scale insects or Soft scales)

11. Diaspididae: (Armoured scale)

12. Kerridae: (Lac insect)

13. Pseudococcidae: (Mealy bug)

15. Thysanoptera

Synonyms : Physopoda

Etymology : Thysano - fringe; ptera - wings

Common name : Thrips.

Characters: They are minute, slender, soft bodied insects. Mouthparts are rasping and sucking. Mouth cone is formed by the labrum and labium together with basal segments of maxillae. There are three stylets derived from two maxillae and left mandibles. Right mandible is absent. Hence mouthparts are asymmetrical. Wings are either absent or long, narrow and fringed with hairs which increase the surface area. They are weak fliers and passive flight in wind is common. Tarsus is with one or two segments. At the apex of each tarsus a protrusible vesicle is present. Abdomen is often pointed. An appendicular ovipositor may be present or absent. Nymphal stage is followed by prepupal and pupal stages which are analogous to the pupae of endopterygote insects.

This order is subdivided into two suborders.

1. Terebrantia: Female with an appendicular ovipositor. Abdomen end is not tube like.

Wing venation is present. Important family is **Thripidae**

2. Tubulifera: Ovipositor is absent. The abdomen end is tubular.

Wing venation is absent.

Importance: Most of the thrips species belong to the family Thripidae and are phytophagous. They suck the plant sap. Some are vectors of plant diseases. Few are predators. e.g. Rice thrips: *Stenchaetothrips biformis* is a pest in rice nursery.

CHAPTER 28. Study of insect orders: Psocoptera, Phthiraptera

22. Order: Psocoptera

Synonyms : Corrodentia, Copeognatha

Etymology : Psoco-rub small; ptera – wings ;Psochos-dust like.

Common names : Book lice, Bark lice, Dust lice.

Characters: They are minute and soft bodied insects. Head has a distinct `Y' shaped epicranial suture. Clypeus is swollen. Mouthparts are biting and chewing type. Mandibles are with well developed molar and incisor areas. Lacinia is rodlike (**`pick'**) which is partially sunken into the head capsule. Legs are slender. Wings may be present or absent. Forewings are larger than hind wings. Wings are held roof like over the abdomen. Cerci are absent. Psocids are frequently gregarious. Some psocids have the ability to spin silk. Dorsal pair of labial glands are modified into silk glands.

Imporance: The common book louse is *Liposcelis* sp. They feed on paper paste of book binding, fragments of animal and vegetable matter and stored products. They are also damage dry preserve insects and herbarium specimens.

23. Order: Phthiraptera - Lice

The lice are small, wingless ectoparasites of birds and mammals. These insects formerly were divided into two separate orders, the Mallophaga (chewing lice) and Anoplura (sucking lice). The suborder Anoplura contains several species that are parasites of domestic animals and two species that attack humans. These insects are irritating pests, and some are important vectors of disease. Many chewing lice are pests of domestic animals, particularly poultry. These lice cause considerable irritation, and heavily infested animals appear run-down and emaciated. If not actually killed by the lice, they are still easy prey for disease. Different species of lice attack different types of poultry and domestic mammals, and each species usually infests a particular part of the host's body: None of chewing lice is known to attack people. Those who handle birds or other infested animals may occasionally get the lice on themselves, but the lice do not stay long.

The Anoplura feed on the blood of their host. The mouthparts of a sucking louse consist of three piercing stylets that are normally withdrawn into a stylet sac in the head. The mouthparts are highly specialized and difficult to homologize with those of other insects. There is a short rostrum (probably the labrum) at the anterior end of the head, from which the three piercing stylets are protruded. The rostrum is eversible and is armed internally with small, recurved teeth. The stylets are about as long as the head and when not in use, are withdrawn into a long, saclike structure below the alimentary canal. The dorsal stylet probably represents the fused maxillae. Its edges are curved upward and inward to form a tube that serves as a food channel. The intermediate stylet is very slender and contains the salivary channel; this stylet is probably the hypopharynx. The

ventral stylet is the principal piercing organ; it is trough-shaped structure and is probably the labium. There are no palps.

The tarsi of sucking lice are one-segmented and have a single, large claw that usually fits against a thumb like process at the end of the tibia. This forms an efficient mechanism for hanging to the hairs of the host.

The Phthiraptera undergo simple metamorphosis. The females of most species lay from 50 to 150 eggs, nearly always attaching them to the hairs or feathers of in most species the developing louse goes through three nymphal instars.

Identification characteristics

a) small and wingless ectoparasites
b) Eyes are usually reduced or absent
c) Antennae short and have 3-5 segments
d) Apterous, dorsoventrally flat
e) Antenane 3 to 5 segmented
f) Prothorax free, meso and metathorax often imperfectly separated
g) Thoracic spiracles ventral
h) Tarsi 1 or 2 segmented, with single or paired claws

e.g. *Menopon pallidum* (Poultry louse)
Pediculus humanus capitis (Family: Pediculidae) (Head louse)

Pthirus pubis (Family: Pthiridae) (Crab louse or body louse)

CHAPTER 29. Study of insect orders: Coleoptera

24. Order: Coleoptera

Synonym : Elytroptera

Etymology : Coleo - Sheath ; ptera-wing

Common names : Beetles, Weevils

Characters: They are minute to large sized insects. Antenna is usualy 11 segmented. Mouthparts are chewing type. Mandibles are short with blunt teeth at the mesal face in phytophagous group. In predators the mandibles are long, sharply pointed with blade like inner ridge. In pollen feeders teeth are absent and the mandibles are covered with stiff hairs. Prothorax is large, distinct and mobile. Mesothorax and metathorax are fused with the first abdominal segment.

Forewings are heavily sclerotised, veinless and hardened. They are called elytra. Forewings do not overlap and meet mid-dorsally to form a mid-dorsal line. It is not used for flight. They serve as a pair of convex shields to cover the hind wings and delicate tergites of abdomen. Hind wings are membranous with few veins and are useful in flight. At rest they are folded transversely and kept beneath the elytra. In some weevils and ground beetles the forewings are fused and hind wings are atrophied. A small part of the mesothorax known as scutellum remains exposed as a little triangle between the bases of elytra. Cerci and a distinct ovipositor are absent. Metamorphosis is complete. Larvae are often called grubs. Pupae are usually exarate and rarely found in cocoons.

Importance:

It is the largest order. It includes predators, scavengers and many crop pests. They also damage stored products.

Classification:

This order is divided into two suborders, viz., **Adephaga** (devourers) and **Polyphaga** (eaters of many things). Adephaga includes Cicindelidae, Carabidae and Dytiscidae. Other families listed out below come under Polyphaga.

Families of predators

1. Cicindelidae: (Tiger beetles)

2. Carabidae: (Ground beetles)

3. Dytiscidae: (True water beetles, Predaceous diving beetles)

4. Gyrinidae: (Whirligig beetles)

5. Coccinellidae: (Lady bird beetles)

6. Lampyridae: (Fireflies, Glow worms)

Families of scavengers

1. Scarabaeidae: (Scarabs, Dung beetles)

2. Hydrophilidae: (Water scavenger beetles)

Families of stored product pests

1. Anobiidae: (Wood worms, Wood borers)

2.Bostrychidae: (Grain borers)

3) Bruchidae: (Pulse beetles, Seed beetles)

4. Tenebrionidae: (Meal worms)

Families of crop pests

1. Apionidae: (Ant like weevils)

2. Buprestidae: (Jewel beetles, Metallic wood borers)

3. Cassididae: (Tortoise beetles)

4. Cerambycidae: (Longicorn beetles)

5. Curculionidae: (Weevils, snout beetles)

6. Dynastidae: (Unicorn beetles, Rhinoceros beetles)

7. Elateridae: (Click beetles, Wire worms)

8. Galerucidae: (Pumpkin beetles)

9. Meloidae: (Blister beetles, Oil beetles)

10. Melolonthidae: (Chafer beetles, June beetles, White grubs)

CHAPTER 30. Study of insect orders: Neuroptera, Hymenoptea, Trichoptera

25. Order: Neuroptera

Etymology : Neuro-nerve; ptera - wings.

Common names : Lace wings, Ant lions, Mantispidflies, Owlflies.

Characters: They are soft bodied insects. Antenna is filiform, with or without a terminal club. Mouthparts are chewing type in adults. Wings are equal, membranous with many cross veins. They are held in a roof-like manner over the abdomen. They are weak fliers Larva is campodeiform with mandibulosuctorial mouthparts. Pupa is exarate. Pupation takes place in a silken cocoon. Six out of eight Malpighian tubules are modified as silk glands. They spin the cocoons through anal spinnerets.

Classification: This order is subdivided into two suborders viz., Megaloptera and Planipennia.

Sub order : Planipennia:

1. Chrysopidae: (Green lacewings, Goldeneyes, Stinkflies, Aphid lions)

2. Mantispidae: (Mantispidflies).

3. Myrmeleontidae: (Ant lions)

4. Ascalaphidae: (Owlflies)

26. Order: Hymenoptera

Etymology : Hymen - membrane; ptera - wings.

Hymeno - god of marriage; ptera - wings,

(Marriage / union of fore and hind wings by hamuli)

Common names : Ichneumonflies, Ants, Bees, Wasps, Parasitoids.

Characters : Mouthparts are primarily adapted for chewing. Mandibles are very well developed. In bees both labium and maxillae are integrated to form the **lapping tongue**. Thorax is modified for efficient flight. Pronotum is collar like. Mesothorax is enlarged. Metathorax is small. Both prothorax and metathorax are fused with mesothorax. Wings are stiff and membranous. Forewings are larger than hindwings. Wing venation is reduced. Both forwings and hindwings are coupled by a row of hooklets (**hamuli**) present on the leading edge of the hindwing.

Abdomen is basally constricted. The first abdominal segment is called **propodeum**. It is fused with metathorax. The first pair of abdominal spiracles is located in the propodeum. The second segment is known as **pedicel** which connects the thorax and abdomen. Abdomen beyond the pedicel is called **gaster** or **metasoma**. Ovipositor is always present in females. It is variously modified for oviposition or stinging or sawing or piercing plant tissue.

Metamorphois is complete. Often the grub is apodous and eucephalous. Larva is rarely eruciform. Pupa is exarate and frequently enclosed in a silken cocoon secreted from labial glands. Sex is determined by the fertilization of the eggs. Fertilized eggs develop into females and males are produced from unferti-lized eggs. Males are haploid and females diploid.

Classification: This order is subdivided into two suborders.

Symphyta Apocrita

1. Abdomen is broadly joined to the thorax. Abdomen is petiolated.

2. Larva is a caterpillar and Larva is a grub and it belongs

belongs to eruciform type to apodous eucephalous type

3. Stemmata are present Stemmata are absent.

4. Both thoracic and abdominal Legs are absent

5. Ovipositor is saw like and Ovipositor is not saw like and suited for piercing the plant is suited for piercing in para-tissue sitic groups or for stinging in other groups.

6. Behavioural sophistication is Behavioural sophistication is less more.

7. They are phytophagous They are generally parasitic

Suborder : Symphyta

1. Tenthredinidae : (Sawflies)

II. Suborder: Apocrita

1. Ichneumonidae: (Ichneumonflies)

2. Braconidae : (Braconid wasps)

4. Bethylidae: (Bethylid wasps)

5. Chalcididae: (Chalcid wasps)

6. Eulophidae: (Pupal parasitoids)

7. Trichogrammatidae: (Egg parasitoids)

8. Evaniidae: (Ensign wasps)

9. Agaonidae: (Fig wasps)

10. Vespidae: (Yellow jackets, Hornets)

11. Sphecidae: (Thread waisted wasp, Digger wasp, Mud dauber)

12. Formicidae: (Ants)

13. Apidae : (Honey bees**)**

14) Megachilidae: (Leaf cutter bees)

15. Xylocopidae: (Carpenter bees)

27. Order: Trichoptera (Caddisflies)

a) Slender, elongate moth like insects
b) Antennae long and thread like usually as long as longer than the body
c) Two pairs of wings held roof like at repose
d) Mandibles vestigial or absent
e) Legs long, slender, tarsi segmented
f) Larvae eruciform, aquatic – respire through tracheal gills, live in cases made of leaves, shoot, sand grains, debris and silken web. Pupae exarate.

e.g. *Rhacophila naviculata*

CHAPTER 31. Study of insect orders: Lepidoptera, Siphonoptera

28. Order: Lepidoptera

Synonym : Glossata

Etymology : Lepido - scale; ptera - wings.

Common names : Moths, Butterflies, Skippers

Characters: Body, wings, appendages, are densely clothed with overlapping scales, which give colour, rigidity and strength. They insulate the body and smoothen air flow over the body. Mouthparts in adults are of **siphoning** type. Mandibles are absent. The galeae of maxillae are greatly elongated and are held together by interlocking hooks and spines. The suctorial proboscis is coiled up like a watch spring and kept beneath the head when not in use.

Wings are membranous and are covered with overlapping pigmented scales. Forewings are larger than hind wings. Cross veins are few. Wings are coupled by either **frenate** or **amplexiform** type of wing coupling.

Larvae are **polypod-eruciform** type. Mouthparts are adapted for chewing with strong mandibles. A group of lateral ocelli is found on either side of the head. The antenna is short and three segmented. There are three pairs of five segmented thoracic legs ending in claws. Two to five pairs of fleshy unsegmented **prolegs** are found in the abdomen. At the bottom of the proleg, **crochets** are present. Pupa is generally **obtect**. It is either naked or enclosed in a cocoon made out of soil, frass, silk or larval hairs.

Classification: Majority of Lepidopteran insects (97%) are grouped under the suborder **Ditrysia** in which the female insects have two pores. The copulatory pore is located in eighth abdominal sternite and the egg pore in ninth abdominal sternite. Ramaining insects are grouped under the suborder **Monotrysia** in which the female insects have one pore.

Butterfly families

1. Nymphalidae: (Brush footed or four footed butterflies)

2. Lycaenidae: (Blues, Coppers, Hair streaks)

3. Papilionidae: (Swallow tails)

4. Pieridae: (whites and Sulphurs)

5. Satyridae: (Browns, Meadow - browns)

MOTH FAMILIES

6. Arctiida : (Tiger moths)

7. Bombycidae: (Silk worm moths)

8. Cochlididae: (Slug caterpillar)

9) Crambidae : (Grass moths)

10. Gelechiidae: (Paddymoth)

11) Geometridae: (Loopers)

12. Lymantridae: (Tussock moths)

13. Noctuidae: (Noctua moths)

15. Pyraustidae: (Grass borers)

16. Saturniidae: (Moon months, giant silk worm moths)

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

Skipper family

18. Hesperiidae (Skipper)

29. Order: Siphonoptera (Fleas)

Fleas are small, wingless, holometabolous insects. With rare exception, the adults depend for nourishment on the blood of warm-blooded vertebrates. However, the larvae are relatively free-living and feed on organic material in the larval habitat. The bodies of adult fleas tend to be laterally compressed and usually have caudally directed setae and spines that expedite forward progress through the vestiture of the host while resisting the backward movements frequently associated with the grooming activities of the host. Adults have shiny, hairy bodies and range from light, yellowish brown to almost black.

Identification characteristics

a) Small, wingless, laterally flattened insects with backwardly directed spine like setae
b) Mouth parts adopted for piercing and sucking, laciniae of maxillae forming the suctorial apparatus
c) Legs long with coxae greatly enlarged, have tremendous capacity to jump
d) Antennae short, lie in grooves in the head
e) Both sexes suck blood from mammals and birds, some are vectors of deadly pathogens

e.g. *Pulex irritans* – Human flea; *Xenopsylla cheopsi* – Rat flea

CHAPTER 32. Mecoptera, Strepsiptera, Diptera

30. Order: Mecoptera (Scorpionflies)

Scorpionflies and hangingfies are medium-sized (about 9-25 mm long), slender-bodied insects with the head prolonged below the eyes as a beak, or rostrum. The rostrum is formed primarily by elongation of the clypeus. Its posterior surface consists partly of the lengthened maxillae and labium, but the mandibles are not unusually elongate and are at the lower end of the rostrum. Most Mecoptera have four long, narrow membranous wings. The front and hind wings are similar in size and shape and have similar venation.

Identification characteristics

a) Slender, moderate sized, carnivorous insects, usually with two pairs of subequal wings
b) Head produced into a vertically deflected rostrum with biting mouthparts
c) Abdominal tergum 1 fused with the thorax
d) Male genitalia held like a scorpion sting at the end of the abdomen
e) Larvae eruciform with compound eyes
f) Pupae exarate

e.g. *Panorpa furcta*

31. Order: Strepsiptera – Twisted wing parasites

The strepsiptera are minute inects, all of which are parasitic on other insects. The two sexes are quite different; the males are free-living and winged, whereas the females are wingless and often legless, and in most species do not leave the host.

Identification characteristics

a) Minute insects and are parasitic on other insects
b) Males-free living & winged, whereas the females are wingless and often legless
c) Front wings are reduced and hind wings are large and membranous, fanlike.
d) Have chewing mouth parts and compound eyes.

Eg. *Neostylops shannoni*

32. Order: Diptera

Etymology : Di-two; ptera-wing

Common names : True flies, Mosquitoes, Gnats, Midges,

Characters: They are small to medium sized, soft bodied insects. The body regions are distinct. Head is often hemispherical and attached to the thorax by a slender neck. Mouthparts are of sucking type, but may be modified. All thoracic segments are fused together. The thoracic mass is largely made up of mesothorax. A small lobe of the mesonotum (scutellum) overhangs the base of the abdomen. They have a single pair of wings. Forewings are larger, membranous and used for flight. Hind wings are highly reduced, knobbed at the end and are called **haltere**. They are rapidly vibrated during flight. They function as organs of equilibrium. Flies are the swiftest among all insects. Metamorphosis is complete. Larvae of more common forms are known as maggots. They are **apodous** and **acephalous**. Mouthparts are represented as mouth hooks which are attached to internal sclerites. Pupa is generally with free appendages, often enclosed in the hardened last larval skin called **puparium**. Pupa belongs to the coarctate type.

Classification This order is sub divided in to three suborders.

Nematocera (Thread-horn) Antenna is long and many segmented in adult. Larval head is well developed. Larval mandibles act horizontally. Pupa is weakly obtect. Adult emergence is through a straight split in the thoracic region.

Brachycera (Short-horn) Antenna is short and few segmented in adult. Larval head is retractile into the thorax. Larval mandibles act vertically. Pupa is exarate. Adult emergence is through a straight split in the thoracic region.

Cyclorrhapha: (Circular-crack) Antenna is aristate in adult. Larval head is vestigial with mouth hooks. Larval mouth hooks act vertically. Pupa is coarctate. The coarctate pupa has a circular line of weakness along which the pupal case splits during the emergence of adult. The split results due to the pressure applied by an eversible bladder **ptilinum** in the head.

i. Nematocera

1) Culicidae: (Mosquitoes)

2. Cecidomyiidae : (Gall midges)

ii. Brachycera

3. Asilidae: (Robber flies)

4. Tabanidae: (Horse flies)

iii. Cyclorrhapha

5. Syrphidae: (Hover flies, Flower flies)

6. Tephritidae: (Fruit flies)

7. Drosophilidae: (Vinegar gnats, Pomace flies)

8. Tachinidae: (Tachinid flies)

9. Muscidae: (House fly)

10. Hippoboscidae: (Dogfly)